1 General Introduction.

1.1 Introduction

The Leica camera has been introduced at the Leipzig Spring Fair in 1925 and in its 75th birth day (March 2000) spans three generations of photographers. Since Berek designed the first lens for the Leica, about 200 different optical systems (as a lens is officially called) have been released by the "optisches Rechenbüro" (optical design department) of Leitz-LeicaWetzlar and Leica/Solms. During this period, we have seen many changes in optical design methods, in production technology, in photographic art and practice and in lens performance. The continuing evolution of the Leica lens does reflect these developments. The Leica camera, in the thirties mechanical instrument of workshop craft, became a truly precision engineering instrument in the fifties. Lenses evolved too and in the words of Lipinski "represent not only the highest skill within the camera but also the highest generally applied skill in the engineering world". The study of the Leica lens line and its evolution then is partly the study of lens design and lens engineering. And a comparison of current designs as the Tri-Elmar-M and the Vario-Elmarit-R 1:2.8/35-70 with the Elmax or Summarex of generations ago indicates the differences in design and engineering. Photography has been called a mechanical representation of reality, as compared to painting or drawing which are assumed to be artistic interpretations of reality and of mood. While it is true that the physical nature of the optical-chemical process is technical, the result of this process is an image that will be perceived and interpreted by the human mind. The craft of photography has always balanced between a technical and artistic emphasis. The Leica cameras have been instrumental in fostering both sides of the craft. Many of the lasting images of the 20th century have been shot with Leica cameras. And the technical quality of Leica lenses and bodies are fine examples of optical and engineering skills. An expertly printed B&W glossy enlargement of a technically impeccable Leica negative is a joy to the trained eye. We should stay sensitive to the content of the image too. The development of the technical expertise of Leica photography is a quite rewarding endeavour. But a picture should be more than an exercise in feasible image resolution. Obviously there is a connection and even a correlation between both approaches. In my view the mastery of the technical and optical aspects of Leica photography is a necessary, but not sufficient condition to exploit the capabilities of the Leica system to the fullest extent. Leica designs its lenses with an admirable ambition for the best image quality in 35mm photography, capable of challenging the mid-format systems. And to be honest, the user pays a lot of money for Leica lenses and bodies. A major part of the cost of a Leica lens can be explained by the mechanical engineering, that is required to hold the very small tolerances that are part of the optical design. This book discusses topics that are of interest to Leica users, new and experienced and to collectors. My approach is a technical one. I will identify and describe most if not all lens designs that have been produced by Leitz and Leica. In the course of my research I have discovered a number of new facts that may be relevant for the collector. The focus is always the change in optical design, not the identification of all different versions of a lens type. In my terminology a lens type is a lens characterized by a focal length and an aperture (1:2/35mm). A lens version of a type is a change in mount, weight or shape. Such changes may affect the use, as a lens mount may be heavier or more ergonomically designed. A change in optical design of a lens type will be identified as the optical system (lens elements) itself does change. In some instances Leica has used a different glass type in an otherwise unchanged design. This will not count as a design change as the optical properties of the lens are not altered. I will also offer comments on how to exploit Leica lenses and their potential image quality. I will provide information that is useful for new and seasoned users of Leica equipment. One topic I do not wish to elaborate upon. Most books on lenses will inform you that a certain type of lens should be matched to certain topics. A 90mm lens is proclaimed as a typical portrait lens and a 21mm lens should be used for landscapes or interiors. Obviously there is a relation between angle of view and what we can capture of the subject in front of the camera-lens. If you care to study the masters of photography, not necessarily confined to Leica photographers, you will notice that any lens can and has been used for any subject. Many new users of Leica equipment expect that their pictures will improve significantly and visible for anyone to see when using Leica lenses. The converse is true. As is the case with any fine instrument, you need to learn the tricks of the trade and train yourself in the craft before satisfactory results can be reaped. It would be too easy and most certainly wrong to suggest that the mere use of a Leica lens will give you superior results from the start. The true character of Leica lenses needs to be carefully explored and will unveil its secrets slowly and in stages, as when looking at Salome’s dance. When the technique, necessary for the use of high-performance lenses has been understood and applied, the Leica photographer is about to explore new worlds.

1.2 Structure of the book.

The book is divided in three parts, which can be read separately, but are interrelated. In the first part (Chapter 1), I will present an historical and evolutionary perspective on the development of the Leica lenses. From the start in 1925 when Berek created the first lens for the Leica format and had to explore new optical territory, Leica lenses have evolved into dedicated optical systems to exploit the small negative format. In the beginning Leitz had no experience with the design, nor the manufacture of photographic lenses for the 35mm format. Lenses for microscopes are designed for one distance only and are essentially aberration-free for a very narrow angular field. The type of optical correction was different from what was needed for photographic lenses, which typically had much larger angular fields, needed to be stopped down and be focused over a wide range of distances. This chapter tracks the development of the optical designs on both sides of the Atlantic Ocean, the management decisions that had to made, the widening scope of the lenses needed for R and M systems, and the need for ever more advanced solutions. It also shows that Leitz could not cope with all these, often conflicting requirements and the efforts to keep abreast of or at least stay in the same league as the competition. The diversification in designs and systems, the costly production of lenses and the method of manufacturing them, all contributed to the erosion of the proud Wetzlar company. Behind the scenes, the Leitz workers continued to explore the wonderful world of optics and mechanical engineering, with sometimes awe-inspiring results.

The leap forward was possible after a painful restructuring, the scars of which can be sensed even nowadays. The new Solms company should be evaluated on its own performance, however, and when doing this, you can only express admiration for the quality of the new generation of lenses, which in my view for the first time fulfil the performance potential that was envisioned by Berek and colleagues. In the second part I introduce the reader to the dark side of the moon, that is the theory and practice of optical design. My approach is new, in this sense that I do not consider the optical aberrations as separate entities, but show the role they have in the degradation of the image quality, why this happens and what the user of Leica equipment can notice of these optical errors. The central concept here is the focused image and the defocus blur, which is also helpful in explaining depth of field and the widely discussed topic of bo-ke: the quality of the unsharpness zones. The evaluation of image quality is treated in a theoretical and practical way. To stay away from conjectures and long time myths, I have to present some detailed figures. This part is self contained and can be skipped without any loss of information for the other parts. The third part may be considered the backbone of the book. I have analyzed, tested and evaluated every Leica lens in a consistent manner and compared every lens, from the earliest Anastigmat to the latest Apo-Summicron-M 2/90mm against the same set of criteria. The terminology for the description of the lenses has been carefully chosen and reflects my own experiences in taking photographs and developing methods for exploring meaningful differences in optical performance. It is true to a large extent that many lenses stopped down to 1:5.6 exhibit comparable image quality. Still there is a wide gap in the results at 1:5.6 between let us say an older Elmar 1:3.5/50 and the new Summulix-R 1:1.4/50mm. This gap is not easily perceived on casual inspection in moderate enlargements, but when using the best of films, like Kodachrome 25 or 64 and Agfa APX25 and Ilford 100Delta at large projection or big B&W enlargements, there are significant differences to be noted. Sometimes is it is remarked that Leica photography (as a generic term) is at its best when the light is scarce, the aperture is wide open, the shutter speed slow and the film speed at ISO400 or higher in order to capture the fleeting moment of the human condition. I do agree that the Leica is a superb tool for this kind of photography. The inference that an MTF test may not be relevant for the required image quality in these circumstances, is not true however. High overall contrast, absence of flare and a very good definition of the outlines of major subject shapes may be decisive here and all of these can be directly or indirectly read off from MTF data. As Leica lenses are supposed to excel at the wider apertures and will be used in adverse lighting conditions, I have given much weight in my evaluation to the performance at the 2 or 3 widest apertures, the occurrence of flare and last but not least the quality of mechanical engineering and small production tolerances as indicated by decentring of lens elements. It does not make sense to promote excellent image quality, if the decentring of the lens kills this quality. What I am not interested in at all, are maximum resolution figures and these are disregarded in my analysis. Contrast and the defocus blur are my objects of study and evaluation and in part two I go to some length to explain the theoretical and practical basis of this modern approach to lens analysis.

1.3 Acknowledgements.

A book of this scope cannot be the accomplishment of one person. The team of EKO, the Department of Optical Development and Engineering at Leica Solms, spent countless hours to discuss the design and construction of lenses, bore the burden of opening all archives and guiding me through the more opaque documents discovered there. The unique lens diagrams, that accompany the lens reports, were drawn specifically for this book, and I wish to express my gratitude to Peter who delved into the archives to find the optical prescriptions to feed into the computer and generate these diagrams. I owe much to Mr. Lothar Kölsch who allowed me to fathom the creativity behind and the beauty of optical design as an art form during my interviews. Many friends around the world have directly and indirectly influenced the contents of this book as their conversations and questions about Leica lenses guided me in my choice of topics and my approach to lens evaluations. Derek Grossmark and Ron Clark of Hove Publishing guided me through my first inexperienced steps as a book writer and Lucien acted as a critical reader for the many drafts of the book. Our cat, Wooster, patiently but uninterestingly acted as a model for thousands of pictures for evaluation purposes, and exchanged opinions about Leica enthusiasts with his Canadian counterpart through subspace channels, while sleeping on my most precious documents. My partner/wife Els, deserves all the credit for making it happen. Her strong mental and emotional support and her taking care of all, literally all, day to day household tasks, to free me completely to concentrate on the research and writing of the book for many months, asked much of her own strength and love. She gave me my first Leica CL, many years ago, and I am sure she had no idea what the future would bring.

2 Chapter 2: The evolution of the LEICA Lens.

2.1 Part 1:

The origins, 1925 to 1930. When Barnack was busy constructing and refining his camera around 1907 to 1911 , and decided to use a format of 24x36mm on cine-film, no suitable lens was available on the market. As any lens projects a circular image, you need a angular coverage equal to the length of the diagonal of the image format . The diagonal of the 24x36mm format has a length of 43,27mm, which gives a maximum image height of 21.6mm from the centre of the image. Barnack therefore needed a lens with a angular view of 46o to cover the format. A lens with a focal length of anything between 40mm and 60mm would do. Barnack, working at the Leitz factory, a well-known microscope manufacturer, found a series of lenses, made by Leitz and named Mikro-Summar and Milar with several focal lengths to choose from.

Figure 1: 2.1 A Mikro Summar

He chose the Mikro-Summar 1:4.5/42mm, which he fitted in at least one of his three prototypes. The Ur-Leica, residing in the museum in Solms, has been equipped with this lens. Some researchers have identified the lens as a Milar or a Summar. There is no inscription on the lens, so there is room for some interpretation. The exact focal length however can be measured and recently the optical engineers at Solms just did this and established a focal length of 42mm. The only lens in the Leitz microscope catalogue around 1910 is the Mikro-Summar, a six element symmetrical lens. So we may now reveal with certainty the identity of the mysterious lens in the Ur-Leica. It is a Mikro-Summar with 6 elements, symmetrically arranged.

2.1.1 Choice of format.

Why did Barnack settle on the 24x36 format? Previous and contemporary designers of cameras, based on the 35mm perforated cine-film ("Kino-film") had used 24x24, 32x44, 18x24, 30x42 formats. Barnack himself tells us that he wanted to use the "Kino-film" and that he decided to go for maximum area to ensure good image quality. The dimensions of 24x36mm have a 1:1.5 relation, just as the 6x9cm negative of the then ubiquitously available Roll film camera, the "point and shoot camera" of the early part of the previous century. The Leica camera had to face a very strong competition from this format, as the most used print format was also 6x9cm and this could be produced from a 6x9cm negative as a direct copy, without any enlarging and subsequent losses in image quality. And the next steps in print format (9x12cm and 13x18cm) have relations 1:1.35, so quite close to the 1:1,5 (with a slight safety margin). It was one of Barnack's primary concerns that his compact camera and its small negative could deliver image quality as good as, if not better than the 6x9cm contact-print. His device would be unacceptable to most prospective users if the image was inferior to the roll-film competitor. Here we see already the interaction between the demands from the practical user and the capabilities and ambitions of the optical designer that will characterize the development of optical design.

Figure 2: 2.1.1A Barnack sketch.

Note similarity to Berek drawing The next step, after having established the dimensions of the image area, was to define the requirements for the recording capabilities of the lens.

2.1.2 Optical requirements

Most photographic prints in the early decades of the 20th century had dimensions between 6x9cm and 13x18cm. A comfortable viewing distance for these pictures is around 25cm. It so happens that we are able to see the whole 9x12cm print at this distance without moving our eyes. The resolution of the eye (that is the finest detail we can distinguish when viewing an object) is of course the limiting factor for the optical requirements. It has been established by research that the best resolution of the eye will be found when the eye is focused at a distance of 1.2meter to 1.5meter. But for photographic purposes we have to stick to the normal viewing distance of 25cm. This distance has been used as the reference distance for the definition of the circle of confusion. Assuming an enlarging factor of the negative of 3 to 5 times for a print of 9x12cm (in fact 7.2x10.8cm) the smallest point on the negative should be at least 0.1mm/3. That is 1/30mm or 0.0333mm. This value is used by Leitz as the criterion for the calculation of depth of field tables or engraving depth scales on the lens mount. The optical calculations however are not based on this value. It is clear that the designer will try to concentrate all light rays on as small an area as possible. The value of 0.03mm then constitutes the limiting case, the minimum value so to speak, that is a point should have at least the diameter of 0.03mm or 30 micrometer (mu). When reflecting on these topics Berek and Barnack settled for 0.03mm. They could not know at what distances the Leica pictures would be viewed by the user, nor what enlargements they would choose. The value of 0.03mm is the standard circle of confusion at the film, used as a reference. It should not be considered the target value. See the chapter 1.2 for more details on this topic.

2.1.3 The first lens for the “Leica” format: some design aspects

The first lens, specifically designed for the Leica format was the Leica Anastigmat , later renamed Elmax (presumably the combination from Ernst Leitz and Max Berek). This lens had five elements, where the Zeiss Tessar had four. Berek designed the Anastigmat with the last group composed of three cemented elements. This lens then has the unique distinction as being the first lens, designed with the specific requirements for the 35mm Leica format in mind. Max Berek designed the lens around 1922 (As the date on the original drawings at Solms tells us).

Figure 3: 2.1.3 A (Computation page: already at Hove)

Figure 4: 2.1.3 B Anastigmat

As the Elmax was a bit complicated to build (as a cemented triple) Berek changed the design to a triplet with the last element as a cemented doublet.

Figure 5: 2.1.3 C Elmax.

The Elmar was born. The design date on the documents tell us that the first design of the Elmar was completed in 1925. This lens had improved imagery when compared to the Elmax. The Elmar design is similar to a Tessar design, with one important exception, the location of the stop. In optical design the location of the stop is part of the tools for aberration correction. Depending on the design this location can be more or less influential. In the case of the Elmar, the stop is located between the first and second element. This forward location cuts off some of the rays at the edge of the lens and while producing some additional vignetting, also improves the central definition. As the lens is now unsymmetrical around the stop, we see some astigmatism and coma in the outer zones of the field.

Figure 6: 2.1.3 D: Elmar diagram

The Elmar 1:3.5/50mm established the fame of the Leica camera, by providing image quality of a high order for its day. Analysis by modern computer based design programs of the original Elmar configuration show that the basic design is difficult to improve upon. A tribute to the old masters no doubt! A designer would cement two glass elements together (or split one element into two separate lenses) to create a glass type that is not available in the glass catalogues. Basically the Elmar is a triplet, where the last lens element is cemented to generate a new type of glass, that was needed for the computation.

If advances are to be made, the only route is the glass selection. And we may be sure that the Elmar lens in its long history of 1925 to 1961 underwent changes of this kind. Inevitably older glass types were removed from the catalogues and so the designers were forced to adapt to these circumstances. But modern optimization analysis also shows that the gains are relatively modest and so it may come as no surprise that the image quality of this lens is quite stable over the years. Of course newer glasses and specifically the coating of surfaces might give a modest gain under adverse conditions. The design of the Elmar allowed for the correction of the basic aberrations with minimal means. This makes the computation especially labourious and when done with only a slide rule and logarithmic tables is very demanding on the insight and creativity of the designer. Any four-element lens has limited possibilities for the correction of the important aberrations. A compromise is always needed. Broadly speaking the four-element triplet has a typical character like good central sharpness and weaker performance in the field. A designer can and will adopt a specific solution, that gives every version of this type a different fingerprint. The Elmar at full aperture gives a low to medium contrast image, with good recording of coarse detail over an image circle of about 12mm radius. One of the advantages of the Leica, when compared to larger format cameras is the extended depth of field when using the lens wide open. Max Berek rightly placed emphasis on the axis (centre) performance and also on a good colour correction over the whole spectrum, including the red part of it. Stopped down to about 1:5.6 the contrast improves markedly, crispening the rendition of fine detail. Berek again assumed that the lens would be stopped down in order to increase depth of field to maximize the comparative advantages with the roll film cameras.

Figure 7: 2.1.3 E-Late type Elmar

We may regard the Elmar as a classical example of an excellent design that stretched to the limits the inherent possibilities of the type. The three element Cooke triplet has comparable performance on axis as the classical four-element Elmar type. Computer analysis show that the relative differences in performance are zonal astigmatism and oblique spherical aberration, both of which are better corrected in the Elmar. The differences are small, but quite noticeable and could make the success or failure in the marketplace. So it was a wise choice from Berek and Leitz to opt for the 4-element Elmar to compete with the Cooke type triplets employed in most roll-film cameras. The performance edge indeed is important and outweighs the higher production costs, due to the more elaborate construction.

2.2 Part 2: The expansion, 1930 to 1957

Around 1925 most films were of the orthochromatic type and had sensibilities of ISO20 to ISO30. Panchromatic films were also available, but with reduced speeds (ISO10 to ISO15). Even with a 3.5 lens, these speeds limited the possibilities of the Leica user to shoot pictures in low light situations. But the Leica was the camera to record all aspects of human life in its various surroundings. Today, when we look at early Leica pictures made in 'available light' we should marvel at the expertise of the average Leica user to use this modest equipment. Ask any modern counterpart to capture indoor scenes at an aperture of 3.5 with an ISO25 film and you will hear all kinds of protests. Using current Kodachrome 25 and the Tri-Elmar 4/28-50mm or the Vario-Elmar-R 1:4/35-70mm at 1:4 would simulate these conditions quite well. Results would be superior, evidently, but we should reflect for a moment on the role of the Elmar in its historical and technical context. For many scenes, the aperture of 3.5 is still an excellent choice as it combines depth of field, needed for most solid subjects with a slightly safety margin for inaccuracy of focus and a good image quality. Using the f/16 rule, we can estimate the shutter speeds to be useable with an ISO20 film as 1/20 sec at f16 or 1/500 at 1:4 in the sun or 1/10 at 1:4 for a cloudy, dull scene with side lighting. The latter conditions are at the limit, but within the grasp of an able photographer.

2.2.1 The family of lenses for the Leica.

It is not clear if Barnack did envisage the use of interchangeable lenses, when he laid out the basic principles of his design. At first no additional lens has been offered and later they had to be matched individually to the body. A sure sign that Leitz was still in the beginning of the learning curve of becoming a manufacturer of high precision camera systems. This is remarkable as Leitz were well acquainted with the production of microscopes. These instruments were designed to be individually calibrated, which could not be done in the photography department. The concept of manufacturing interchangeable lenses to match with great accuracy to any body was really a challenge to the factory. But the availability of lenses with different focal lengths and apertures was the raison-d'-etre for the Leica. From 1930 the Elmar design is stretched in two directions: wide angle: 35mm and narrow angle: 90mm, with a short excursion into the 105mm focal length, and the 135mm. In fact we have only two major configurations in the Leica lens line-up from 1925 on. The triplet basic form uses a configuration of three singlet elements (positive, negative, positive). If we replace the third element by a cemented triplet, we get the Elmax. Replace the rear element by a doublet and we have the Elmar lenses 1:3.5/35, 1:3.5/50, 1:4/90, 1:6.3/105 and 1:4.5/135mm. Exchange all three singlets by doublets and we get the Hektor 1:2.5/50 and 1:1.9/73mm. Replace the front and rear singlets by a doublet and we get the Hektor 1:6.3/28mm. Replace only the centre element by a doublet and we have the Hektor 1:2.5/125 and Hektor 1:4.5/135 and Thambar 1:2.2/90mm.

Figure 8: 2.2.2 A: basic lens types

The second basic form is the symmetrical doublet or double-Gauss type. This lens had been expanded to a six element version by Lee and the basic configuration has a grouping of singlet, cemented double and cemented double, singlet in a slightly asymmetrical sequence. This is also the design of the Summar. Split the first singlet into two separate lenses and we get the Summitar and first Summicron versions. Split the rear singlet into two air spaced elements and we have the Xenon/ Summarit versions. Use this configuration, add a Merté surface and we get the Summarex 1:1.5/85mm. When adding the long focus designs of the Telyt 1:4.5/200 and the 1:5/400mm, the complete lens line is covered by three basic designs. There are several reasons for this economy of design types. First of all, there was not enough time and theoretical knowledge to explore more exotic designs. Several studies done by Leitz designers in the early period, generated some very promising and exciting designs, but lack of suitable glass types, the required mechanical tolerances and careful assembly made such designs not feasible in those days. So the designer had to use his ingenuity to stretch existing lenses to cover the requirements. Secondly it made sense in those early days to concentrate on a few designs and glass types and try to manufacture as many lenses as possible. One should remember that the cost of designing a new lens was often prohibitively high and success was not guaranteed. The designer calculated the lens on paper and had a good idea of the performance that it could deliver. In those days the designer had limited means for the calculation of aberrations. Tracing rays through the optical system is quite labourious. And sometimes, in the case of skew rays, the mathematics are quite complex. So a designer could not trace enough rays to get a full picture of the design. The physical prototype was needed for a practical evaluation of the design. The design on paper was a close approximation to the desired correction, but the designer could not predict fully its state of aberration correction. Some mysteries remained, that could be detected after the prototype had been built. A proven design then was often the only or more practical way to proceed.

2.2.1.1 2.2.1.1 The Summar type.

In those days then every additional speed gain would be welcomed. The Hektor 1:2.5/50mm was the first answer by Leitz to the request for more speed. Its design in 3 groups of 2 cemented elements each, classifies it as a triplet variant. It had only six air-to-glass surfaces and was intended by Berek as the answer of Leitz to the Sonnar designs with 6 air-to-glass surfaces too. Definition of finer detail on axis could be preserved, but at maximum aperture overall contrast was on the low side. Films in those days had thick emulsions and low resolution, which gave the muted sharpness impression of many older photographs with the 35mm format. The modest wide open performance would have been in line with what was the accepted norm then. High speed lenses for the 35mm format were quite difficult to compute, as the relatively wide aperture introduced a high level of coma and astigmatism, which softens the outer zones considerably. Furthermore the absence of anti-reflection coatings produced additional sensitivity to flare and reduced contrast. And last but not least, the requirements of Leica users for enhanced recording capabilities, triggered by improved emulsions, necessitated the search for new optical designs. To reduce unwanted flare and reflections, one had to reduce the number of air-to-glass surfaces and one could use one of several types of the triplet (like the Hektor). This triplet type (consisting of two positive singlet elements (crown type) at front and rear and one inner negative singlet element (flint type) is the base configuration. We can then play with this design and use one or more cemented doublets to replace a singlet element or we can split a singlet into two or more elements. The second major type is an expansion of the original Gauss doublet (two air-spaced meniscus elements). When we place two Gauss doublets back-to-back symmetrically around an aperture stop we get the double-Gauss type and playing again with the design we can add a cemented element to each negative meniscus. The classical and justly famous Double-Gauss six element lens is born. This design type has excellent possibilities for aberration reduction. So Berek was quite right in his decision to base the Leica high speed 50mm lenses on the Double-Gauss design and neglect the triplet derivatives (as the Zeiss Sonnar and Ernostar), even if these had a short-time practical advantage. Without anti-reflex-coating, the many glass to air transitions of the Summar lowered the overall image quality. The cross section of the Summar looks remarkably similar to that of the later Summicron family. The Summar 1:2/50mm exhibited a low contrast image at full aperture, with a strong presence of astigmatism in the outer zones and a fair amount of veiling glare. The edges of the fine detail outlines are fuzzy, which give the impression of a slight unsharpness.

Figure 9: 2.2.1 A Summar lens rigid

The Summar had not the crisp recording of coarse detail that the contemporary split-triplet-type of lenses could offer, and its image quality lacked punch. Leitz however, kept on studying and improving the design and so gained valuable experience, which could be used to good effect when Leitz introduced the Summitar 1:2/50mm in 1939. This lens has somewhat higher contrast and noticeably less vignetting, partly due to a bigger front lens . Its general characteristics wide open closely follow the Summar specs. Its central area of good definition is larger as is the reduction of astigmatism. Most importantly the Summitar improves rapidly on stopping down The improved colour correction (longitudinal) and better definition of finer details were needed to support the new generation of emulsions. The first Kodachrome from 1935 offered a staggering ISO value of 6, but the monochrome emulsions, especially the Agfa Isopan Super Special already had a speed value of ISO100, which is as sensitive as current standard B&W films. So in a few years time effective film speed increased two- to fourfold with finer grain than before and demands for better corrected high speed lenses became louder and louder. The colour negative and transparency films hovered around 20ISO for a long period and in 1950 reached ISO40. The first ISO100 colour film was the Super Anscochrome from 1957. It is also of interest to note that the granularity and resolving power values were in a really different category than what we expect today. The 1930 generation of films had RMS values that were four times higher than today's films of comparable speed and offered a resolving power of around 20 to 30 lp/mm in standard lightning conditions . This value, low as it may seem today, still presented a challenge to the lens designers. While the performance of the Summitar on axis exceeded the capabilities of the film with great ease, the image quality in the field (zonal areas) showed a low contrast at 10lp/mm already. The value of 30lp/mm (an indication of the recording capabilities for finer textural details) was reached but with very fuzzy edges and low contrast. The wider the aperture and/or the larger the image field, the more difficult it will be for a designer to control the aberrations. The low sensitivity of the film-emulsions and the wish of photographers to record events in very dim light encouraged the designers to compute lenses with an aperture of 1:1.5 was busy with a 1.5 design and finished one in 1938. But in 1932 the Contax offered already a 1.5 lens of Sonnar (triplet) design and Leitz needed a lens with similar specifications urgently. So the company licensed the Schneider design, the Xenon 1:1.5/50mm. From a historical perspective we may regret this decision, as it would have very interesting to see which design of the two contemporary giants in optical design (Bertele and Berek) would be the better one. The Leitz Xenon allowed the user to expand his practical picture taking opportunities into hitherto uncharted realms. The performance of the lens at full aperture is however only acceptable for reportage type of pictures. A strong presence of coma introduces patches of flare around specular highlights. The quite dreamy and romantic atmosphere of pictures taken with high speed lenses at wider apertures in those days can be witnessed in many picture examples.

2.2.1.2 2.2.1.2 The Elmar type.

The Elmar family expanded quickly from 1930 in a few years to a range of lenses, covering 35, 90, 105 and 135mm focal lengths. Apertures were a modest 1:3.5 to 1:4.5. The Elmar 1:4/90 at full aperture has low to medium overall contrast and renders coarse detail with good clarity over an extended area (image height about 12mm). The 90mm lens started its life not as a portrait lens as they have been baptized later. In the '30's film emulsions were coarse-grained and even at moderate enlargements, details in the subject could get lost in the grain clumping. So the first use of the 90mm was the ability to record details sufficiently large on film that the grain could handle the finer image details. The so-called Berg-Elmar 1:4/105mm is a compact and very light-weight lens of only 240grams. This lens shows the concern of the Leitz company to produce lenses that are compact and light-weight. These characteristics match the Leica body as the camera for dynamic photography and the camera as travel companion. The Elmar 1:4.5/135mm again has the typical Elmar fingerprint of good central sharpness, but showed also chromatic errors, which are unavoidable in a long focus design. Leitz replaced this lens with the better Hektor

1:4.5/135mm. The Elmar 1:3.5/35mm at full aperture has some vignetting and the family character of lower contrast, good central definition of details and soft outer zones. It is a very compact lens, as were most of the lenses for the Leica in those days. Leitz even announced an Elmar 1:4.5/35mm in 1935. It had fix focus click stops for ease of use. This one and the Berg-Elmar are indications that Leitz made every effort to provide the user of the Leica with a system of lenses that covered a wide range of applications. Every type of photography (from travel to commercial illustration) could be covered with the Leica system. 2.2.1.3The Hektor type. The Hektor 1:1,9/73mm was the first attempt of .i.; to design a high speed lens with a moderate angle of field. The triplet design however could not be stretched too much. The Hektor 2.5/50mm and the Hektor 1.9/73mm allow the same amount of energy flow to pass through the lens. The wider aperture of 1.9 (2/3 of a stop more than the 1:2.5) is offset by a 50% smaller angle of field. (30oversus 45o). clearly was aware of the limits of the generic Hektor design. The 1:1.9/73mm short telephoto lens at the wider apertures has that typical softness at the edges of outlines and the very smooth transition of the sharpness plane into the unsharpness blur of fore-and background, that became the defining characteristic of the portrait lens for generations of photographers. The Thambar 1:2.2/90mm is a so-called soft-focus lens that allowed the photographer to make portraits with the soft effects that were very popular in those days. The extent of softness can be regulated by the iris diaphragm and a special opaque disc, that can be placed in front of the lens and cuts off the central rays. As now only the outer rays will be available for image formation, we see a strong degradation of quality as these outer rays are generally less well corrected than he central rays, that are blocked now. Longer focal lengths have a smaller angle of field and the correction of aberrations is somewhat simpler as long as apertures are moderate. The wide angle have a larger angle of field and now vignetting and zonal aberrations are becoming a problem for the designer. The first 28mm lens, the Hektor 1:6.3/28mm, was introduced in 1935. When the angle widens the vignetting and distortion ask for all attention. The large front and rear lenses help reduce vignetting which indeed is gone by 1:8. The diameter of the front lens is ±10mm, twice as large as is needed from geometry only. The overall image quality is a bit dull and fine detail is softly rendered without the clarity and bite we do note in current lenses. 2.2.1.4 The Telyt type. The coupling accuracy of the Leitz rangefinder/body combination is limited to the 135mm focal length and when a longer focal length is required, a new device, the mirror reflex housing (Visoflex or the as it has been designated in the early period PLOOT), had to be used. This device, ingenious and a marvel of mechanical engineering, transforms the Barnack camera into a mostly stationary photographic instrument. For some assignments however the longer focal lengths are indispensable. The Olympic games in 1936 were a strong incentive to produce new telephoto-lenses and the Telyt 1:4.5/200mm and 1:5/400mm were designed with this deployment in mind. Both Telyt lenses were true long focus lenses, and performance is good for the 200mm version, but weak for the 400mm.

2.2.2 The war period.

During the war Leitz managed to keep the production lines going, but production increasingly shifted to military, medical and projection purposes. The only new lens to appear for the presumably civilian market was the Summarex. This lens is described in the beautiful and colourful Leitz brochure from 1943: "auswechselbaren

Leica-Objektive". The state of the economy would not have encouraged anyone to buy this lens, even if it were available, which is highly unlikely. The price in 1936 for the Hektor 1:1.9/7.3 cm was RM 260.00, way beyond normal purchasing power. The Summarex 85mm had modest image quality at full aperture but improved remarkably on stopping down to 1:5.6 and 1:8.

Figure 10: 2.3A- lens overview 1943

The last lens-series has been registered on March 15, 1944. It was a batch of about 10 lenses of exotic specifications: 1:0.85/150mm, the last lens having the serial number #594852. The list of specialized designs is quite long. Examples are the Elkinor 1:1.5/300 and 1:1.5/400mm, IRSummar 1:0.85/75mm and 1:0.85/150mm, URSummar 1:1/90mm and 1:1/150mm. Coating was also introduced on the military versions of the lenses in 1941. The civilian production however did not receive this treatment until after the war. The topic of the use of coating has not found its final treatment. Rogliatti notes that coating had been applied to lenses from #587601 (Summitar) from 11 November 1945. The factory lists indicate that at 6 November 1945 the serial numbers 600000 to 601000 have been allocated for a batch of Hektor 13.5cm lenses. The first Summitar series begins with 603000 in early 1946. The #number 587601 is part of a batch of Summitars from #586001 to 590000, allocated in 1942! The factory archives in the optical department note that coating was applied from October 1941 (from serial# 580000) and I quote:" from October 1941 all Leica lenses receive anti-reflexion coatings. These lenses are not available for amateurs, but only for war photographers (Kriegsberichterstatter)". A report by the US Naval Research Labaratory, dated 3 October 1946, on German coating methods during the wartime does indeed note that Zeiss, Leitz and Schott all used several methods of coating during that period. The report remarks that Dr. Männchen from Leitz demonstrated an (experimental) method of centrifugal coating (as compared with the Zeiss method of thermal evaporation coating), which however produced a very soft coating.

Production was resumed already in June 1945 with serial number 595000: a batch of 1001 Elmar 1:3.5/50mm lenses. Between October 1941 and June 1945 Leitz manufactured about 15000 lenses, and some larger batches were reserved for the specialist lenses for military applications, some of which were very rare, like the IRTessar 5/5000mm. It is reasonable to assume that most of these 15000 lenses went to the government. As it is also very likely that not all lenses, produced before October 1941 were sold out at that date and Leitz would be able to provide amateurs with the non-coated version of their lenses.

2.2.3 The postwar period till 1957.

The Leitz factory emerged after the war almost intact. The buildings however were in a desolate state and the American Occupation had copied and transferred all the valuable Leitz documentation to the USA. It is typical of the wisdom and vision of Ernst Leitz that he was not bothered at all by this transfer and he remarked to a close aid that as long as the Americans allowed the workforce in the factory to continue with their work he was not worried about it at all. He knew what is still valid today. The real power of the factory is the creativity, brains and motivation of the people. Already in the spring of 1945 Leitz-Werke resumed production with the same core product line as was available in 1939. The first new design was the Summaron 1:3.5/35mm, introduced in 1949. Like the Hektor 28mm, the diameter of the front and rear lenses were quite large for the same reason (reduction of vignetting). This six element Gauss design had more potential for aberration correction than the Elmar of the same specifications, and its introduction so soon after resuming civilian production, showed the determination of Leitz to improve the image quality of the Leica lens line. During the war Leitz introduced single layer coating (around 1941) and after the war new glasses became available, many of them specifically researched in the Leitz glass lab, founded in 1949. In the past the optical designers had stated too often that they could get better correction of aberrations if they could use a glass with specific properties. These glasses however did not exist and the idea to have to wait and see if and when Schott or other manufacturers produced the glass so eagerly awaited for, was not in the interest of Leitz. In 1950 the Summarex 1:1.5/85mm was relaunched in a chrome version and with coated glasses. Its inherent characteristics were not changed and, while having an impressive appearance and a heavy weight , image quality became quite good only after stopping down to 2.8. At full aperture the lens gave modest performance, and its weight must have been a heavy burden for the Leica bodies of the day. Indeed, the structural weakness of the screw mount Leica bodies when the heavier lenses were mounted, was one of the arguments to develop the M-series. The Summaron 1:5.6/28mm (1955) improved upon its predecessor. Its design is symmetrical which gives better performance when taking pictures at closer range. Also distortion and coma are slightly reduced by this design. Overall it is medium contrast lens with a commendable definition of fine detail over a larger image circle of about 12mm. The outer zones are soft to very soft. The wide angle of field gave the designers a lot of trouble and an even coverage including the edges was still a pipe-dream. When considering the introduction of a new lens, Leitz had to weigh two factors. The high cost of the design process and the number of units sold. But sometimes the Leitz designers had no suitable design available. The 21mm lens is an example. The optical solution for the design of an ultra wide angle lens had been found by Zeiss and Schneider. Leitz offered the Schneider Super-Angulon 1:4/21mm from 1958. This is a symmetrical design that covers a wide angular field. Its construction incorporates negative outer elements and a wide spacing between the elements. This type of construction helps flatten the field, which is very important for a wide angle. Coma and distortion are also reduced. The Super-Angulon has indeed very low distortion and slight curvature of field. It also exhibits the low to medium contrast typical of the period and the rendition of fine detail is on the soft side.

Figure 11: 2.4 A-early Summicron

The collapsible version of the new Summicron 1:2/50mm (1953) is a lens that marks the transition to the next period. While the lens itself belongs in the first period, I will discuss it in relation with the newer rigid version, that is specifically designed with the new M-mount in mind.

2.2.4 Summary for first period 1925 to 1957.

Theoretical knowledge of the optical aberrations and how to correct them is based on the work of some eminent scientists of the period around 1900. Schröder, Moser and Miethe studied the equations needed for the complex calculations for photographic lenses, Abbe experimented with new glass types, and people like Rudolph, Merté and Lee explored unknown territory to get the best imagery possible. The designs they used, (triplets, Petzval versions, double-gauss derivatives) were all based on constructs from the 19th century and it is in fact remarkable to note that most of the early efforts were concentrated on improving old designs and specifically to get rid of astigmatism. It is also interesting to remark that in the period form 1900 to 1940 the demand for photographic lenses was so high that most designers at first had to generate designs that could satisfy that tremendous demand. Room for fundamental research hardly existed. Commercial arguments prevailed in this expanding industry and the manufacturers exploited the available experience to the utmost. The widespread use of the Leica and its 35mm format and the expansion of focal lengths into the wide angle area, put heavy demands on optical performance and so did the surprising introduction of colour film around 1935. It became clear to some designers that the traditional methods and formulae for the calculation of aberrations did not suffice and that even the theoretical knowledge of the aberrations themselves deserved a reworking of basic principles. The geometrical (trigonometric) approach to lens design was insufficient to study and correct the higher level of aberrations that needed to be controlled for better image quality. The direction to follow was a study of the energy balances in the optical system, Berek understood this very well and he even devoted a full chapter to this topic in his book "Grundlagen der praktischen Optik" (1930). This chapter 10 ("Energiebilanzen") is part of the Leitz philosophy of lens design. The staggering amount of numerical results, needed to analyze lenses in this new theoretical approach, could not be handled with the classical log-tables and numerical methods. Indeed the full use of these insights had to wait until the computer became available early in the '50s. Max was not the only one to run against the limits of the traditional methods of computation. Albrecht Tronnier of Nokton fame was also acutely aware of the vanishing possibilities of the old approach. War however changed the course of humanity for a long period. Behind closely guarded doors the research continued, and the foundations for this new approach were intensively studied. Also new evaluation methods for the appraisal of optical performance were introduced as the mirror image of this research. The first studies into the importance of contrast for image quality were laid down by a Zeiss employee, Hansen in 1943. The period from 1925 to 1957 can be characterized as the search to adapt the known optical principles to the exacting demands of the Leica format and of colour photography. A few proven designs were selected as the platform on which to construct and manufacture the lenses that were commercially and conceptually required by the quickly expanding user base for the Leica camera.

Figure 12: 2.5 A :the Leica system Study of the production

Figures over the period 1930 to 1940 indicates that a total of 414.000 lenses left the factory, of which 169.000 were of the type Elmar 1:3.5/50mm and 123.000 of the type Summar 1:2/50mm. The Elmar 1:4/90mm and the Elmar 1:3,5/35mm had a production of 28.000 and 26.000. More than 70% of all lenses that were produced by the "Leitzianer" in the Wetzlar "Hochhaus" were of the 50mm focal length. The 35 and 90mm lenses added another 13%. These figures are a clear indication of the commercial viability of new designs, and when we add the worldwide recession after

1929 into the equation, it is sound business practice of Ernst Leitz to stick to the well-proven designs.

Figure 13: 2.5B: the Leica image

In the late thirties the Leica user could choose focal lengths from 28 to 400mm and apertures from 1:1.5, including some special lenses like the Berg-Elmar 1:6.3/105mm and the Thambar 1:2.2/90mm and (hypothetically) the Summarex 1:1,5/85. While it is true that some of the Leica lenses overstretched the optical limits a bit, designing and producing the lenses was of paramount importance for the next period. Leitz tried to expand the system concept of the Leica as quickly as possible as he understood quite well, that the success of the Leica depended on a comprehensive line of lenses, that provided most users with every option they could imagine. When evaluating the optical performance of a lens, designed and produced in those days, one should take into account that the lenses then were not checked and tested as we do today. The British report states that the Summitar was checked for image quality at the factory at the aperture of 1:3.2. Presumably the lens testers used some numerical rules to relate the quality available at 1:3.2 to the one at full aperture. The success of the "Leica"-camera was in part based on the large depth of field of the lenses, coupled to the 35mm format. The depth of field is greater when one stops down to middle apertures, and this technique was used in most circumstances. The full aperture setting was primarily reserved for the really difficult low light situations, where slow shutter speeds and high speed, grainy film-emulsions would not record fine detail at all. It was a fact of life that the image quality available at full aperture would be less that what could be delivered at smaller apertures.

2.3 Part 3: The challenges, 1957 to 1988

The Leica company had to face several challenges during these decades, some of which were optical in nature and others were related to the course of the photographic industry. The German "Wirtschaftswunder" generated unprecedented economical wealth, photography became the prime hobby for large segments of the population in the industrialized western part of the world. In 1955 the Leitz company, now located in three different factories in and around Wetzlar, produced 40.000 camera bodies a year and close to 100.000 lenses.

Figure 14: 2.3 A: lens # 2.000.000

In 1964 the production of lens# 2.000.000 was proudly announced, 12 years after #1.000.000 in 1952. In those days Leitz manufactured a thousand different products, which were assembled from 300.000 discrete components. Every month millions of parts had to be shop tested for tolerances, often less than 0.01mm. Such a diversified range of products, most of which were of high precision optical-mechanical nature, put a strain on the production and engineering divisions and of course on the design department too. Manufacturing technology was in essence the same as before the war, improved and modernized of course, but manual labour constituted the bulk of the workflow. Around 1965 the economy slowed down and the photographic industry became dominated by the Japanese and one main camera type, the single lens reflex. The high quality compact rangefinder camera was the second strategic product for the market. Leitz was squeezed by both product types, for which they did not have an immediate answer. The Leicaflex (1964) and the Leica CL (1972) were too late and of too modest specifications to have any impact on the market. The optical challenges were large too. Japanese designs covered an ever growing range of lenses of improved optical performance. The Leitz philosophy of design and manufacture of lenses made them less flexible in the area of extended specifications. The universal adoption of computer aided optical design gave lens designers equivalent opportunities and in the seventies one might note a plateau in lens performance. The leading marques produced lenses that delivered image quality on a level that satisfied most professionals and amateurs alike. It became increasingly difficult for Leitz to distinguish themselves and create optical systems of cutting edge performance. The amounts of money for the required research and development to stay ahead were simply not available, as the falling production of the Leica cameras reduced the profits of the company and asked for investment money too. The challenges seemed indeed insurmountable. On the organizational and management level, Leitz worked within the constraints of a traditional method of manufacture and decision making and the famous feeling of Leitz for the trends in photography was fading away too. On the marketing level, Leitz had to cope at the same time with the problem of a smaller production volume and the need to expand the range of products. On the level of design and innovation one has to note that the Leitz designers were quite innovative within their chosen domain of excellence, the high speed lens of fixed focal length, and were very advanced in the research for new solutions (glass, aspherics, even vario lens designs and even auto focus). Leitz focused all attention and development on one goal only and that was the development of lenses with very high image quality, which could only be delivered when the mechanical mounts were of very high quality too. . The true dilemma is simple: the high optical performance necessitates an expensive production process and a mechanically elaborate mount , which in turn defines the physical dimensions of the lens and as these dimensions cannot grow beyond manageable proportions, the specifications are fixed too. Leitz started the period in great prosperity, with an enviable product line, that sold very well, and a fine tradition of design and manufacture. The allowed themselves the luxury of two different and sometimes competing design departments in Wetzlar and Midland and a glass research lab. Later Leitz even added a very elaborate and costly technical lab for testing lenses and designing new methods for image evaluation. The big changes in the photographic world and in the photographic industry were only reluctantly acknowledged and Leitz tried with cooperation, and the adoption of lenses made by several manufacturers to expand the product line, while staying faithful to the traditional values of optical quality and superb mechanical craftsmanship.

Figure 15: 2.3B: telyt 3.4/180

Figure 16: 2.3C Macro Elmarit

Figure 17; 2.3D Noctilux 1/50

In 1972 the Leitz family stepped back from the management and in 1974 Wild Heerbrugg was in complete control. Not much changed however and the next period from 1974 to 1988 is characterized by a painful process of global marginalization. Some outstanding products were created in this period, like the M6 and R6, the Noctilux and the Apo-Telyt 3.4/180 and the Apo-Macro-Elmarit-2.8/100mm, but the impact of Leica on the market had been lost.

2.3.1 Evolution of the Leica camera.

During this period the photographic division of the Leitz company did indeed change dramatically. With the M3 and its range of lenses, Leitz established itself as the premium manufacturer of precision miniature rangefinder cameras and was without doubt the photographic company with the highest esteem in the world. The M3 with the Noctilux 1:1.2/50mm (1966) confirmed the position of Leitz as a world leader in advanced optics and the role of the M3 as the available light/reportage camera.

Figure 18: 2.3.1 A M3

While Leitz concentrated a substantial part of its resources on the rangefinder concept, the photographic world at large gradually shifted to the SLR-concept. This change occurred in a few years and must have been a surprise to Leitz. They were the only company in the world that expressed faith in the rangefinder concept for a professional camera system. The factory however could not overlook the drop in sales figures for the M-series. Leitz reluctantly followed the trend with the Leicaflex in 1964. The birth-pangs of this camera have been noted in the contemporary press and the announcement of a reflex Leica were rumoured since 1958. The design and development of the reflex line is not part of this story. Suffice it to say, that the Leicaflex and its successor models were less successful than Leitz anticipated. The development of a comprehensive lens-line to compete with the professional Japanese and German models of those days was no easy task. At the same time the sales of the rangefinder camera dropped significantly. In 1960 the sales of the M2/M3 were around 30000, and a few years earlier were above the 35 thousand level. But in 1970 the M4 sales were around 12.000, and the Leicaflex SL had a designated production run of 10.000. Leitz was in a difficult position as its market share shrank, while the investment for research and development had to increase to compete with the ever more innovative Japanese companies.

Figure 19: 2.3.1 B M System

Being alone in the rangefinder market, Leitz tried to break out of the M3/4 mould, with bold new designs. The M5 was clearly targeted at the professional photographer who was accustomed to features like the through the lens exposure metering. The CL, on the other hand incorporated modern features that tried to open up the new vast market of the dedicated amateur photographer. These models, with their quite innovative engineering, did not capture the mood of the market however and were withdrawn after only a few years. In fact the fate of these models dealt a heavy blow to the confidence of Leitz in the RF-future. Is was decided in Wetzlar to end the RF-production and to concentrate on the SLR as the main product line. The dedication and enthusiasm of a few persons, saved the M-system: the production of the camera was transferred to Midland (the M4-2).

Figure 20: 2.3.1 C: Leicaflex

The Leicaflex SL2, the last of the ‘true’ Wetzlar reflex bodies, had run out of steam already at its introduction and Leitz, following the maxim “if you cannot beat them, join them”, teamed up with Japanese suppliers to produce the next generation SLR, the Leica R3. The history of the R-development is not part of our story. Suffice it to note that the Leica R3 and the successor model R4 sold well, but did not inspire that confidence in the solid engineering Leitz were famous for. The R5 and especially the R6 and R7 restored the reputation, but now we already entering the nineties and that is the Solms-era. The cooperation with Minolta did extend into the optical area, and Leitz used several Minolta designs to fill in the gaps of the lens line for the R-system. In the mid-seventies the photographic industry reached a performance plateau: the SLR development had virtually stopped after the incorporation of Auto-Exposure techniques. The lenses too, helped by computer assisted design programs, had evolved to a state where it was becoming difficult for the casual and critical observer alike to see big differences in image quality between the leading marques. The independent suppliers of lenses, improved their optical quality to a level that started to challenge the leaders, at least optically. And with a very favourable price-performance ratio, coupled to innovative designs, these makers made substantial inroads in the traditional markets. On the optical front, the Leitz designs, while still first class, ran into stiff competition from several Japanese and German companies, whose design teams, aided by computer programs and a large selection of commercially available glass types, produced lenses that were sometimes uncomfortably close to the Leitz designs in image quality. The domains where the Leitz performance could show its advantages (slide projection and large format B&W prints) were shrinking. The increasing use of the colour-negative print also diminished perceivable differences in mage quality. Leitz had one very important advantage, that is often overlooked: the mechanical quality and engineering precision of the lens mounts is second to none. The longevity and durability of Leitz lenses can be seen in any older lens that is in use today. Leica lenses also stay within tolerances, even after prolonged and heavy-duty use.

Figure 21: 2.3.1D: Lens mount

The Leitz company started the 35mm boom in photography in 1925. The company was sold to Wild in December 1986 and the production facilities transferred to Solms in June 1988. It is a strange quirk of history that Leitz always went against the current mood: in the twenties when against all odds and advice the Leica Standard was produced, in the fifties when the decision was made to continue the development of the RF system and in the eighties when they decided to stick to the manual focus SLR. The Leitz management then had to accomplish a true mission impossible. They felt pressed to offer a comprehensive range of lenses for two different systems, they had to improve the optical quality and at the same time contain the cost of production to adjust to a lower sales volume of the R- and M-systems. These decisions had important consequences for the development and characteristics of the Leitz lens families. For the rangefinder and reflex systems the company wanted state of the art performance for their lenses. Where “state-of-the-art” was to be defined within the limits of the Leitz philosophy of lens design. The designers had set themselves a certain minimum level of image quality. When you have designed a lens (focal length, aperture, volume, number of lens elements etc.)

you can calculate the (theoretical) performance of a lens with a technique called 'ray intercept curves'. These curves can be graphically displayed and their shape is very important as they give the designer a full insight into the quality of the lens. Now you can define that the bundle of curves should be within certain upper and lower limits. Any lens that has curves that extend beyond these limits, delivers less image quality than a lens that has graphs within these boundaries. Leitz did design several prototypes for the R-system, but performance at full aperture could not be fitted within these optical limits (and the production constraints). They might have been very good lenses by most standards and would certainly have drawn attention to the Leica R, but Leitz, bound by their own strict performance levels could not be persuaded to manufacture this lens.

2.3.2 An Herculean task From 1957 to 1988

Leitz introduced more than 40 new or redesigned lens types for the M-system and more than 50 lens types for the R-system, on average three lens types per year. The Leicaflex has been introduced on the market in 1964, but the design of lenses for this system started around 1960. At first the designs for the R-system were optically completely different from the M-equivalents. In 1964 the Leicaflex was accompanied by four lenses: 1:2.8/35mm, 1:2/50, 1:2.8/90 and 1:2.8/135, the classical quartet. All four were new optical designs, and of Canadian origin with the exception of the 35mm lens, which was created in Wetzlar. The larger throat diameter of the R-body and the bigger distance from lens flange to film plane (27.8mm for M and 47mm for R) force the designer to create retro-focus designs for lenses with focal length below 50mm, which are more difficult to design. The retro focus principle also requires larger front elements. There is a 'hard' rule in optical design that states that a physically larger lens is easier to correct for aberrations than a smaller lens. And the type of correction could be different too. Leitz then needed two distinctive design philosophies so to speak, one to optimize the smaller M-lenses and one to optimize the larger R-lenses. How did Leitz cope with these incompatible challenges? In the beginning the factory followed two different design strategies, one for M and one for R. In the M-domain, they pursued to improve the image quality of existing designs and to develop lenses with daring specifications, like the Noctilux. These new lenses were made possible by the advances in optical knowledge, partly by theoretical study, creative inspiration and the assistance of the computer and partly by the research into new types of glass. In the R-domain, Leitz started quite conservatively with lenses of moderate specifications and forged ahead later with longer focus lenses with apochromatic correction. Of course there was a sharing of insights between the developers of the M and R lenses and this can be seen quite clearly in the development of the 50mm lens.

Figure 22: 2.3.2 A reliance on manual labour.

One of the first strategies to be used by Leitz is the pooling of resources by designing lenses that could be used in the M- and R-systems. One example was to use the long lenses, developed for the Visoflex, in a different mount for the R-system. The later Summicron 1:2/50mm lenses, the Summilux 75/80 lenses and the Elmarit 1:2.8/135mm lenses are examples of this trend too. We should note however that the two design-departments (ELW and ELC) were thousands of kilometres apart, and pursued their own design philosophy under two independent management teams and so the potential for competition was as much part of life as the potential for synergy. Another strategy is to cooperate with other lens manufacturers. The range of lenses that Leitz could develop themselves was limited, so for a number of lens designs , notably zoom lenses and very wide angle lenses, the factory used lenses from third parties, like Schneider, Zeiss and Minolta. Behind these strategies, the true battle of that period is between the drive to improve the image quality and the possibility to translate this improvement into the production of the lens, while holding down the cost of manufacture. The use of the computer, new research into optical glass, better grasp of the optical theory and more insights into the design process all helped to improve designs significantly. There is a hint of a true Greek drama here, that Leitz succeeded in advancing the theory of optical design, but could not find the right way to produce these exciting designs. First of all: the method of producing, assembling and mounting lenses did not change over the years and had much in common with the way lenses were manufactured in Berek's days. But the improved designs needed tighter production tolerances, that were not possible without a higher cost. And that was the economic constraint as the lower sales volume could not bear this.

2.3.3 Evolution of the lens systems for M and R.

The development of the lens systems for R and M has to be described and interpreted against this background. We can illustrate these developments with a few significant acts. From 1954 to 1971 (the period of the M2/3/4) Leitz expanded the M-line into a full blown system concept, with lenses from 15 to 800mm. At the same time the factory redesigned many of the lenses, for improved performance, and/or easier handling. In several instances the drive for enhanced optical quality collided with the limits of production technology and/or production costs. After 1971 (introduction of the M5 and CL) the rangefinder concept was developed more selectively with lenses in the 21 to 135mm bandwidth. But the reduced sales forced the design-department to economize on the introduction of new designs and find ways to control the production costs of existing designs. Between 1975 and 1980 Leitz introduced a number of very high speed lenses for the resurrected M4-2 (and M4P), that could be seen as the state-of-the-art profile for the rangefinder concept. From 19080 to 1990 no new lenses for the M-system have been constructed.

Figure 23: 2.3.3 A CL

Figure 24: 2.3.3 B M Lenses

For a long time Leitz maintained and expanded the M-system as the dedicated tool in the great tradition of the documentary photography. Many lenses were redesigned for improved optical quality and/or better handling. (smaller volume, less weight). Some exciting designs like the Noctilux 1:1.2/50mm indicated the dedication of Leitz to deliver the best possible optical quality to its demanding customers. But the system-concept of the M was not abandoned after the introduction in 1964 of the Leicaflex and for a longer period Leitz had to develop two lens lines which at the long focus end were competing with each other. This also blurred the distinction between the two systems. With the Telyt lenses (400mm to 800mm) Leitz used the same optical cells in different mounts, which reduced cost of development, but hardly of production, one may assume.

Figure 25: 2.3.3 C Noct 1.2/50

The evolution of the R-system can also be sketched in some clearly defined stages. After 1964, the year of the introduction of the Leicaflex, the development of the lenses for the R-system proceeded slowly. For the R-system Leitz concentrated on these focal lengths they had most experience with, that is the lenses that were also the backbone for the M-system: 28mm to 135mm. The maximum apertures however were quite modest (even for those days). The 35mm, 90mm, 100mm, 135mm and 180mm all had apertures of 1:2.8. The first 1:1.4 design was the 50mm Summilux in 1969, ten years after the M-version.

Figure 26: 2.3.3 D R-1.4/35

The aperture of 1.4 for the 35mm had to wait till 1984, before Leitz felt confident enough to produce he Summilux 1:1.4/35mm. The 1:2/35mm lens arrived in 1972, more than a decade later than the M-version. One may only guess why Leitz has been so conservative in the specifications for the R lenses. The obvious commercial argument might be that they did not want to have competition between the Leitz camera-systems. Leitz obviously had defined the SLR-system as a complement to the M-system, not as a competitor. More philosophically one might argue that the focusing screen and the mirror box with its time lag, typical of the SLR-system, dedicated the Leicaflex to a different type of photography and Leitz designed lenses exactly for that goal. Leitz, with its rangefinder expertise, may have had the opinion that the inaccuracy of focus with the split-image rangefinder of the SLR precluded the use of very high speed lenses. And on a more mundane level, one should be aware that Leitz had hardly any experience with the design of lenses for a SLR-system.

Figure 27: 2.3.3 E R19

Around 1975, more than 10 years after the Leicaflex appeared, the first wavelet of innovations for the R-system was announced: the 19mm and the Apo-Telyt 3.4/180mm, the first apochromatically corrected lens, developed by Leitz Canada. It is interesting to note that the Wetzlar designers were more concerned with the technique of aspherics and Midland with the apo-correction, at least in those days. The M5 and the R-body however required many lenses in the wide angle and standard focal lengths to be redesigned as retro-focus lenses. Leitz however had at first hardly any experience with retro-focus lenses for Slr-systems. That learning curve is visible in the many redesigns of the 28mm lenses for the M-system and the 35mm lenses for R-system. The first original Leitz designs in the very wide angle domain are the Elmarit-R 1:2.8/19mm and the Elmarit-M 1:2.8/21mm in 1975 and 1980, an indication of the long gestation period that Leitz needed to feel confident to design these types of lenses. After 1980, when the development for the M-system stopped, the R-system expanded rapidly with landmark designs like the Summilux-R 1.4/35mm design (1984) with floating elements and the Apo-Elmarit-R 2.8/100mm (1987). At the same time, Leitz adopted many designs from Minolta and others. It is evident that Leitz had not the capacity nor the money to undertake a massive development program for two different systems and we see a relocation of forces over time, and a switch of main focus from Rangefinder to SLR after around 1978.

Figure 28: 2.3.3 F: expanding system

2.3.4 The quest for image quality;

As suitable glass types seemed to be the biggest obstacle for the advancement of new designs, Leitz set up its own glass laboratory and around 1953 the first fruit of that effort was the introduction of the Summicron 1:2/50mm (collapsible). Its design was completed in 1949 and a slightly different computation became necessary in 1952 when Schott glass had to be incorporated. After the introduction of the Summitar, the "Leitz Rechenbüro" continued to explore this design as it was clear that the competition would not sleep and a high quality 2/50 lens was of utmost importance for the critical Leica user. In those days the limits of the diameter of the lens mount of the current models became painfully clear. When wider apertures were needed or a higher level of correction , the diameter simply was too small. The patent literature of the four-tap bayonet mount for the later M-models, specifically mentions the reduced vignetting as one of the prime characteristics. The first Summicron version closely followed the design parameters of the Summitar and the increase in image quality was slight. It too is a low contrast lens, and shares the optical 'fingerprint ' with its predecessor. The rigid version of the Summicron 1:2/50mm arrived on the market in 1957, but was on the drawing board several years earlier. It utilized the optical improvements that were made available with the wider throat for the M-body. The seven-element Summicron split the front element in two separate lens elements and used the air space between the two elements as an additional lens (an air lens or Luftlinse). Leitz also separated the front doublet and used the same technique for enhanced correction, specifically for a reduction of spherical aberration and of the secondary spectrum (the chromatic aberrations). The Leitz designers also incorporated in the new design the new Lanthanum glass types, developed by the research lab. The air-lenses are a mixed blessing though as they allow for a better control of aberrations, but also introduce more flare and they are very sensitive to small deviations in tolerances. After 1957 Leitz introduced in quick succession several lenses for the M-system, that can be regarded as the first series of lenses with markedly improved imagery, when compared to the predecessors. The image quality of these lenses was a true testimony to the progress in the optical and mechanical fields, that the Leitz engineers had been able to make since the war ended. In the late thirties Leitz had noted that the traditional methods of design, the knowledge about aberrations, the commercially available glass types and the methods of production would seriously handicap the search for new optical solutions. In 1949, the year that Max Berek died, the company had inherited a large body of knowledge and had accumulated a vast pool of experience. One should remember that much of optical theory originated in the microscope division, which was very valuable but needed some fundamental transformation before it could be used with good result in the photographic department. The microscope lens has a much smaller field than the standard photographic lens and aberrations which are very troublesome in photographic applications are less so than in the microscope. The converse is true too, of course. As example I may remark that apochromatic correction of microscope lenses was standard practice, long before this approach was applied in photographic lenses. A major part of the research and design efforts of Leitz in the period from 1950 to 1980 was devoted to the exploration of the double-Gauss high-speed lens. As I mentioned before, this lens type is very flexible and can be adapted to several classes of demands. A lower speed wide angle lens as the Summaron 1:2.8/35mm and the high speed Summilux 1:1.4/50mm or the Summicron 1:2/90mm ask for a different type of aberration correction. The difficulties in fine-tuning the several sets of requirements can be seen quite clearly in the long list of lens versions for the M- and R-systems. Some designs were replaced very soon by improved versions: witness the Summicron 1:2/90 (1959) and the Summilux 1:1.4/50mm (1961). Here we see a trait that is most characteristic of Leitz lens development. The optical department in the Wetzlar “Hochhaus” tried to refine and improve the existing lenses continuously, and they committed a fair share of their resources to that end. Leitz would never be content with the idea that a certain lens is good enough. His drive was to provide the photographer with the optimum optical performance. The many redesigns of classical focal lengths in the 28mm-135mm range do show this intention. Sometimes a lens is not changed for decades. The Summilux 1:1.4/35mm is an example. At full aperture it has low contrast and it suffers from coma. Its overall characteristics would indicate it to be a Summicron 1:2/35mm, opened up one stop. Given the constraints (optical and mechanical) of a high speed wide angle lens, the definition of this lens could not be improved upon. It is perhaps more accurate to say that the Leitz designers could, within certain limits, create a (theoretical) lens that could deliver better performance, but it would be very difficult to produce such a lens. We do not often realize that suitable glass must be available, that the production tolerances must be realistic and that the amount of manual adjustments during assembly should be low. The designer might calculate a very fine lens, but if the glass needed has a thermal expansion that is not in line with the other glasses, or has properties that make it difficult to manipulate (grind, polish), he cannot use it. It took almost 30 years before the technique of aspherical lenses could break this Gordian knot for this type of lens. The first Noctilux 1:1.2/50mm with two aspherical lens-surfaces (1966) does indicate the relationship between the several variables. This lens was optically a breakthrough, but the amount of manual labour, the exactitude of the tolerances and the overall optical/mechanical sensitivity denied the lens the commercial success, Leitz had hoped for. In the category of very high speed lenses (1.4 and wider) Leitz redesigned the 1:1.4/50 in 1961 and introduced the R-version in 1970. The R- lens stayed in production until 1998 when a much improved version with 8 elements appeared. The M-lens is still in production, but begins to show its age. It is however not that easy to design a version that delivers improved image quality while staying competitive in price and physical dimensions. The long production period of the Summilux 35 mm (M and R-version) is a clear indication how difficult it is to improve on a well designed lens when the parameters are really difficult (1.4 aperture and an angle of 64o are heavy obstacles for a designer.). The Summilux -R for the 35mm focal length was a Wetzlar design and they needed a vast array of optical means to improve upon the M-version from 1961. The M-version had to be designed within the limits of a compact lens and it may represent what was possible with conventional means. The R-version could be designed with more liberty concerning the size and so a ten element optical system with floating elements emerged from the drawing board.

2.3.5 Containment of costs.

During and after the mid-seventies, Leitz tried to rationalize their lens systems, sharing mounts and lens elements wherever possible. As example we may look at the Summicron 1:2/50mm standard lens. This lens family is an example of the double goal for more image quality (and cost containment at the same time). The Summicron (type I) was the collapsible one from 1953 or 1954. The Summicron (II) for M was introduced in 1957. For the new R-system (1964) Leitz Canada designed a different lens, now with six elements and higher level of symmetry and different glass types. A few years (1969) later ELC introduced the Summicron (III) for the M-line, a design that differed from the predecessors and generally offered higher image quality. In 1969 the Summicron for M had the same overall construction as the Summicron for R, introduced in 1964 and the reduction from 7 to 6 lens elements improved the imagery and at the same time reduced the assembly and production costs. There was evidently one element less to grind, check and mount and the performance was improved at the same time. The next stage of the design for the R arrived in 1976 with the Summicron-R (II). This lens is a highly evolved design that delivers high image quality, better than the predecessor, especially in its behaviour at full aperture. It gave a high contrast image with quite even performance over most of the image area. An almost identical version for the M-system was introduced in 1979 with the Summicron-M (IV). Both versions are remarkable as they have 5 plane surfaces, instead of the curved surfaces of the other types of Summicron lens. A plane surface is easier to manufacture and handle, so its use will lower the production cost. In addition a plane surface does not generate unwanted reflections, and it is sufficient to use a single-layer coating.

Figure 29: 2.3.5.A M50

Figure 30: 2.3.5B R50

On the other hand a plane surface has less potential for aberration control. The key for explaining this apparent contradiction (simpler design and higher image quality) is the improved optimization capability of modern optical design programs. The Tele-Elmarit 1:2.8/90mm is a very interesting example. This lens has been introduced in 1973, as a parallel development of the Elmar-C 1:4/90mm for the Leica CL. It shared no components with the 1964-version for the Leicaflex. In 1980 a completely different and improved 90mm for the R-system appeared, but this lens was not adapted for the M-system until 1990. There is an interesting story behind the Tele-Elmarit for M. The 135mm lens was not selling well and disregarding its outstanding imagery, was to be axed from the catalogues. But the focal length of 135mm had to be taken care of. In the Leitz archives we find the key for the strange role of this lens. The Leitz designers had in mind a teleconverter 1.4x for the M-system and the compact Tele-Elmarit. This combination would deliver a very small and lightweight 135mm lens of acceptable aperture (1:4.0). This idea however has been shelved, because of lacklustre performance. It does indicate that creative solutions were actively searched for.

Figure 31: 2.3.5.C Novoflex

A third example is the Novoflex system, which used the optical cell of the Telyt lenses, made for Visoflex and R-bodies too.

2.3.6 Cooperation

Here we can identify one of several strategies that Leitz choose to use: cooperation with several lens manufacturers. In hindsight it is easy to comment upon the decision of Leitz to neglect the zoom lenses for the R-system. The official position of Leitz regarding this type of lenses was the statement that the optical quality of Leitz lenses with fixed focal length could not be attained by the zoom-lens. I would regard this as a marketing act. Technically Leitz were not equipped to design zoom-lenses that lived up to their standard of optical quality at those days. On a more philosophical level, I would venture to remark that the zoom lens with its physical bulk, its many lens elements and complicated engineering and indeed its lower quality, did not fit in with the Leitz philosophy of lens design. Leitz tried to use the least possible lens elements to get optimum results by studying the character of a lens system in depth first. The basics of a complex zoom lens are very difficult to study as there are so many variables involved. A zoom lens can be designed with optical compensation or a mechanical compensation as a tool for correcting aberrations. When the first zoom lenses arrived on the market, both methods were used, but none of them gave the results Leitz was looking for. The optical compensation did not give exciting results, but the mechanical one was an engineering nightmare, at least in the Leitz tradition of mechanical precision.

Figure 32: 2.3.6

A Angenieux Whatever Leitz' view on the zoom lens, the market demanded a range of zoom lenses and so Leitz had to offer them in order to broaden the appeal of the R-system. The first supplier of zoom lenses was the French company Angenieux. This company offered three versions:1:2.8/45-90mm, 1:2.5/35-70mm and 1:3.5/70-210mm. The cooperation was quite limited. Leitz allowed Angenieux to use the bayonet-mount of the Leicaflex, and promoted the sales of these lenses. The relationship with Minolta was much tighter. There was in fact a technology transfer deal, and we may remark that in optical matters Minolta learned more from Leitz than the other way around. The Japanese contacts however established a base on which Leitz and later Leica could expand their contacts with Japanese suppliers. The Minolta zoom lenses were delivered as Leitz lenses and they were 'adopted' as Leitz products. The optical performance of these lenses was for many intents and purposes good enough for a broad range of users. Branded as Leica lenses, they did not perform with the characteristic Leica fingerprint. And critical users might question the choice of the Leica system if the backbone of that system consisted of third party lenses.

Figure 33: 2.3.6 B Minolta

Figure 34: 2.3.6.C Schneider

Figure 35: 2.3.6.D Zeiss

Leitz clearly lacked knowledge and possibly resources to expand the Leicaflex and Leica R system with only Leitz designed lenses. The Mirror lens, the Fisheye lens and the 15 to 24 wide angle lenses came from various sources (Zeiss, Schneider and Minolta). The same strategy was followed with the zoom lens. Angenieux, Minolta and were the suppliers. There is some discussion if the third-party lenses were just rebranded designs or if Leitz added some value to these lenses. The Angenieux 1:2.8/45-90mm was the first in 1969, in 1974 followed by the 1:4.5/80-200 from Minolta. The next was the 1:4.5/75-200, again by Minolta and the redesign in 1984 while the 4/70-210 had additional Leitz input? The 3.5/35-70 had two versions, one in 1982 and the second in 1988. (both Minolta design). (The 3.5-4.5/28-70mm in 1990 was a Sigma product.) We have to wait till the next period to see what Leica designers can do with a zoom lens after they had acquainted themselves with the technicalities and optical properties. The very wide angle lenses for both M and R were supplied by Schneider (21mm) and Leitz also used Schneider designs for the wide angle lenses with perspective control. Leitz did not design their own zoom lenses, and at first used Angenieux designs. This strategy of cooperation and adoption of lenses from third party suppliers continued and expanded during the seventies and early eighties with several Minolta designs, (fisheye lens, wide angle lenses, mirror lens and zoom lenses) and a Zeiss super wide angle (15mm).

2.3.7 ELC and ELW

In 1949 Max Berek died and Dr. Zimmermann took over. Some years later a second optical design department was established in Canada under the direction of Dr. Walter Mandler. The fifties presented several challenges to the Wetzlar company. The introduction of faster means of computation (desk calculator and electronic computer) allowed the exploration of better designs and as a result deepened the theoretical understanding of aberration theory. This research could be transformed into commercially viable designs if new glass-types were available and if the small engineering tolerances that were required could be held in manufacture and assembly. And last but not least, the demands of the Leica users for ever better imagery intensified the exploration into the realm of image assessment. The arguments for the establishment of the Midland branch have been the bleak cold war prospects in Europe and the prominence of the American market for Leitz. The choice of Midland as a town has been a decision of Leitz himself as he had some private relations with the town. Midland was set up as a design and production facility and many lenses have left the factory since the first days. The first lens to be manufactured was the Summarit in early 1952 with serial number 987101. After about 1955 some fundamental changes occurred. One of the most far-reaching is the gradual shift of balance of camera lens design to the Canadian factory. Many of the lenses for the M-system and a fair proportion of the lenses for the R-system originated from ELC (Ernst Leitz Canada). Mr. Mandler, who already worked in the Wetzlar factory when Max Berek headed the department, went to Midland, Canada in the mid fifties to organize and manage the optical department there. Both Wetzlar and Midland used electronic calculators and later computers for faster and more elaborate computations. At first the speed of the computer was employed as a convenient replacement of the older logarithmic tables and to speed up ray tracing. Later algorithms were programmed to compute and analyze the aberrations themselves and in a third stage additional computer programs were written to optimize (automatically correct) optical designs. In Wetzlar the foundation of aberration theory and its corrections originated from the design and construction of microscopes and its lenses. The specific concerns and characteristics of 35mm photography were added to this body of knowledge and experience in proprietary programs. In the mid seventies prof. H. Marx almost single-handedly designed the computer programs that are still used by Solms designers, all be it in much improved format. The COMO program is the heart of the computer programs in use now in Solms. Correction, Optimization, Minimization, Orthogonalisation are the keywords in the name.

Figure 36: 2.3.7: Marx pictures on CD!!!

Research into exotic designs continued in both departments. Looking at the list of prototypes, it seems as if the Wetzlar people were deeper into the fundamental research. In Wetzlar we find lenses with three aspherical surfaces, and specially designed glass composites. The prototype 1.2/50mm lens with aspherics and segmented glass is a fine example of this drive to the limits of design and manufacturing technology.

Figure 37: 2.3.7.A lens picture

Figure 38: 2.3.7.B drawing

Meanwhile in Canada, the designers adopted the optimization programs at an earlier stage and so were often able to design lenses faster than their Wetzlar counterparts. ELC designed lenses were also optimized for economical manufacture. More so than the Wetzlar designs. In a period that Leitz became more and more vulnerable to the prevailing market forces, this was an important consideration. Recall that around 1970 the M-system was far beyond its zenith and the R-system faced stiff competition. The M5 and CL bodies needed new designs (resp. more retro focus lenses and more compact ones) and the Leitz philosophy to stick to high quality fixed focal lengths and thus neglecting the trend of the zoom lenses, put a heavy load on the design teams at both sides of the Atlantic. Commercial considerations however forced Leitz to include zoom-lenses in the catalogue and just as a decade earlier with the Schneider cooperation, Leitz added some Minolta zoom-lenses to fill the gaps.

2.3.8 Glass research.

The glass lab existed from 1948 to 1990. The Leitz glass lab is the focus of many stories. The glass lab, by its very dimensions was not equipped to handle or melt large blocks of glass in any quantity. The true role of the glass lab was the research into the composition of new glass types, with properties that could be used by the optical designers to help them with the computation of new lenses. This role was an important one and many of the glass types now in the catalogues of large manufacturers like Schott or Corning have been first explored in the Leitz glass lab. One may say that without the glass lab the Leitz designers would not have been able to acquire the tools and the knowledge to improve the Leitz lenses. The original building is still to be seen on the old Leitz Wetzlar Industry Park (Werksgelände), tucked away between the imposing main ten-storey buildings. It has an area of about 10x20 meters and these dimensions indicate its role. There were four small melting pots, that could handle 5 to 10 kilograms of glass at a time. The dilemma for the optical designer is that he needs special glass to optimize his designs, but only in small quantities. The direction of research for Leitz was in the exploration of high refractive glass with very good colour transmission. That proved to be a problem and only when one started to use lanthanum oxide and (radio-active) thorium oxide, both characteristics could be combined. The use of rare earth additives (lanthanum) is an invention of Kodak in 1938 and later widely used by other manufacturers.

Figure 39: 2.3.8 A glass map of Schott two versions!

Figure 40: 2.3.8.B Leitz additions

The glass lab did introduce many new formulations of special glasses that could be more easily machined. Often glass with exotic specifications can not be handled in the manufacturing process, due to specific problems: glass too brittle, glass starts to discolour, etc. As the lab had no production capacity, they had to make an arrangement with a glass manufacturer, like Schott or Sofirel or Corning who would then produce the glass under several types of agreement. The true significance of the glass lab is for the optical development that it helped to support and even foster and for the microscopy department where one needs glass of more demanding specifications and tolerances than is needed for photography. Only very few glass has been melted there for production purposes. The well-known Noctilux glass (900403) has been produced for some time in the glass lab, as Schott could not comply with the specifications. Later the glass has been replaced by one that could be obtained from regular sources.

2.3.9 Design and manufacture of Leica lenses

The design department needed about two years and sometimes longer to complete a new design. Often the designers had to address other topics and could not work continuously at the project. Sometimes optical problems proved to be difficult to tackle. And sometimes one had to make a fresh start At least a year was needed for testing and adjusting the production cycle to this design and then another period was required to stabilize the production to the manufacturing quality that was expected.

Figure 41: 2.3.9.A Centering of lenses.

The manufacture of the lenses was separated, physically and as organizations, from the design department. The optical designers were primarily focused on the goal of optimum image quality and left it to the production engineers to find a way to hold the necessary tolerances for machining and assembling the mechanical and optical parts to the required specification. It is clear that some professional tension existed between both departments. The optical people might specify a certain glass, because it had the required optical properties. During the processing stage, one could discover that the glass would discolour a bit, and the transmission properties were altered. In such a case, an alternative glass had to be searched for. Or the rim of the glass was too thin and would give problems when fitting the lens in its mount. For a classical Double-Gauss design, the optical department would specify the thickness tolerance of the cemented doublet (the middle part) as 0.1mm and the sum of both doublets as 0.02mm. Such a matching scheme is only possible as lenses are manufactured with tolerances on both sides and this matching may be labourious and error prone. The mechanical department then would ask for a different set of tolerances.

Figure 42: 2.3.9.B Checking mounts

Thicknesses of lens elements and spacing are very critical and the natural tolerances within a production process need to be taken into consideration. A thickness tolerance of 0.1mm is acceptable for larger scale grinding of lenses, but to keep a tight tolerance of 0.01mm in even a small production run, is a hell of a job and a very expensive one too. The optical designer has the goal to find the best optical performance, but also to create an optical system that can be manufactured economically. The division of labour asked for an elaborate interaction between the departments. After the lens is computed on paper a few prototypes are manually assembled, which includes the grinding of lenses. When prototypes are assembled, elaborate testing in the laboratories (to check the residual aberration, but also to test the quality of manufacture) and in practical photo shootings (to check the visible image quality) is required. If the visible image quality is not as expected (compared to predecessors and other lenses) the defects are noted and the optical department has to change some of its parameters. Or the lens may be optically on target, but it is too difficult to produce. There are no clear-cut solutions in this interplay of mathematical and engineering parameters. Sometimes an optical redesign would take a long time to accomplish and might not deliver the required improvement. In such a case it would be cheaper to make educated guesses and make new prototypes on the basis of these proposed changes.

Figure 43: 2.3.9.C Interferometric testing of surfaces. Interferometric checks

To understand the magnitude of this task you may reflect on the fact that the optical designers are looking at the sub-micron level when they discuss tolerances and changes (much less than 1/1000 of a mm). The mechanical engineer however will consider tolerances of 1/100 of a mm as quite exacting. This ‘engineering’ gap of a factor of 10 to 20 in requirements, presented a challenge to the Leica engineers working in the optical and mechanical departments. A challenge by the way that still exists today. As Leitz took very great care that the lens at the end of the assembly line was indeed within the specified tolerances, the process of cost cutting had its ‘natural’ limits. Lens assembly at Leitz was and is a labour intensive process, that only a qualified and experienced workforce can handle. Any new lens design requires that the workforce has to be retrained to produce and assemble the lens. A designer can easily create an exciting design that is impossible or very difficult to construct. Lens elements are polished on a single block and the more elements can be polished in a single run, the cheaper it will be. But then the curvature of the elements should be as flat as possible. That limits the designer's freedom. Any lens element or steel or brass or aluminium component has some deviation from the zero-tolerance norm, however careful the production process. A clever designer has to allow for some tolerance and make sure that image quality does not drop beyond a certain specified level, as some manufacturing deviations are to be expected. This is part of the optical design itself. But many components will have different values within the tolerance bandwidth. Throwing away is no option, so the technique of matching and compensation is required. This matching and checking and correcting takes time and the design should allow for this technique. A common method at Leitz was to assemble lens elements in sub-units that could be individually and manually adjusted to the required specifications. Leica lenses are solidly build with finely machined components. These characteristics are the result of the design and production methods used then and exemplify the level of quality Leitz did build into any lens. There is a persistent view that the Leica lenses till the sixties are better built than later series, with a "cost is inconsequential " consideration. That would be economical suicide of course. But is there a grain of truth is this view. As with many Leica topics, a clear-cut answer is not easy. Brass and aluminium and a layer of chrome give an impressive appearance and feeling. Part of the truth is this: older designs were assembled form subassemblies, that housed some of the lens groups. This was done to be able to adjust the lens elements and lens groups to the required tolerances as specified by the optical department. Manufacturing technology of mechanical parts, in those days, could not hold the very fine tolerances needed. The same applies to the individual lens elements. The assembly workers used parts that were classified into tolerance groups, finely graded in plus and minus tolerances so as to combine a suitable pair to match the numerical demands. As so many lens elements have to on stock to help the matching process, costs will be higher too. It is true that Leitz built their lenses with high quality materials and with great precision, but the manufacturing cost of the lens governed the production process.

2.3.10 Summary for the second period: 1957 to 1988.

The level of performance of the lenses for the R and M systems had improved over the years to an enviable level and it is quite easy to understand that any further improvement in image quality required more and more study in the optical department. It is one task to design a new or improved version with a lower level of aberrations as calculated. It is quite another task to transfer this improvement into production, given the much tighter tolerances and it is a third task to make these optical improvements clearly visible for the user in practical shooting assignments. It is the same story as with an athlete. To cut the time for the 100 meters from 13 to 11 seconds takes a short training period.

To go from there to the sound-barrier of 10 seconds takes years of intense training. So it is with a lens. To control the classical third order aberrations is relatively easy, once you have understood the principles. To get a grip on the next level of aberrations is much more complicated. When we take a closer look at the Leica lens history we note a slightly different pattern of evolution for the M-system. Here we see four trends: the change to retro focus designs in the wide angle group of lenses, the simplification of optical systems for many lenses in the 35 to 90mm category with some improvements, a markedly higher performance in the 135mm group and a special effort in the 50mm group of lenses to advance the higher speed lenses to a class of its own. For the R-system we see some similar and some specific trends. Again we see a simplification of designs with the additional aim to provide enhanced performance. Then we note the adoption of third party lenses to close gaps in the proprietary lens-line to provide a comprehensive system of lenses and a specific strategy to enhance performance of the longer focus lenses markedly by apochromatic correction. The complete strategic neglect of the zoom-lenses may seem strange at first, but can be explained if not excused by the concentration on the core strength of the company: fixed focal length systems. Still Leitz had a special team of people that studied the theory and possibilities of the zoom lens. It seems as if Leitz were reluctant to explore new worlds. The invention of the Correfot is another example of a Leitz innovation, that was not developed further. When the M5/CL pair failed in the marketplace and the R3 succeeded the Leicaflex line, the spirit of the Leitz company faltered. With the M5 and the Leicaflex SL, Leitz tried to redefine the classic rangefinder concept and define the SLR-camera within Leitz parameters and in both cases had to admit that the Leitz approach failed to capture the market. Designs like the Noctilux 1:1/50mm and the Apo-Telyt -R 1:3.4/180mm were true to the optical mission of the company. The exploration of the ultra high speed lenses for M and R too (a 1.2/50 design for R has been contemplated) and the design of the best possible image quality by using special glasses and apochromatic corrections continued. Quietly however, a new level of possibilities for optical correction gave rise to designs of less spectacular specifications. The Elmarit-R 1:2.8/90mm (1983) and the Apo-Macro-Elmarit-R 1:2.8/100mm (1987) were of much humbler specifications, but they were signposts of the direction to follow. The Apo-Macro-Elmarit-R 1:2.8/100mm is the last lens that, supervised by Mr. Vollrath, left the Wetzlar design department. It became the standard by which all other Leica lenses were measured. At full aperture it delivers outstanding image quality over the whole image field with very high overall contrast. The outlines of larger subject details are recorded with almost 100% contrast transfer. And finer detail still is delineated with a rarely seen 95% contrast transfer. This high edge contrast is supplemented by a very crisp recording of the finest possible textural details that are rendered with very good clarity The last lens to leave the Wetzlar factory was a Summicron-M 1:2/50mm with serial number 3451920 at the end of 1987. The new owners separated the camera manufacture and optical design department from the Wetzlar microscope and instruments division and set up a new and independent factory in an existing building at the outskirts of Solms, about 7 kilometres from Wetzlar.

2.4 2.4 Part 4: the new generation from 1990

From 1980 to 1990, no new lenses for the M-system have been produced. If we look closely at the M-lenses, we note that the last lenses specifically designed for this system have been the Noctilux 1:1/50mm from 1975 and the Elmarit-M 1:2.8/21mm from 1980. The 2/50mm, the 2.8/90mm, the 2/90mm, the 2.8/135mm and the 1.4/75 were all developed in parallel to the R-system. The Summilux

1.4/75mm is the last lens that left the drawing boards of ELC. ELC became a manufacturing division and a design department for non-photographic lenses. During this decade the introductions of new lenses for the R-system were quite few too. The 1.4/35mm (1984), the 2.8/280mm, the 2.8/100mm, (1987) and the 2.8/19mm were designed during this decade. The centre of optical excellence shifted back to Leitz Wetzlar, but the much reduced resources for R&D and the precarious state of the photographic department discouraged the pursuit of new optical designs and techniques of manufacture. In hindsight one has to make some critical remarks about the decision to split the optical design department over two continents. The official argument by Leitz for this division of labour is the threat of the Cold War and the possibility of a nuclear clash between the super powers. Leitz wanted to preserve the optical expertise of the factory and thought it wise to duplicate the design department. A more practical argument might have been the growing demand for military optical equipment by the American army. The Canadian optical department developed, only partially influenced by the Wetzlar department their own design philosophy, and used different tools to compute the lenses. The fact that many lenses were designed in Midland and manufactured in Wetzlar, certainly induced some tension into the production cycle. It was however accepted practice to split the design and production departments into two groups with different and separate responsibilities. The dominant position of ELC during the period 1955 to 1975 gave the Leica lenses a specific flavour and character. It also helped the Wetzlar team to pursue fundamental research into optical design and aberration theory. This work laid the foundations for the next generation. No doubt the practical dominance of the ELC designs, frustrated the Wetzlar engineers and designers. In practical testing the ELW designs were often better than the ELC counterparts. Still the Midland proposals were selected as the production versions as they could be produced more quickly or efficiently. And that was an important consideration in those days. The theoretical studies in the Wetzlar department became, in a certain way, a goal in itself and the famous optical lab was the result. It did not live up to its promises however and it was finally closed. The head of the lab, Mr Thomas, noted in LFI (7/1982) that the role of the lab had been reduced to the testing of lenses of the competition.

2.4.1 New visions

Lothar Kölsch became the new Head of the Optical department at Leica, Solms. The first lens to be produced by the new team, working in the Solms factory, was the Summilux-M 1:1.4/35mm aspherical. The patent is filed in 1991, and its inventor is identified as Walter Watz, one of several unknown masters of optical design. As an important aside I would like to draw attention to the many anonymous individuals, who worked in Wetzlar and who now work in Solms, outside of publicity. Their tireless research into the foundations of aberrations and their creativity in transforming that knowledge into an optical system, consisting of glass and metal, that will satisfy the demands of exceedingly critical users, has to be mentioned and acknowledged.

Figure 44: 2.4.1.A Summilux aspherical

This first Summilux with two aspherical lens surfaces is evidently the direct descendent of the original Noctilux 1:1.2/50mm from 1966. During the design stage of the 1.4/35mm lens, it became clear that the use of aspherics alone would not bring the desired improvements. A high speed lens with a focal length of 35mm is more difficult to correct than a 50mm lens, because of the increased influence of zonal aberrations. One can identify these zonal errors when one takes a look at the performance of the original 1.4/35mm lens for the M-system. The new design performs very well already at the wider apertures, with a high contrast image at full aperture and a clear, crisp definition of finer detail in the zonal areas. The revolution of the aspherical design is not so much the use of the aspherical surfaces, but the radical departure from the classical and time honored Double-Gauss principle. The system comprises nine lens elements in five groups, with the first surface of the first element and the last surface of the last element of a concave shape. The design is more symmetrical too, which helps reduce some aberrations. The path of the light rays, passing through this system, is more ‘relaxed’ than in a traditional Double-Gauss system, a characteristic, that is not obvious and of a more philosophical nature. It does signify a new aspect of lens design at Leica. That is the study of and reflection on the fundamentals of a design. The current approach to lens design in Solms is characterized by several interlocking aspects. The most important trait is the search for the most simple solution for the required lens parameters, as maximum aperture, focal length and physical size. To find such a solution, the designer needs to study the intrinsic behavior and possibilities of the optical system. Supported by quite sophisticated and indigenous computer programs, the designer will then search for an optimum solution, that can be manufactured within the required tolerances. New insights into the character and potential of the glass types available on the market bring additional advantages for aberration correction. If I had to single out the most important characteristic in the current design approach, it would be the tight cooperation between the optical designers and mechanical engineers. The second factor which helps explain the performance and the cost of a new Leica design is the principle of manufacture, where the fabrication process is adapted to the requirements of the selected glass and of the tolerances needed. This is a large step forward when compared to the previous method of manufacture that was the same, irrespective of the specifics of lens design and glass manipulations.

Figure 45: 2.4.1.B grinding the aspherical

The two aspheric surfaces were grinded and polished mechanically on a spherical glass surface. This method was an improvement on the original manually grinded aspherics, but still quite labourious, with a high rejection rate. The second version, recomputed in 1994, employed a new press-molding technique, in combination with Hoya glass. Leica has been heavily involved in the invention and development of this technique.

Figure 46: 2.4.1.C 2/180

From 1993 to 1996 the designers gave all attention to the renewal of a number of lenses for the R-system. A new series of high speed telephoto lenses with exceptional apochromatic correction and high speed were developed. The Apo-Telyt-R

1:4/280mm is probably the best corrected lens in the whole R-stable. This one is indeed diffraction limited. The Apo-Summicron-R 1:2/180mm (1994) and the Apo-Elmarit-R 1:2.8/180mm (1998) offer performance that is truly a quantum leap ahead of the predecessors and do indicate the mastery of the optical designers. These lenses also embody new techniques, like internal focusing that is in addition employed for further aberration correction and macro-functions. New mounting techniques deliver a very smooth, fast and accurate focusing operation.

Figure 47: 2.4.1.D 2.8/180 apo

In the field of zoom lenses, Leica has made impressive progress and reduced their dependence on third party suppliers. And one might add, with a vengeance as the new variableness, including the first one, the Vario-Apo-Elmarit-R 1:2.8/70-180mm, equal and often surpass the image quality of the equivalent fixed focal lengths. In quick succession the family is expanded with a 4/80-200 and a 4.2/105-280mm version. It does show that as soon as the designer has studied and understood the basics of a design, it is relatively easy to develop several versions. This same technique of spin-off we see in the Summicron-M 2/35mm ASPH, which is a variant of the 1.4/35mm ASPH. The Elmarit-M 1:2.8/21mm ASPH and 1:2.8/24mm ASPH share family characteristics and especially the 24mm lens delivers outstanding imagery and is a landmark design.

Figure 48: 2.4.1.E Vario 70-180

Figure 49: 2.4.1.F vario 80-200

The first combination of apochromatic correction, which is primarily a glass selection technique and the use of aspherical surfaces which can be used for several purposes (see chapter 1.2) we find in the Apo-Summicron-M 1:2/90mm ASPH. This lens is arguably one of the very best lenses Leica has ever designed, as of this moment of writing. Already at full aperture it delivers outstanding quality that even surpasses the performance of the Summicron-M 1:2/50mm at 1:2. In the same league we can place the Apo-Telyt-M 1:3.4/135mm, a compact and light weight telephoto lens, that approaches the old dream of a lens that does not improve on stopping down. At apertures from 1:5.6, the Apo-Telyt is only slightly better than the previous Tele-Elmar-M 1:4/135mm (thanks to the apochromatic correction, which brings a small but visible improvement, even at smaller apertures). For most purposes these differences are not that important. The exceptional performance of Leica lenses is best appreciated at the wider apertures. To deliver this quality, the manufacturing tolerances, the production technique and the quality checks must all match. The lens that in my view exemplifies this marriage of mechanical and optical expertise and production technology is the new Tri-Elmar-M 1:4/28-50mm. Its image quality is better than most Leica-M lenses of comparable fixed focal length. But its mechanical layout is the true measure of excellence in this case. This lens can be used on all Leica M bodies, even the earliest ones, like the M3. The rotating ring that selects the different focal lengths has to accommodate different spring tensions and cam curvatures. The solution is mechanically very complex, but it brings zoom convenience in a rangefinder model and so defies obsolescence. The engineers however have designed an even better solution, which will be introduced at Photokina 2000 and sports improved ergonomics and redesigned internal mechanics.

Figure 50: 2.4.1.G Tri-Elmar

Many observers of the Leica world would select the two Noctilux versions as the defining icons of the optical excellence in the rangefinder domain. I would beg to differ. The Noctilux lenses are optically quite good and do radiate exquisite mechanical engineering and optical expertise. The Tri-Elmar, Elmarit 24mm and Apo-Summicron 90 and Telyt 135mm point to an exciting future direction and are more versatile and effective in everyday use. The position of the R-system is not so easy to sketch. The current Solms-designed vario-lenses are outstanding products, but physically at the limit. Now Leica will tell you that this volume is needed to deliver the optical quality and I do not question this statement. Still the challenge is twofold: to design fixed focal lengths with even better performance than the current vario-lenses is not easy and the efforts and cost must be offset by a sizeable sales volume. The demands for designs of variableness are threefold: a wider zoom range; ergonomically convenient to use in handheld situations; small physical dimensions and comparable, if not improved performance versus the fixed focal length lenses. These requirements are very difficult to combine in one set. The current range of R-lenses is composed of three groups. In the first group, the vario lenses, we find new lenses, designed by Leica itself and some lenses supplied by third party manufacturers. In the second group, the fixed focal length, we have a number of recent developments, like the 2.8/28mm and the 1.4/50mm, both of outstanding quality and a family of telephoto-lenses in the 180mm to 280mm class of really superior performance. A number of the older fixed focal lengths lenses, however, begins to show their age, like the 35mm lenses, the 60mm and the 80mm. As with the vario group, , there are a number of lenses from third parties, like the 15, 16 and 24mm and the PC 28mm. The third group consists of the module system from 280mm to 800mm, which is specifically designed for economy of cost and flexibility of use. This system has added value if the user needs more than one focal length and so the target group of users is limited.

2.4.2 Current status of optical design and lens manufacture.

The improvements in image quality in current Leica lenses are visible for anyone with an experienced eye. Some Leica users might defend the idea that the older lenses are as good as, or even better than the current ones. Image characteristics, like 3-dimensional representation, plasticity and smooth unsharpness gradients, cited as being instrumental for the unique fingerprint of older Leica lenses, are supposed to have disappeared. Some observers have tried to discern two different schools of design theory, the German and the Japanese philosophy, the latter putting all emphasis on image contrast and the former school going for a smoother image quality. In all fairness, these two schools do not and have never existed in this extreme juxtaposition. Of course designers differ in their balancing of aberrations and the rigor of aberration corrections. It may be the case that Japanese designers follow a different route to design a lens. But generally any designer everywhere has the same type of tools and uses the same aberration theory. Why and how are the current Leica lenses improvements on the older designs and how do they differ from others? Modern optical design is a creative activity, based on experience, insight, a very thorough knowledge of optical theory and even a sprinkling of luck. We know that optical systems for photographic purposes are not completely aberration free. (There are exceptions. Some R-lenses, and many microscope and telescope lenses, are indeed diffracted limited (which amounts to stating they are aberration free). Most photographic lenses will exhibit, after correction and optimization, some residual aberrations. These residuals have to be carefully controlled and balanced. The optimization techniques will help of course, but no computer program can improve on a design that is not promising from the start. Leica lens designs will start a design with the absolute minimum of lens elements. Having less elements one can study the aberration content and the contribution of every lens element to the aberrations more carefully and more effectively. Current computer programs are very powerful and can make the best of any design by a kind of brute force method. By using more and more lens elements to counter the aberration content, a lens can be made to perform quite satisfactorily. It will not show the finesse and elegance of design of the Leica lenses and it most certainly will not perform on the same level.

2.4.2.1 2.4.2.1 Progress in design methodology.

The art of designing optical systems is a most fascinating subject. The lens designer today still uses methods, concepts and terminology that have been developed in the previous century. The employment of high speed computers and very sophisticated software has freed the designer from the drudgery of the past, when slogging through labourious computations to trace the light rays, using tables of logarithms or mathematical approximations was the only way to design a lens. The current practice of optical design then is a fine example of a successful amalgamation of a century-old (time honored) science and a very potent modern technology (the high-speed computer). The genius of Gauss, Clark, Rudolph, Lee, Berek and others should be acknowledged with great admiration, as they combined quite crude computational methods with a most profound insight into the fundamentals of aberration theory. The computer, as we all know, is a very sophisticated device for number crunching with phenomenal computational speed. It took Rudolph and Lee and later Berek at least five years of dedicated attention to trace enough rays with the required precision to get a good grasp on the aberrations in the optical system. Nowadays a potent personal computer can trace 600.000 skew ray surfaces per second. In 's time this amount of skew rays would take a big part of the lifetime of one designer. Before the advent of the computer a lens would be designed and evaluated by tracing real (trigonometrical) geometrical rays from lens surface to lens surface. In the past, every calculation of a surface took a few minutes. You need to trace a few hundred rays through all surfaces, often more than 10 or 12 surfaces and do that again and again after you find that the image points you calculated so diligently are still distorted by aberrations. All the points calculated with this method are meridional rays, that is rays that lay in the same plane (are coplanar with) as the optical axis. When we trace a ray on a flat piece of paper, as we all do, the paper plane is the meridional plane. This a two-dimensional plane. But we also have skew rays, that is rays that go into the lens from an oblique angle. Now we need three-dimensional ray tracing, which is almost impossible to do by hand or even pocket calculator. So in the past these rays were not traced at all, or all kinds of 'tricks' or approximations were used to study the skew rays. Many of the troublesome aberrations (coma, astigmatism as examples) are caused by these skew rays. So in the not so distant past ,designers had to accept they could not all the information they needed to fully correct a lens. So working with imperfect knowledge, the designs could not be as fully corrected as was theoretically feasible. If we look at the older designs with modern expectations, their image quality may be a bit disappointing. The designers of those days (1930 till 1960) compensated their approximation strategy with admirable creativity and let us call it gut feeling to select basic designs that work and serve the photographer well. Leitz was one of the first to implement a computer in order to support the designers, The Zuse Z5 was introduced in 1953 and helped the designers to compute the oblique pencils of rays. Before the introduction of the computer Leitz designers used the Seidel-Theory to circumvent part of the complex computations of oblique rays. This knowledge and experience proved to be of great value after the Z5 became the preferred tool for ray-tracing. It is fascinating to know how this work was organized at Leitz. The romantic idea of one designer working for years on his design is of course a myth. In reality, the chief designer supervised a group of workers, mostly women, who carried out a good part of the calculations. The chief designer gave instructions and got the partial results of every ray tracing equation from them at the end of the day and then decided to proceed or adjust his design. The resulting design is invariably a compromise, composed of both known and unknown factors. The development of lens design methodology interacted with the development of aberration theory and both allowed lenses to be designed with a much higher image quality. Now we have two new areas to give close attention to. The first area is hardly ever mentioned, but in fact it might be designated as the true revolution in lens design. The manufacturing processes (grinding, polishing, coating, centering) and the mounting procedures are of paramount importance for the image quality . Studying fabrication tolerancing to ensure that the image quality as defined by the designer, is a major part of the design process. Here the art of optical design and a superior grasp of the manufacturing process and the limits of tolerancing join to create the results we see and expect (if not demand) from current Leica lenses. The Leica aspherical lenses may only be serviced in the factory itself. An indication that the mounting procedure is quite demanding. In this case we see clearly the value and necessity of the manufacturing processes in boosting or supporting the higher level of image quality possible.

2.4.2.2 2.4.2.2 Progress in manufacturing processing and mounting techniques.

I have remarked several times and documented in the lens reports, that Leica lenses are designed for higher contrast at much higher frequencies than in the past. A design that is can record higher frequencies with high contrast needs very small tolerances. Contrast of very fine detail is very sensitive to focus and alignment errors.

Figure 51: 2.4.2.2.X precision grinding

Decentring is very bad for the ultimate image quality. In the past, when manufacturing tolerances were not so tight, groups of lens elements were mounted in their own subassemblies. At the final mounting stage these subassemblies could be adjusted a bit to compensate for decentring and other errors. An optical surface has two related qualities: accuracy and quality. Accuracy refers to the dimensional characteristics: is the surface uniform in its radius value?. Quality refers to the finish of the surface: is the polish incomplete (rough spots), does it have pits?

Figure 52: 2.4.2.2.A Interference patterns check

Figure 53: 2.4.2.2.B Checks for centring etc

If the surface quality is not immaculate the following process of thin film coating with its thinness of several microns will also be irregular. Relatively speaking of course: we are dealing with wavelength dimensions where a micron is a big distance. Some requirements at Leica demand that a polished lens must be coated within hours after the polishing as the surface can deteriorate when not protected immediately. A Leica lens is now designed by a team of optical and mechanical engineers who work together from the start. The production engineer has the last word: if the tolerances are unrealistic, the optical designer has to start all over. In the past the departments were more divided. Then the optical designer designed the lens as he deemed necessary according to its state of aberration correction. Then he almost literally would hand over the design prescriptions to the production department. Sensitive glasses with strong radius and thin ends that were very difficult to mount without stress gave the designers of the mounts headaches. And sometimes the designed lens could not be built within required tolerances. One had to accept a slightly lower image quality or a production with a much higher rejection rate. At the beginning of this section I mentioned that physical ray tracing is still the approach used by designers to study and correct aberrations. Physically we should not look at individual rays but at the total energy that flows through the lens at one single instant in time. When we take a picture all energy reflected from the subject enters the lens in one instance (1/250 sec as example) and the total light energy flows through the optical system in one flash. Leica designers take care that this flow is eased from lens element to lens element. Abrupt changes in the path of a ray that occur when glasses of highly different refractive indices or greatly varying curvatures are employed are avoided. One might see a Zen approach here.

Figure 54: 2.4.2.2.C complex mount

Can modern Leica lenses be improved? Yes they can and Leica is constantly searching for economical means to produce improved versions of existing lenses and to expand research into exciting new designs. Just as with the Olympics the levels of achievement are set higher every time, so these new generation Leica lenses also set the quality level a few notches higher.

2.4.2.3 2.4.2.3 procedures for testing a lens.

When a lens is designed, it is obvious that you calculate with the exact figures, that is you assume a zero-tolerance. After the ideal design, you have to allow for fabrication errors and tolerances. It is also obvious that if you optimize the design to the utmost level, any manufactured lens will be below tolerance and these errors will degrade performance. So the assumption of fabrication errors must be part of the design process. A small list of fabrication errors would comprise: surface curvature errors, index and dispersion errors, thickness errors of the lens elements or air spaces, axial displacement errors, surface tilt errors (decentring). All of these errors occur and have to accounted for in the design and manufacture. The nature of fabrication errors implies that errors occur at both sides of the target figure. If a tolerance of 5% is specified, then in reality the values will be ± 5% around the target. Some of these errors cancel out, and sometimes you have a lens that is above the target value and sometimes below this norm. You may however not assume that the spread around the target is normally distributed, with the same number of lenses above and below he target. Leica specifies the target line very high and so most of the lenses will be a bit below the norm, but well within the tolerance band.

Figure 55: 2.4.2.3.A Testing MTF

There is however a second method to handle production errors. That is the use of compensators in the lens. One could designate one lens-element or group of lenses as a mechanical compensator and use the possibility to shift this element a little or one can shift the whole lens s bit, which is identical to a focus shift, which can improve the optical performance significantly. (see the chapter 1.2). Leica uses all these methods of testing a lens and adjusting the parameters. Every lens that leaves the assembly department is tested. For lenses that have a stable performance pattern and are relatively easy to assemble, the projection test is used. A complicated test pattern (of Leica design) is projected through the lens on a wall and studied at close distance to check for errors. If the reproduction of the pattern is within specifications the lens is passed. Some types of lenses are individually tested and adjusted with an MTF device. Here the method of focus shift adjustment is employed. The optical cell (that part of the lens that comprises the glass) has its own effective focal length and the mount of the lens has a mechanical flange focal distance. The lens is adjusted for best focal position (optimum focus plane) with the help of very thin shims (0.01mm) that can be inserted between the bayonet flange and the lens mount. The target value is the contrast value. These measurements are done for 8 circular positions on the lens in steps of 45o. After the lens is adjusted for optimal focus, a new series of contrast measurements is conducted to check for decentring and other errors. This procedure ensures that every lens meets the specifications, stipulated at the design stage.

3 Chapter 3:

Part 1: A gentle introduction to optical design and aberrations.

3.1 Optics and optical designers: ray bending.

The basic property of a lens is to converge light rays to a common focus. A burning-glass will converge the energy from the sun to a very small and very hot spot. In fact "focus" is Latin and means "hearth", a nice reference to the heat that will burn a hole in a piece of paper. Never leave your Leica rangefinder-body in the sun with the lens uncapped: the sun could burn a hole in the shutter curtain! The light-bending property of a curved piece of glass has been known for ages. The single lens (singlet) was for ages the only instrument to be used for changing the path of the light ray. Many substances, like ice, diamonds, quartz, turpentine and glass, have this property of ray bending or diverting the path of the ray. We can experimentally establish the amount of deflection and scientists have given it a name: index of refraction (n). Already in 1621, the Dutch scientist Snell discovered a Law, which defines accurately how light is bent when it passes from one substance to another with different indices of refraction. The law is a very simple one: n1.sinè1 = n2.sinè2 It tells you in simple words that the angle (sinè1) with which a ray travels through a substance with a certain index of refraction (n1) is changed into a new angle (sinè2) which is directly related to the index of refraction of the second substance (n2). And in fact that is all there is to know about optics. Look at figure 1.1, which shows the paths of some rays when they pass through an early Summicron. At every air-glass boundary the path of the ray is diverted from its original course. Quite miraculously however all rays from the same object point do focus at the same image point. Or do they? In order to answer that question I have to introduce a few conventions that will help to understand the basics of optical design. Any lens is a piece of glass with a curved or plane surface. Most often the curvature is positive, that is outward. The front lens of the Summicron is an example. We also have plane surfaces, like the front lens of the current Elmarit-M 2.8/28mm or inwardly curving surfaces like the Summilux -M 1:1.4/35mm ASPH. Most lenses are circular too, which might be puzzling at first as the negative format is a rectangle. In fact you could produce a rectangular lens, matching the negative format, but it would be expensive to produce. Circular lenses with spherical or flat surfaces are the most cost effective pieces to manufacture. The curvature of the surface of a lens is part of a circle: the word 'spherical' means 'part of a sphere' and for a lens with two spherical surfaces, we have two centres of curvature. The line connecting these two points is called the optical axis. It is also the midpoint of the lens itself when viewed from the front.

Figure 56: 3.1.A: ray path

The Summicron lens, we will use as example has a focal length of inscribed 50mm, but in reality is 52mm. The focal length is the distance from the optical centre of the lens to a point on the optical axis where the rays converge that arrive from a very distant object point. On the distance ring of a lens you will notice the infinity setting (8). This location is theoretically at an infinite distance, which is a bit too far away for photographic purposes. There is some confusion what the real distance is of this indication. The optical definition is simple: when all the rays from a distant object point are parallel to each other ("collimated") when they enter the lens, we have what may be called optical infinity. It is more correct to say that all the rays enter the lens with the same angle of incidence, which is in fact the same. (but see later!).

In photographic practice, we can use this thumb of rule: at 100 x the focal length we have practical infinity and for wide angles we can use 5 meters as a rule. Image height of the negative. A lens projects a circular image of the object onto the focal plane. The Leica format, as it was originally referred to, has dimensions of 24 x 36mm. A rectangle with these dimensions has a diameter of 43.2mm or a radius of 21.6mm. As a lens is symmetrical around the axis, it is customary to discuss only the area from centre to edge, which in this case has a distance from 0 to 21.6mm. As we will see later, the performance of a lens differs from centre to corner and so we need to establish a way to define or locate the positions of an object point on the image.

Figure 57: 3.1.B image height on CD2

The image height tells us how far from the centre an object point is located on the negative format. Leica uses increments of 3mm to locate image positions and the 0, 3, 6, 9, 12, 15, 18 and 21.6mm distances from the axis (centre) define the most important areas. The 12mm position as example defines the negative area at the 24mm (horizontal) line and the 18mm position gives the limit of the negative format at the vertical line (the negative area in the horizontal direction is 36mm). Zones of a lens. With these image heights we can define zones on the lens if we draw circles with a specific length of the radius. The on-axis position is evidently the '0' distance. All other locations are off-axis or field positions. The zone from 18 to 21.6 mm is often called the marginal zone, the 9 to 15mm is the outer zone and the 3 to 9 is the most important zone, as it covers the portion of the negative area , where the important picture elements are normally located. Surface height of a lens While the diameter of the negative area has a fixed value (21.6mm) we can assign definite numbers to any position, as we did when discussing the image height. The diameter of a lens, however is not fixed and mostly smaller than the diameter of the negative or image. The front lens of the Summicron 2/50 has a radius of ±18mm, but the Elmar 2.8/50 of 10mm.

Figure 58: 3.1.C surface height

Only lenses like the Noctilux-M 1/50 or the Apo-Summicron-R 2/180 have a radius larger than that of the image. (25mm and 45mm). If we need to specify the location on the surface of a lens where a certain ray of light enters the lens, we can only use relative positions, measured from the optical axis, or absolute numbers, like 6mm from the centre (op optical axis). If we want to define the position of a ray on the surface of the lens, we use the notion of surface height as a fraction of the total radius. A ray located at surface height 0.5 will be positioned halfway between the axis and the edge.

3.2 The origin of aberrations.

The rays from a distant object point strike the surface of the lens parallel to the optical axis and all rays should converge to one point only, as this is the exact image of the object point and at a location that is the geometrical equivalent of the location of the object point. The law of refraction tells us that any ray that arrives at a certain angle at the lens surface will be deflected. The angle is measured with respect to a strange thing called the normal, which in the case of a lens is the line drawn between the centre of the curvature and the surface height.

Figure 3.1.C shows that parallel rays striking the surface at different heights will have different angles of incidence and so also different angles of deflection.

One has to realize that we are used to seeing a few rays drawn from an object point through the lens. In reality rays of light are fantasy constructs: they do exist only in the mind of the designer. Light is a form of energy, consisting of photons. The object point that emits or reflects light is radiating a stream of photons in all directions, like an inflating balloon. The surface of the lens is bombarded by a barrage of photons from axis (centre) to rim (edge) and if we would draw the trajectory path of every photon stream, we get the familiar ray path. So the light energy of one single object point fills the whole surface area of the lens. Tracing rays would be hopeless as there are millions of rays that can be traced from one single object point. Happily we can simplify a bit. The surface of the lens is part of a sphere and the curvature is the same at every location. If we imagine a ray entering the lens at an image height of 0.9, that is at the outer edge of the lens, we only have to draw one ray. If we rotate the lens, the image height does not change, nor does the curvature and most importantly the angle of incidence. One ray is enough for all rays that enter the lens at that specific surface height. And all rays from the object point entering the surface of the lens at that location will converge to the same image point as all angles of incidence are the same. We do have to pay attention to a few rays only, that is rays that enter the lens at different surface heights in the same plane. If we draw a lens on a piece of paper, we say that the plane of the paper is the main section for which we will draw and calculate rays. Any ray will intersect (pass through) the optical axis and this plane is called the meridional plane.

Figure 59: 3.2.A angles (Figure to show different angles at different heights)

If we draw a second ray at a surface height of 0.5, we will notice that now the angle of incidence has changed and so will the amount of deflection of the ray. This ray will strike the optical axis at a different location and now we are in trouble! Very big trouble indeed. We have defined the image plane as the plane upon which the lens will project its image of the object points. It is located at a distance from the lens where the rays close to the optical axis converge. All other rays that cross the optical axis before this plane will intersect the image plane above and below the central point. Instead of a very small point of light, we see on the image plane a patch of light with a higher core intensity and surrounded by rings of d

nishing intensity. This representation of the point light source by a bright spot surrounded by flare is the basic aberration of a spherical lens. It is known as spherical aberration or Offnungsfehler.

Figure 60: 3.2.B spot diagram

This behavior of a lens was known to everybody engaged in optical constructions, but the craftsmen building telescopes and other instruments, lacked the knowledge to do anything about it. As long as the angle of view was quite small, as it can be with a telescope, only the rays close to the axis were used and an acceptable image could be produced. When Daguerre in 1839 invented the first useful photographic process, he needed a lens with a much wider angle of view. In 1812, Wollaston had, by experiment, found a solution to the demand for a lens with a wide field of view, by employing a singlet meniscus lens and an aperture stop in front of the lens, but at a substantial distance. He may be the first person to use the location of the aperture stop as a design element. Berek did the same a century later with his Elmar design. So Daguerre at first used a lens of the Wollaston type. But he ran into another problem. In those days, the photographer would focus by moving the lens closer to or farther away from the film plane and observing the sharpness of the image on the ground glass screen. The best focus as established visually departed significantly from the best focus needed for the Daguerro-type plates. The emulsion was sensitive to the blue-violet region of the spectrum, but the human eye is more sensitive to the green-yellow region. This phenomenon is the well-known dispersion: the refractive index changes with the wavelength. We have all seen the rainbow which is a clear example of the fact that white light is decomposed into the several colours of the spectrum from ultraviolet and blue to red and infrared. We have monochromatic rays, that are refracted (deflected) depending on the surface height, but now we have to accept that rays with a different wavelength, but at the same surface height will be deflected at different angles, due to different wavelengths. The red rays are refracted less than the blue rays. And if the image plane would be located (as a compromise) between the blue and red extremes, the white point now is visible as a spot with a green-yellow small core and a magenta soft ring (red + blue). The ideal of an image point becomes more and more an enigma. The bending of the different colours (wavelengths) to different focal points is a characteristic of the glass, some glass types do deflect colours more than others do. The amount of this change in direction is indicated by the index of refraction and because this index depends on the wavelength (ë) of light, we can describe a certain glass with a series of numbers. Visible light has a spectral range from 400 nm (violet light) to 760nm (red light) and in fact there are an infinite number of wavelengths in this range. It is customary to use a selection of wavelengths to indicate the bandwidth of refractive indices. See table in Chapter 1.2, apochromats A certain glass type (as example Schott BK7) will have a refractive index for the 435 wavelength of 1.52668 and for the 706 wavelength an index of 1.51289. How close these rays will focus on the optical axis can be seen from the picture which shows an actual computation with these data. Optical designers are indeed working with very small dimensions in the micrometer space where a millimetre is a vast distance. Compare the values for these wavelengths with another Schott glass, like SF2: 1.67249 and 1.63902. This variation of refractive index with wavelength is called dispersion and we saw that the range is different for each type of glass. The amount of change can be as big as 4%. Ernst Abbe found a formula to indicate the magnitude of this change and the Abbe-Number is the result. A number higher than 50 (or 55) indicates a low dispersion and glass that has a number is this range is called flint glass. A lower number (below 55 or 50) indicates high dispersion and this glass is called crown glass. There are, as usual, exceptions to this classification. The correction of chromatic errors then is first and for all a matter of suitable selection of glass types. When we combine two glass types with dispersion characteristics that complement each other, we can design a lens with a good colour correction. Such lenses are called achromatic (achromat = a-chromat = non-colour) doublets and the first one was made in 1729 already. It is a very important class of lenses and we can find them as telescopes, microscopes, magnifiers, eye-pieces and several other types of optical instruments. Two lens-elements however do not correct all of the chromatic errors. There is a small rest of errors left and this is called the secondary spectrum.

Figure 61: 3.2.C monochrome

The designer can choose two wavelengths to focus to the same location, but all other wavelengths (colours) will be closer or farther away from that point. This focal shift is smaller than the focal shift produced by the spherical aberration. Remember that in that case the rays from the outer zones focus closer to the image plane than rays near the optical axis. Stopping down will exclude the rays from the outer zones from image formation and so the focus plane will shift. Here we note one of the most troublesome aspects of optical designers. You can correct one aberration to a high degree and another one pops up. Telescopes and other instruments were mainly employed to look at objects close to the centre and so another disturbing aberration did not get much attention. It is clear that a curved surface of a lens will produce an image that is curved too. The classical box camera acknowledged this fact by using a curved negative to counter this effect. But any flat image plane will be plagued by this curvature of field. Let us return to Daguerre, who asked many professors and craftsmen to design for him a lens for his camera with the required flat image and wide angle of field. No one, however could, and now experimental knowledge and tradition failed. Optical theory and mathematical methods were not en vogue then, even if the laws of optics (refraction, dispersion etc) were known for some time. The first person who computed a lens on paper, without any experimentation with the real glass, was Joseph Petzval, and his lens was clearly superior to anything then available. With Snell's law and the knowledge of the refractive index of a glass, we can compute the angle of deflection of a ray that strikes the lens at a certain surface height. Knowing this we also can locate the surface height where the ray will hit the next surface and so on till the image plane. The computation of angles however needs a lot of trigonometric number juggling and as the numbers are very small a high accuracy of maybe 3 to 5 positions behind the decimal point is required. We can compute to any required accuracy the exact location on the image plane of a ray traced through the lens system. But an awful lot of equations and logarithmic tables is a must. And then we may imagine that an experimental approach, trying this glass and that shape in order to get a decent result, was very tempting. But while Petzval could compute the path of the ray through a lens, he did not exactly understand why this path sometimes deviated from the expected course. He had a good understanding of the optical aberrations and he specifically gave attention to this curvature of field. The theoretical 'curvature' for a flat image plane is of course zero and we call this construct still the Petzval curvature.

3.3 The primary aberrations.

In 1856, Ludwig von Seidel made the first comprehensive study of the aberrations and he was the first to establish a theory of image formation. Aberration is from the Latin words áb' (from) and érrare' (to stray), meaning 'to stray from the right path". Seidel formulated his theory, based on an analysis of the principles and problems of image formation, as aberrations are fundamental design shortcomings. He identified 5 monochromatic aberrations and two chromatic ones. The monochromatic ones are the familiar spherical aberration, coma, astigmatism, field curvature and distortion. The chromatic ones are the longitudinal and lateral chromatic aberrations. These seven aberrations all work together in an optical system do degrade the image quality. They can be grouped in a different way to make them more understandable. We have sharpness errors: SA, C and A, positioning errors: FC and D and chromatic errors: longitudinal and lateral CA. We should note here already that image degradation in an optical system is the sum of optical and mechanical errors, the latter ones being quite nasty. The ideal (theoretical) image quality will be found on or near the optical axis, as in this region the curvature of the lens is not a problem. All rays that enter the lens close to the axis will have almost identical angles of incidence and so their refraction will be identical too and all rays from one object point will converge to one and only one corresponding image point. These two points, the object point and the image point, that are intimately related are called 'conjugates'. The plane of focus where all rays close to the axis, converge is known as the Gaussian plane or par-axial plane. Gauss studied the theory of image formation from the ideal perspective, assuming that there are no aberrations involved. Indeed, around the axis we have surprisingly few optical errors. This may explain, by the way, why older Leica lenses, and certainly the first ones (Elmax, Elmar, Summar) had such good performance in the centre of the image.

3.3.1 Spherical aberration

We already have met the spherical aberration. Rays that pass the lens at the outer zones, all focus closer to the lens than do the rays that pass along the axis. From the figure we can infer that all rays from an object point enter the lens as a cone of light, with the tip pointed at the focus plane. Due to spherical aberration, we do not have a really sharp pointed tip of the cone, but we have a small bundle of rays with a certain diameter, that passes the image plane.

Figure 62: 3.3.1. A and B caustics

We now that the ideal plane is the Gaussian plane, but in this case only the rays close to the optical axis are sharply focused. All the others will be unfocused and produce the familiar rims of light of diminishing brightness around the central core. If we would locate the image plane closer to the lens, the rays from the outer zones will be sharply focused, but now the axial rays will produce blurred spots. A compromise has to be made and here the designer has to be very careful. If the photographer stops down the lens, the outer rays are cut off and now the cone of light is more like the ideal shape, but the focus plane has more depth. Incidentally, this is the effect of extending the depth of field when stopping down.

Figure : colour slide 1a: spherical aberration.

So if the designer would select a location for the image plane close to the lens, to assure that the outer rays (for wide open performance) will be focused correctly, he might find that stopped down the result s unsatisfactory. The skill of the designer is needed here. As a numerical example: assume that the core of the image point at the Gaussian plane has a diameter of 0.02mm, with a halo rim around it of 0.08mm. The total dimension for the spot would be 0.1mm. At another location, very slightly shifted away from the original, we have a core of 0.025mm, a bit larger, but now the rim is reduced to 0.04mm, the total now being 0.065mm. In the first situation, the resolution would be a slightly higher, in the second one the contrast would be better. Overall, the second location would be optimized for photographic purposes. Mechanically the demands are very high here. The image plane is the film plane which is defined by the register between the film guide rails and the bayonet flange. A difference of a few hundreds of a millimetre in the location of the actual film plane might reduce the theoretical image performance substantially. Leica indeed uses an accuracy of 0.01mm when machining and assembling the Leica bodies and an even higher one in the assembly of lenses. The manufacturing tolerances need to be as small as to support the quality of the lens design.

3.3.2 Coma Spherical aberration

Coma spherical aberration affects the object points around the optical axis (the centre of the image). Object points farther away from the axis, will enter the lens in a skewed (asymmetrical) fashion. The bundle of rays has still the shape of a cone, but the rays will transverse the lens obliquely. This generates the second monochromatic error: coma. Coma is in fact the skew version of the spherical aberration and is also called asymmetry error. The rays that strike the glass surface will have different angels of incidence, because the bundle of rays is skewed. In the illustration you can see that the rays coming in from below are bent more strongly than the upper rays.

Figure 63: 3.3.2.A coma(picture of coma)

Note also that the rays from below are fanned out over a larger area than the rays from above, producing the familiar coma-shape of a bright central core and a fanned out triangular tail. This aberration becomes larger in the outer zones of the image. In a picture, coma is not only visible when bright light spots are being imaged, but also as a reduction of contrast in the outer areas of the image.

Figure 64: 3.3.2.B coma spots figure to show coma over the area.

Figure 65: colour slide 2 (grey slide): coma

3.3.3 Astigmatism

This cone of light that strikes the lens asymmetrically, introduces yet another aberration. It is related to the field curvature , that we already encountered. It is astigmatism. The Greek word 'stigma' means 'point' and a-stigmatism means not-point. If a lens has no astigmatism and also a flat field, we call it an Anastigmat (not-not-point) and this type of lens was fitted to the first Leica bodies. The oblique cone of light will be intersected by the curvature of the surface of the lens. If you look at a circular lens from the front, you will see s full circle. If you now rotate the lens in a vertical direction, it will become an ellipse, like a cat's eye. It is clear that rays entering the lens in the vertical direction, the longer one, will have different angles of inclination than rays entering in the horizontal (the shorter direction). Geographers who had measured the earth and put a grid on its surface for navigation purposes, call the lines from pole to pole 'meridional' lines and the lines parallel to the equator do not have a particular designation. In optics, these 'equator' lines, which run perpendicular to the meridional lines, are called sagittal lines and the meridional lines are alternatively called tangential (but often meridional as well). The bundle of rays in the meridional plane focus to a different location than do the rays in the sagittal plane. They do not form a point of light, but a line, one laying in front of the other and mutually perpendicular. All object points that have a tangential focus, are located on a tangential plane, which is not flat but has the shape of a parabola or ellipsoid. In the same pattern, we also have a sagittal plane, which is curved as well. At the optical axis, these surfaces coincide, but they diverge quite significantly in the outer zones. This aberration is difficult to correct and progress had to wait till 1890, when Schott introduced new glass types.

Figure 66: colour slide 3a: astigmatism

Figure 67: 3.3.3.A astigmatism

3.3.4 Field curvature

Field curvature is an easily observed phenomenon. Most projector lenses can demonstrate it. Focus the slide in the middle of the image and the edges will be blurred or when you focus sharply at the edges, the centre will be blurred. Any lens has one focal length, as the focal point is related to the curvature. Assume that a lens has a focal length of 50mm. If we have an object point, close to the optical axis it will be focused at 50mm distance from the lens. If we now take an object point at the periphery of the image, this point will also focus at a distance of 50mm. But the distance from the lens to the edge of the negative is longer than to the centre of the negative, as some simple geometry will show. The image space is not flat, as is the emulsion plane, but an arc of a circle (in this case with radius 50mm) and the resulting image surface has the shape of a saucer, or more scientifically a paraboloid shape. The fact that the rays from the lens to the edge of the negative area have to travel a longer distance, is also illustrated by the phenomenon of light fall-off or vignetting: the darkening of the edges of an image is due to the lesser amount of light reaching the corners of the image. The sum of both astigmatism and field curvature is the occurrence of three different shapes where the mage is formed and it results in severe blurring of the overall picture in the zones of the image. In a laboratory setting these three may be made visible and the optical designer has to battle with them all. Photographically we only see one result: loss of contrast, and blurring of details. If only field curvature would be present and we use an R-Leica, you should be able to focus on a subject in the centre of the image and note a blurring of the edges. If you now focus on the outer zones, you see the image there progressively becoming sharper, with the centre now becoming blurred. Such an extreme manifestation you will not encounter easily, but with some very wide angle lenses it may be observable.

3.3.5 Distortion

All of these aberrations are sharpness errors that diminish the sharpness and contrast of the image. But there are other aberrations that only affect the shape of the image, even if the image points were absolutely sharp. This, the fifth aberration is called distortion. An optical system always depicts an object in a specific size. A 50 mm lens focused at 10 meters (32'10") reduces every object by a factor of 200. But one can expect that the reduced image is geometrically accurate and that the ratio of reduction remains constant across the entire image. This is called scale fidelity. Unfortunately this is not the case with most lenses, because the reduction scale varies within the image area. When the scale increases as the distance from the centre of the image increases, the result is pincushion distortion. When the scale is reduced towards he edges of the image, we get barrel-shaped distortion.

3.3.6 Chromatic aberrations

These five aberrations are called monochromatic aberrations because they act on a single wavelength. Because light diffraction (colour dispersion) is not the same for blue light as that for red light, these colours are refracted differently. Blue, for instance, is bent more sharply than red light and they converge on different focal points. If we place the image plane in the middle between these two focal points, we will see a green (or yellow) core with a purple fringe (red plus blue). If we shift the image plane, the colour of the fringe will change from blue to red or vice-versa. This imaging error is called longitudinal chromatic aberration and just like spherical aberration, it causes the image to appear flat because it reduces contrast. With this chromatic error the image plane will be in a different place for each wavelength. The dispersion of the glass will also cause a change in the size of the colour image in each wavelength. Because short-wave light (blue) is refracted more strongly, blue rays will converge at a closer focal point. The effect is similar to that of a lens with a short focal length, which depicts objects at a reduced scale. The focal length is linked to the magnification factor, and that is why a variation in the refractive index also causes a variation in magnification. This error is called lateral chromatic aberration and it mostly affects the reproduction of fine structures. A white image point is separated into its component colours and reproduced as a stretched rainbow. A dark point with a light background is reproduced with a colour fringe that appears in blue on the upper rim and in red on the lower rim. Aberrations are often reduced when the lens is stopped down, because marginal rays no longer contribute to the imaging errors. Lateral chromatic aberration is not diminished by stopping down the aperture and it is very difficult to correct. The chromatic aberrations (lateral and longitudinal) increase from the centre of the image towards its edges. (Here the colour plates from Solms)

Figure 68: colour slides 4a, 4b, 4c 4a: achromatic correction type 1. 4b;: achromatic correction type b, 4c: apochromatic correction

3.4 Higher Aberrations.

I noted earlier that rays close to the optical axis are, basically, aberration free and that form an image in the Gaussian space. As soon as the angle of view becomes larger, as with the Daguerre lens, a first group of aberrations emerges, which are called the Seidel aberrations. There is a kind of law here, which tells you that the wider the angle of view and/or the greater the aperture, there will be more and more severe aberrations. You will see, when I discuss the evolution of the Leica lens, that high aperture lenses and wide angle lenses, or worse a combination of wide angle and high aperture, as in the case of the Summilux 1:1.4/35mm are quite challenging for the optical designer. There is a logical order in the levels of aberrations. Remember that the index of refraction is at the bottom of all aberrations and calculations are based on the sine of the refracted angle. The sine function can also be expressed as a geometric series: sin p = p - p3/3! + p5/5! – p7/7! + . Each term in this series is related to a group of aberrations of a certain order. The first term represents an error-free image, as it occurs in the centre of a picture. This very small area around the optical axis is called the paraxial region. It is customary to associate it with aberrations of the first order or Gaussian errors (two Seidel aberrations). The next term incorporates the number “3” and it is therefore related to the aberrations of the third order (the five Seidel aberrations). Because this series only contains uneven numbers, the next term involves aberrations of the fifth order (the nine Schwarzschild aberrations), the seventh order (14 different aberrations without names), and so on. For many photographic lenses, the correction of the third-order aberrations, will result in very fine imagery. Many Leica lenses however are now on such a level of sophistication, that fifth- and seventh- aberrations need to be corrected, or more accurate need to be balanced.

3.5 The analytical approach in designing lenses.

Now that we have identified the aberrations or image degrading components of an optical system, I will give a short sketch how a lens designer tries to correct and eliminate them. For all rays close to the axis (the Gaussian space) the equations are relatively simple and the calculations can be based on the two-dimensional trigonometric concepts of sine and cosine. While tedious and cumbersome with log tables , theses calculations are accurate. As soon as we leave this space and widen our field or aperture, the oblique rays are becoming more important and we need solid geometry and three dimensional trigonometric formulae to calculate the rays with good accuracy. Such calculations however were beyond the abilities of the designers, and if they were able to trace an oblique ray, it took too much time. So these rays were not calculated at all or only a few or approximations were used. The Seidel theory of aberrations used approximations to approach the exact values. The value of this method was its relative simplicity and good accuracy. The designer had incomplete knowledge of the exact state of the correction of the aberrations. He employed approximation formulae and in addition to this, he had to use his full experience, and knowledge and creativity to find the desired solution. In those days the chief designer at Leitz would employ a whole group of (up to twenty) calculators, often women, because of their great accuracy and reliability, who would do part of the calculations and pass the intermediate results on the next in the line. At the end of the session, the chief designer would evaluate the results and decide on the next step. The design of a lens could take years to complete and naturally one would be reluctant to start all over again, if the end-result was not satisfactory. The final test for the performance of a lens, was the finished prototype and the actual photographs taken with this lens. Leitz used test equipment too for the analysis of the lens performance. While the designer had a very clear notion of the image quality of the lens, he was not sure of its real performance before the prototype was finished. And then some unpleasant surprises might be discovered. The performance was less than expected or the mechanical department might send a message that they were unable to build the lens, because of the too small tolerances for the lens elements or the mounting. In such cases a new design was developed or some compromise solution had to be found. Before the introduction of computers and, even more importantly, the use of optical design programs, the analytical method was the only viable option. An experienced computer, (as these persons doing calculations were called in the past) needed two to three months to calculate a sufficient number of ray traces through an only mildly complex optical system, like a triplet. It is understandable that approximations were used and that very complicated calculations were simply omitted. The resulting optical design showed inadequate knowledge of the exact extent of optical aberrations. Still, one has to recognize that these approximations helped the designers to determine the characteristics of many aberrations, and their experience constitutes valuable background for today's optical designers at Leica. It was not easy to optimize a design. The algebraic equations that describe the aberrations are non-linear, which means that they cannot be predicted by solving the equation. The exact calculation of all ray traces through the lens system, is the proper way to analyze and optimize a lens design. A successful design required much creativity and a very sensitive grasp at the effects of aberrations. When one looks at some of the older designs today, one is compelled to admire the achievements. An unbiased evaluation with modern instruments shows that many of these famous designs often lack refinements, but that they do have a worthy character. This method of lens design, using calculations, approximation formulae and experience, was the only one that could be used until the widespread introduction of the computer and design programs, which could calculate faster and also handle the oblique rays.

3.6 The numerical approach in designing lenses.

With the introduction of computers, the limitations of optical calculations were lifted, so that the (more exact) numerical method could now be employed to full advantage. Numerical methods can be used to achieve better control of important aberrations and they can also be used to optimize an optical system. This wealth of information can also entail its own problems. Did anyone ever tell you that the task of an optical designer nowadays is easy? The magnitude of the optical designer's task can be illustrated quite forcefully. A lens element is characterized by a few basic properties, as glass type, curvature of surface, thickness, and the distance to the next elements. They are also known as parameters, that is properties that can change in value and magnitude. As the designer is free to change any one of these values, they are aptly referred to as degrees of freedom. It can be shown that every degree of freedom can be used to correct only one aberration. As a simple example: the degree of spherical aberration can be changed by the bending of the lens, that is changing its surface curvature. And chromatic aberrations can be addressed by selection of suitable glass compositions. A six-element 50 mm f/2 Summicron lens has 10 air-to-glass surfaces and curvatures, six thicknesses (one per lens element) and four distances between elements. In addition, each type of glass has a refractive index and a dispersion number. The exact position of the iris diaphragm must also be determined. With these 36 degrees of freedom, the designer has to correct more than 60 (!) different aberrations. Every parameter can have approximately 10,000 distinct values and more than 6,000 different ray paths have to be computed for every change in a parameter. The 36 degrees of freedom also are not fully independent. Some need to be combined, and some are tightly constrained by other parameters. Thus the 36 degrees of freedom are in fact reduced to only 20, making the task even more complicated. Given the specified conditions and considerations, it is not surprising that hundreds, if not thousands of designs can be generated that are very close to the desired solution. It has been estimated that a complete evaluation of all possible variants of the six-element Summicron design, using high speed computers that calculate ray traces at a rate of 100,000 surfaces per second, would require 1099 years! That is obviously impossible. In order to select the best design from this virtually infinite number of possibilities, the designer needs a lot of creativity and insight in the true nature and character of a design. The dilemma is now clear. The analytical method offers understanding and insight about a design, but its solution is an approximation of the required state of correction. The numerical method gives the true state of the correction, but the computer program has to consider thousands of possibilities without any guidance. And even an optimization program will be fooled.

Figure 69: slides 5 and 6 show aberrations together: 5 = colour astigmatism and 6 is coma + astigmatism.

Berek was very well aware of this 'conflict of interests' and in his book from 1930 he presents both approaches and expresses his preference for the analytical method, as it fosters understanding. He is aware of course of the limitations and gives many rules for the analysis of the magnitude of aberrations. He also proposes to do some exact ray trace calculations, when the problems of a design do require more study.

3.7 The designer at work.

Berek notes in his book, that the triplet, as designed by Taylor (1895), is a very interesting design, as it will correct all seven Seidel aberrations with a minimum of effort. This example is very important, because it demonstrates how an optical designer goes about his task and why creativity still plays such a large and decisive role in that task. The seven aberrations can be corrected with a minimum of eight independent system parameters (degrees of freedom). (The focal length also has to be taken into account). A triplet (a three-element lens) normally consists of two collective outside elements (crown glass) and one inside dispersive element (flint glass). That results in six curvatures and two separating distances between the three elements, giving eight degrees of freedom. At the beginning, the designer selects basic system parameters, such as type of glass, element thickness, distances between elements, and curvatures. The designer now has six surfaces to play with, and he or she can now calculate the amount and kind of aberrations that each surface contributes. As an example, we can establish (in a very simplified manner) that in the case of the triplet, the radius of the second surface (of the first lens element) contributes spherical aberration and chromatic aberration, and that the radius of the third surface contributes coma and astigmatism. The optical designer must now decide how to correct these aberrations. He might try to change the curvature of the first lens in such a way as to reduce spherical aberration. But the curvature also determines the focal length, which should not be changed. It may also happen that a change in the curvature will reduce spherical aberration, but that the amount of coma will simultaneously increase. The designer may also choose to distribute the correction over several system parameters in order to reduce the likelihood of increasing other aberrations. It is dangerous to use one single system parameter for the correction of one particular aberration as fully as possible. It might happen that the construction department cannot manufacture this very parameter within established tolerances. And then the whole system will be out of balance. But let us return to the correction of aberrations. The optical designer will continue to alter system parameters until the correction of the seven aberrations has reached a level where residual imaging errors are very small. The designer will also strive to correct each aberration by using several degrees of freedom at the same time. The "burden" of correction will then be distributed over several surfaces and the entire system will appear more balanced. The designer can select the types of glass and the curvatures within certain limits, but each combination will result in a different kind of overall correction. Berek remarks that even the simple triplet has so many possibilities, that is would be almost impossible for two designers to find exactly the same solution. If we reflect on a classical seven-element system, like the first Summicron or the Summilux, we may get a feeling for the enormous complexity of the task of a designer to find the solution that is desired. This state of affairs explains the large variety of characteristics of lenses, that look superficially the same. Here I want to caution the reader not to try to extract too much information from published lens diagrams, as they lack vital information for a true appreciation of the art. Two lens diagrams may be very different, yet quite close in performance and character and two others may be superficially almost identical, but with markedly different characteristics. The Elmar lens, is in fact a triplet, where the last element is replaced by a cemented doublet. Using the available standard glass, the designer may encounter restrictions in required dispersion characteristics of a glass type. When cementing two different glasses, a new glass type is constructed. A cemented doublet might also be employed to get a wider aperture or a slightly better correction.

3.8 Max Berek (1886 – 1949).

The success story of the Leica camera (at first introduced as Leica-camera), had not been possible without the genius and persistence of Oskar Barnack and the daring decision of Ernst Leitz to go ahead with the production of the Leica, against the strong negative advice of his managers. Without the optical computations of Max Berek however, the potential of the Leica might have been impossible to exploit. He was a modest man, who loved to work at night in the quiet of his room, where he would sit at his desk with a pot of tea and smoking cigars, pondering questions of optical nature. Max was born on August 16, 1886 in the small town Ratibor as son of a mill worker. As so many of his contemporaries in the late part of the 19th century, when Germany experienced a cultural and scientific explosion, he went to the university to expand his knowledge. He started his study in mathematics and mineralogy in Berlin in 1907 and finished there in 1911 with a famous crystallographic research. He worked from 1912 till his death in the Leitz company. He made important contributions to the design of and measurement techniques for polarization microscopes. The “Berek-compensator”and the “-prism” are well known concepts even today in their field, as is the formula to compute depth of field of microscopic vision). The first Leitz lens for the Leica, the Anastigmat, had been designed by , and a long list of lenses for the Leica followed, 23 in total, including the Elmar 1:3.5/35 and the Elmar 1:4.5/135 and his last one, the Summarex 1.5/85. He received a personal price, the Grand Prix in 1937 at the Paris World Fair for his accomplishments. Up till now Leica has produced for the rangefinder system about 65 different lenses. Berek alone accounts for more than 35% of all Leica rf-lenses and his design considerations still can be noted in today’s designs. He wrote a major study about optical design, called “Grundlagen der praktischen Optik” (Untertitel “Analyse und Synthese optischer Systeme”) or “Fundamentals of practical optics (subtitle: Analysis and Synthesis of optical systems). It was published in 1930 and many reprints were made till 1986, when the last version was printed. The book is still very interesting for its approach and contents. Berek was very well versed in the flute and played in many chamber music sessions. Given the close relationship between optical and sound-waves, his accomplishments in both areas are not surprising.

3.9 Erwin Lihotzky (1887 – 1941)

From the same generation as Berek, Lihotzky was born in Vienna within a upper-class family. He studied engineering and specifically railway design. In his spare time he studied optics and made some remarkable observations. He discovered, that with wide aperture lenses the rays from a point will not converge to a common point (a focus) , but they will be many foci, that will describe a surface, known as the caustic surface. Imagine that the converging rays form a tunnel of light, that becomes quite narrow over a small length and then widens again, just as when the light is passing through a funnel. At some point where the mouth of the funnel is very narrow, the designer will locate the focal plane, as the converging rays are close together, and will represent the object point as a small circle of light. Lihotzky designed a method with the designer could always determine the status of the caustic surface. In 1919 he made improvements on the theories described by Petzval and Fraunhofer with his seminal study: “Generalisation of the Sine –condition of Abbe (as a prerequisite for the disappearance of coma close to the optical axis) for optical systems with longitudinal aberrations”. In this work he formulated the so-called isoplanatic condition, which even today is part of the designer’s toolbox. did read the book (long titles in those days were not a deterrent) and invited Lihotzky to join him at Leitz, what happened in 1920. At Leitz he improved the viewing systems for microscopes, designed the illumination system for the Leitz enlargers, projectors and became in 1934 the head of the department for micro-optics. Here he systematized the design of optical systems in several optical groups, and the designation of all new microscope lenses starts with an ‘L’, which stands for Lihotzky. All camera lenses start with a ‘B’ for Berek.

3.10 The current design team and design method.

Some snapshots from the past will help you to understand the vast differences in design environment since Berek’s days. Some aspects have not changed surprisingly. The basics of ray tracing, the study of the aberrations, the general approach to the design process are comparable, but as usual, the most far-reaching differences are can only be detected in the subtle details. Berek designed his Elmax, working alone, often at night with a pot of tea and smoking a cigar, on a piece of paper, tracing rays with log tables and using the Seidel coefficients to optimize his creation. In the thirties, mechanical calculating machines were introduced and the designer now employed a staff of people to work out calculations, while he could concentrate on the work to correct the aberrations. In the fifties the electronic calculators speeded up the calculations with a factor 2 and the chief designer would delegate more of the work and check the progress. With the advent of the computer and the optical design program, both methods will work. One team can design a lens, or one individual person can. Leica has opted for the latter approach.

If you look at what they are doing, you might think you are in a average computer department. Every person sits in front of a very large monitor and on the desk you will see a number of print outs of long rows of figures and graphs and diagrams. Looking a bit more closely you will note a most remarkable phenomenon. Every person is studying and analyzing his own lens. If you would need to single out one important characteristic of Leica lens design, it would be this: a Leica lens is the work of one creative individual. Nowadays we have computer programs that can design a lens almost without human intervention. This is a bit exaggerating of course, but you get the point. Consider this: when we take a photograph of an object (let us say a portrait) this face will be recorded on film and every point in the face (eyelashes, pupils etc.) will have an equivalent point on the film. In a lens without aberrations, we have an exact replica to the smallest detail. In a real lens we have some aberrations, which means that the position and shape of an image point is not recorded in the same position and with the same shape on the film. We can calculate these differences and we can even identify the causes for these differences. This is not a new science. The designers from the ‘thirties could do it too. They just lacked the time and the computing power. If we start the computer program we can specify the location of a point in object space and let the computer calculate the corresponding position of that point on the film plane. Repeat this a number of times and we get a clear view of the image. Then we ask the computer to give us the values of the aberrations detected. This is a list of figures and specifies that spherical aberration has a value of 0.0003 and coma has a value of 0.0457. (Ideally all these values would be zero). You could then tell the computer: please, re-arrange the lens elements in the design such that the coma value is halved, meaning of course less coma in the design. So a team of designers could produce a lens design in shared tasks. Everyone could do a part of the design and later it could be put together. This is how (as example) some Japanese design teams function. A lens design has a character of its own. Some designs are more promising, some are more elegant in its choice of glass or shape of glass elements and more. It is the difference between a novel written by one writer or a novel written by a collective. The latter one is certainly readable and enjoyable, the former one shows more genius and cohesion, because its concept is linked to that individuals creativity. When a Leica designer starts with a lens design, (s)he often starts with a blank piece of paper. You may not have thought about it, but the physical dimensions (diameter of bayonet throat, length of the lens, thickness of the lens) already determine many characteristics of the lens. (S)he will study the potential of the design, its requirements, its imaging capabilities etc., partly from scratch, partly from own experience and partly from the archives of Leica, where many designs and studies are kept that have been done in the past.

Why is this initial stage of free creativity so important.? In lens design we encounter any number of aberrations we need to correct to make sure we get good image quality on the film. These aberrations can be grouped into several classes: the third order aberrations and fifth order aberrations are the ones the designers will encounter when creating lenses for photographic purposes. The wide aperture of current Leica lenses make the correction of these fifth order aberrations mandatory to get excellent image quality. When a designer has corrected the third order aberrations, (s)he will encounter the fifth-order ones and while you can not correct these fully, the designer has to allow for some third order aberrations to be used as a balance against the higher order errors. So any designer will study a design to see how well it can cope with the corrections needed for fifth order aberrations. At the start however (s)he has not a good idea of how these aberrations will materialize. Now this looks a bit hopeless: you have to account for trouble you do not know about. In real life the computer will help you, as by adding lens elements you can correct part of the higher order aberrations. But then you have more lens elements that will also influence your earlier calculations etc.

So a designer needs to study the image quality that is needed at the end and (s)he should have a very firm idea of what design (initial layout) is promising enough to make the requirements fit. That is why Leica insists that one person should study one design. Of course colleagues will help when needed, but the responsibility of a design is with the designer. This approach has advantages too. The design of the 70-180 took more than 18 months, because it was new territory to Leica. But after studying the true character of such a design, the second one (80-200/4) could be accomplished in about half a year. You know the basics of a design and its optical characteristics and then a simpler version is not that difficult. The same with the 1.4/35 asph. The first design took two years, the 2/35 asph less than a year. But both lenses, while obviously closely related, show a different fingerprint. I will tell you more about this. The Leica design team is not grouped into R or M segments. Anyone will in principle design any lens. The young woman designer who computed the 70-180 lens, also designed the 2/35 asph. The designer of the 2.8/24 M also produced the 2.8/35-70. As examples!

3.11 What about this fingerprint of a lens?

Looking at the pictures (see colour print section) the reader will notice that the aberrations have a different shape and magnitude when you see them in front of or behind the plane of sharpness. This phenomenon will translate in unsharpness areas that will be slightly different before and after the object of sharpness. But the choices here are very critically related to the sharpness plane too. The choice of glass types, the sequence in which aberrations are corrected (first spherical aberration, then chromatic aberrations, then coma or any other sequence) the magnitude of corrections, the balance between the aberrations left over in the system, all these design components will influence the image quality we get on film. The best lenses of other companies may not differ that much in the factual correction of aberrations (that is computer stuff partly), but they will certainly differ in image quality if Leica meets their target with a 7 element design and some one else needs 11 glass-elements for the same kind of target. Leica designers, backed up by a vast pool of knowledge about photographic and microscopic optical designs, and supported by a high level creativity in design, and some unique insights into the intricacies of the light rays flowing through a design are able to generate remarkable optics today. The graphs generated by the computer which give an accurate view of the aberration correction are in fact an excellent substitute for a prototype glass lens. These graphs are, again, not new. In the Leica archives you will find the same diagrams, now being generated by the computer, and then drawn by hand!. It must have taken months to compute and draw all these lines! It also shows that the link with the past is still strong. Leica designs now may be created by a new and young generation of designers, the roots are in the Berek days and we are very fortunate that the original creativity of lens design is still very much alive in Solms. A Leica lens often exhibits a character as does a good wine or a good novel. Because it is designed by a strong minded and very creative individual we might consider it as a work of art. But without the help of the computer it would not be possible to redefine the state of the art of lens design. We may be very fortunate that Leica has never abandoned the individually creative side of lens design. In any modern Leica lens there has been invested several years of highly creative opto-mechanical design, that is truly cutting-edge technology. There is evidently a tension between the optical quality of the current Leica lenses and the users of these lenses, who are striving to get this quality on film. But it is up to us, Leica users to honour the work done and to give serious feedback to the designers.

4 4 Chapter 4:

Part 2: Some advanced topics in optical design and manufacture

4.1 Apochromatic correction

The notion "Apochromat" has been introduced around 1880 by Ernst Abbe. He used it for optical systems, that were very well corrected for chromatic aberrations. The Greek word 'achromat' means no-colour and 'apochromat' means no-colour traces. We know already that the refractive index of glass changes with the wavelength. This spreading of the light is known as dispersion and we can see it in nature quite often when looking at a rainbow. The smaller the wavelength, the higher the refractive index and the closer the focus is to the lens. Within the visible spectrum about 200 different colours can be identified and named. The scientist Fraunhofer gave the more important of these spectral colours a letter for easy recognition. If we only have one glass element, we have to choose which colour we will use to locate the sharpness plane on the optical axis. It is customary nowadays to select the E or D(d) line as the primary or reference wavelength for optical analysis. When the focal length of a lens is computed, the D or E line is used. All monochromatic aberrations are also computed with this wavelength as the reference.

Table: Some wavelengths and their spectral source

Wavelength	Designation of Fraunhofer line	Spectral source	Name of Color
706.52	R	Helium	Dark red
656.27	C	Hydrogen	Red
589.29	D	Sodium(doublet)	Orange yellow
587.56	D or d	Helium	Gold yellow
546.07	E	Mercury	Green
486.13	F	Hydrogen	Pure blue
435.83	G	Mercury	Violet-blue

All colours (with the exception of the primary wavelength) will have different focal points and also different enlargements of the object point. The focal length is a direct measure of the magnification of the object. A 200mm lens will give images four times as big as a 50mm lens. All deviations from the reference wavelength are known as chromatic errors. Errors in the difference from the focal length are called longitudinal chromatic aberrations and errors in the magnification are called lateral chromatic aberrations. These chromatic errors are the result of the dispersion of the glass. As every glass type and wavelength has different values, we need to find a simple way to identify and compare glass. We can measure the average dispersion over a range of wavelengths and use this number for comparison. That is what Abbe did, when he introduced the Abbe-number. Take the reference wavelength (D-line)and subtract 1 from its value. Then take the difference between the extremes for visual light (F-line minus C-line). Divide these two numbers and we have the Abbe-Number.

$V = [ND - 1] / [NF - NC]$

These values range from 20 to 85. Crown glass has high dispersions and flint glass has low dispersions. The value of 50 or 55 is usually given as the demarcation line between both types. But these indications have only historical meaning. Glass can be identified by its Abbe-Number or a name, often from the Schott catalogue (SF2 of BK7) or by a glass number. This is a six digit number where the three first digits are the most significant digits of [ND – 1] and the last three digits are 10 times the V-number. The famous "Noctilux"-glass from the past was designated as '900403': an Abbenumber of 40,3 and a very high refractive index of 1.900 for the Fraunhofer D-line. By suitable selection of glasses with dispersion characteristics that are mutually complementary, the designer can match a crown and a flint glass, such that two colours are focused to the same focal length. Often the C and F lines are chosen, as these lines correspond to the visual spectrum for which the eye is most sensitive. Such an achromat has much reduced chromatic errors, but they are not gone. The residual errors are called secondary spectrum. The designer can carefully try to match special glass types in order to bring three different colours (now C and F and d) to a common focus and this type of lens is called an apochromat or apochromatically corrected lens. The negative definition of this type of lens, is a lens where the apochromatic error is not corrected. This error can be explained as follows: the overall dispersion does not tell you how the individual wavelengths are refracted. We might assume that there is an orderly pattern in the dispersion range. If we construct a graph with on the vertical axis the index of dispersion and on the horizontal axis the wavelength, we do not see a straight line, but a curved one, which has a different shape for every glass type. So the dispersion in the blue part of the spectrum relative to the red part is different for a crown glass and a flint glass. This phenomenon is known as partial dispersion, and is responsible for the apochromatic error. The designer can try to match two curves for two wavelengths but the rest of the spectrum will be out of synch and generate colour fringes and contrast loss over the whole image area. The apochromatic error will be enlarged when using telephoto-lenses, as the idea of a telephoto lens is the magnification of the object. With this enlargement, the colour errors will be enlarged too, as aberrations are linearly related to the focal length. The first Leica lens with apochromatic correction was the Apo-Telyt-R 1:3.4/180mm. The apochromatic correction is now introduced in the 90mm focal length, and there is no reason why to stop there. When stringent demands for colour correction are formulated, even the 50mm lens (and shorter) could become a target for this type of correction. The lens designer needs to find glasses with a characteristic pattern for the partial dispersion that is not normal, or abnormal. We saw that the normal partial dispersions do not allow for the best correction. Such glasses can be found on the glass-map and are called abnormal-dispersion glass or anomalous-dispersion glass. Such glass is very difficult to employ. Leica designers are well acquainted with these glasses, however, which explains the high level of the apochromatic correction of Leica lenses. You will see the apochromatic error at the edges of a dark-white border. On one side the edge is red and on the other side blue-violet. Or as a green band on one side and a reddish-violet band on the other side. These phenomena indicate two different types of chromatic error. Both can be unrelated, so one can be corrected and the other not or only partially. There is no agreed upon definition of what constitutes a 'true' apochromatic correction. Leica will designate a lens as an apochromat as both errors are corrected at full aperture, and over most of the image field. For this type of correction you need to employ these special glasses with abnormal-partial dispersion. It is also possible to reduce the apochromatic error to a small value, when using normal glasses. Then we have a lens with a very small secondary spectrum, which looks like an apochromat, but is not. Every manufacturer has its own correction philosophy.

4.2 Can lenses be corrected for black & white emulsions only?

In the Leica community, you can often hear an assertion, that is as persistent as it is untrue. The older lenses, it is sometimes stated, are corrected and optimized for black& white photography. This statement, presumably, originates form the idea that colour corrections were not needed in the past, as colour film was unknown or not yet invented. When we photograph a scene with monochromatic film (black & white), we must realize that all colours of the spectrum are recorded as grey values on film. All wavelengths will be involved in the process of image formation. Red and blue light (the extremes of the visual spectrum) will be focused at the same locations by the lens, irrespective of the film used. The film will record the blue and red part of the light, coming from an object point, as grey tones. The apochromatic error, as we saw before, will image an object point with a red band on one side and a blue-violet on the other side. In B&W emulsions, that will be recorded as different shades of grey. So in fact, B&W film is the more demanding medium as it is very difficult for the eye to detect small differences in grey values. In addition I may add that the quality of light involved in black and white photography is always composed of all wavelengths, and will involve all residual aberrations.

4.3 Aspherics

Many of the aberrations, that I have discussed, are related the spherical form of the surface of the lens. It seems logical to assume that a non-spherical form, like an ellipse or a parabola, could be used to correct some of these errors. An aspherical lens surface is defined negatively, that is any surface that is not spherical or planar (flat) is called a-spherical. A hyperbola and an ellipsoid are examples of aspherical surfaces. An intuitive visual example would be the shape of an American football or a cylindrical lens. One of the basic aberrations of a spherical shape is the spherical aberration, whose name is aptly chosen. The principle of the use of aspherical surfaces to correct this inherent optical error, is not new. Kepler (1611) proposed its use and Descaters (1637), developed the necessary theory. But an aspherical surface is very difficult to make and it is easier and much more economical to restrict the manufacture of lenses to spherical shapes. If you look at figure (xx) you will see a classical lens shape, with two spherical surfaces with a radius of curvature of 20 (in this case). The rays do not converge to a common focus, as the definition of the spherical error has it. In the next figure I have introduced a certain asphericity to the first surface and now we see that the rays do focus in a much narrower band. The amount of departure from the spherical is small. In this particular case, it is about 0.1mm. In order to understand this number, assume that we start with a spherical surface with a diameter of 25mm, and the distance from the centre of the lens to the rim or edge is 12.5mm. The surface has a certain curvature and when we draw a line from the top of the surface to the axis, it will intersect the axis at a specified location. If we give this lens an amount of asphericity, and repeat the act of drawing the line, we will now find that this new line intersects the axis 0.1mm way from the first (spherical) location. See picture. To get a rough understanding of the dimensions involved, you should reflect for a moment on the length of a millimetre. Divide this small space into 1000 equal parts. That is the length of a micrometer. The world of optics is really a cosmos of microscopically small dimensions. A wavelength has a mean length of 0.5 micrometer. For precision optics, it is required to stay within tolerances that are a quarter of a wavelength. The amount of asphericity, a small as it seems, is large, when compared to the required precision of a spherical surface, which may deviate only 0.1 micrometer. Luckily, Leica can produce lens elements that are so accurate, because if they could not , the whole idea of an asphere would be useless.

Figure 70: 4.3.A- spherical lens

Figure 71: 4.3.B- aspherical surface.

Note perfect point The above is an example of the use of aspherics to correct simple aberrations. The true power of the asphere (as the surface is commonly referred to), is the correction of higher order aberrations. I noted in chapter 1.1 that every surface of a lens (optical system) has its unique aberration content and the use of an asphere adds simply an additional component to the errors already present. The fascinating idea is that the asphere changes the mixture of aberrations at that surface and so helps correct higher order aberrations by introducing new ones. It is also evident, that the introduction of large errors on one surface and compensating them on other surfaces, demands a high precision in alignment and positioning of the lens elements. As noted so often in these pages, mechanical precision and tight manufacturing tolerances are a necessary condition for high quality Leica optics. Wide aperture lenses and or compact lenses with aspherics are very demanding to manufacture as the requirements for tight tolerances grow exponentially. You pay for this production quality, even if you do not realize it.

Figure 72: 4.3.A CNC grinding

It is often assumed that the use of one or more aspherical surfaces does automatically enhance the optical performance of a optical system. That is not true. Optical designers, employing the usual array of glass types, number of elements, curvatures of surfaces etc, might create masterpieces, but also lenses of modest performance. And there are indeed on the market now lenses with aspherical surfaces, where the optical role of these surfaces is less evident. To be useful, an asphere can be integrated into an optical system only if the correction of the higher order aberrations is required. If you have a lens, where mainly the third-order aberration are corrected, an asphere would be of no great help. Aspherics will be employed to enable the designer to build in an elegant way high quality optics in a compact format and with less weight. There is a rule of thumb that every aspherical surface replaces one lens element. As illustration, compare the six element Noctilux 1.2/50 with two aspheres with the current Summilux-R 1.4/50 with 8 elements, which is of higher overall optical quality. They can be used to correct aberrations, like spherical aberration and distortion (spherical aberration of the pupil), as in the Tri-Elmar. They can also be employed to get wider apertures and wider angles of field with a high level of correction (as with the Summilux 1.4/35 asph). The application of the aspheres is not restricted to these examples and can be used for many optical and/or mechanical purposes. The first economical large scale production of aspherical surfaces will be found in the Kodak Disc camera (1982), which used a glass lens, that could be pressed into shape. The classical way to give a lens surface its desired shape is grinding and polishing. The aspheric surfaces used in the Noctilux 1.2/50, were polished into shape manually with the help of specially constructed equipment. The failure rate of this process was high and abandoned after a few years. At the other extreme we have a manufacturing process where a plastic (Acrylic) lens is injection-moulded in a special mould. The fabrication of such a mould is very expensive and only feasible if large quantities of a lens are needed, say 50.000 pieces a year, as you can make about 200/day in this manner. The second method is compression molding where a lens blank is pre-machined close to the required shape and then the lens is put between the moulds and the whole assembly is heated. Leica does not use plastic elements or hybrid (glass-plastic) elements in their lenses. There are now two methods to produce aspherical surfaces. The first one, is the technique of direct precision molding of finished glass elements. It is basically the same technique as the blank pressing of components, where the mould and the glass are both heated and pressed into shape. The precision molding technique is a joint development of Leica, Hoya, and Schott and can be used to manufacture high precision surfaces. The limitation of the technique is not the accuracy of the aspherical surface, but the restriction to a few glass types and to glass of a diameter of about 20mm. Aspherical surfaces, formed with this technique can be found in many of the wide-angle lenses for the M-system. The current technique at Leica is the employment of computer-controlled polishing and grinding equipment, so-called CNC- machinery. (CNC=Computer based Numerical Control). The computer is fed with the necessary data, like surface specifications and tolerances and will then automatically ‘operate’ the tool. In this case every lens element is individually produced. There are no restrictions to diameter of the element, type of glass or level of precision, which allows the designers to explore even more exciting possibilities. The Apo-Summicron-M 1:2/90mm ASPH is the first lens with an asphere, manufactured with these new tools. The accuracy that can be attained when using this type of machinery is in the area of 0.1 micrometer, which means that the precision of classical spherical surfaces is now within reach, offering even more possibilities for correction of aberrations. Leica uses interferometers to check the correct asphericity. A compensation system is employed that adapts the spherical wave front as generated by the interferometer to the aspherical shape. A new method is the use of holograms to check the lens surface: Leica uses nowadays the CGH technique (Computer Generated Holograms).

4.4 Vignetting and the cos4-effect.

The simple explanation of vignetting is the mechanical obstruction of oblique rays. It is customary for photographic optics, and Leica lenses are no exception, that a 50% drop in illumination occurs at the edges of the frame. In many circumstances this drop will go unnoticed, especially if the change is very gradually. Mechanical vignetting can be reduced, but at the cost of a much bigger lens. But even that will not solve the problem, because the throat diameter of the lens is fixed. The free diameter for the rays is less than the full diameter suggests. In the case of the R, the mechanical linkage of the automatic diaphragm asks space that will block some of the rays and in the case of the M it is the coupling of the rangefinder mechanism that will reduce the free space. Vignetting is often used by the designer to improve the image quality in the field. Full illumination of course, is always a design aim and should be balanced against other requirements. Generally the designer ensures that the maximum diameter of the aperture stop is sufficient for all central rays to pass through the system and uses the vignetting to block some off axis rays to improve the performance. The worst aberrations are the oblique tangential rays in the outer zones. And exactly these can be clipped off when some vignetting is allowed. In lenses with a very wide angle of view, we note a second type of loss of light in the corners. I hinted at this phenomenon when discussing the field curvature. All light energy from an object point has to pass, as a cone of light, through the aperture stop. The physical stop is the device we see when we look through the lens and count the aperture blades. In optical theory however, the aperture stop is less important. Why? Well, the aperture stop is located somewhere in the optical system and there are lens elements before and after the stop. These lens elements will deliver an image of the aperture stop and these are called, the entrance pupil and exit pupil respectively. The light rays that exit from the lens, are optically coming from the exit pupil. If we now take a point on the optical axis, and look from that location into the lens, we see the exit pupil and all rays coming from there form the cone of light. The solid angle (remember: we are in three dimensional space!) subtended by the exit pupil is the area of the exit pupil divided by the square of the distance from the pupil to the centre of the film plane. From an off axis point, let us say at the corner of the film plane, the distance to the exit pupil is clearly greater. The difference between the two distances is greater by a factor equal to 1/cos è and the increased distance will reduce the illumination in the corner by a factor of cos2 è. Now from the corner location the exit pupil is no longer circular, but we look at it obliquely and so is more ellipsoid. The projected area of the exit pupil is reduced by a factor about equal to Cos . The illumination at our corner point is reduced by cos3 è. But we are not yet ready. From our location at the edge of the frame we look at the exit pupil along the axis of the cone of light. But the film plane makes an angle with that cone of light and we have to add yet another factor of Cos to the equation, which now gets the familiar form of cos4 è. This phenomenon is very bad for wide angle lenses as we will see: a wide angle lens with an angle of 60o has a drop in illumination of cos4 30o = 0.56 and a wide angle lens with an angle of 90o has a drop of cos4 45o = 0.25, that is two stops loss. The cosine-fourth effect then is the sum of four different cosine factors. In wide angle lenses, this effect can be reduced by an optical construction, that the apparent size of the exit pupil increases for off-axis points or to introduce barrel distortion to offset the drop in illumination.

4.5 Coating and lens flare

When light strikes a glass surface, some of the light is reflected and lost for the process of image formation. Less light energy will reach the film emulsion and the transmittance of the lens is reduced. More importantly however, some of the light is not bounced back out of the lens system, but will stray into the lens elements and create veiling glare and ghost images. Specifically the veiling glare is a bad phenomenon (it works like a soft focus filter) as it will reduce overall contrast and especially will considerably lower the contrast of very small details, giving them a fuzzy look. The official definition of 'flare' is: non-image forming light, more or less evenly distributed on the film plane. You can easily see this phenomenon for yourself if you compare two pictures taken in exactly identical situations, one with a lens prone to image degrading flare (like the Summilux 35mm at full aperture) and one which has good flare control (like the Summilux-ASPH 35mm). In the first image the deep shadows are lighter (more deep grey than ink black), very fine subject detail can not be detected (which the ASPH easily shows) and the overall contrast is lower, where the ASPH has brilliance and deep saturated and clear colours (in the small subject areas that is). The ASPH also suppresses light fringes around the small subject outlines in strong backlighting and side lighting, where the older lens exhibits strong halo around the subject outlines. The second way to show the image degrading by flare is measuring the deep shadows with a densitometer. You will then find that the older lens has actually a higher reading in the deep shadows than the ASPH, which you could interpret (wrongly) that the older lens is better in the area of light transmission. Ghost images or secondary images, like the well-known round or hexagonal images of circle of the closed aperture blades, can be suppressed by effective reflection control, but they will occur and always unexpectedly at your best picture. When you are taking important pictures, you really should give the topic of reflections some analysis and precautions. Look at the angle, the sun or light source is making with the lens, see if light rays enter the lens directly and try to shade them off. Current Leica lenses are quite effective in the reduction of flare, but they are not immune to it.

Figure 73: 4.5.A coating

The principle of reduction of the reflected light is simple. If you add a thin layer of some substance to a glass surface, there will be two additional boundaries that the reflected ray has to transverse. It is possible to design the thin layer such that the reflected rays from the upper and lower boundary cancel each other before exiting the surface. This is called destructive interference. Optical coatings are thin films of various substances, often magnesium fluoride, zinc sulphide, hafnium oxide and many others with exotic names. Every substance has its own index of refraction. We habitually speak of single layer and multiple layer coatings, assuming that the latter have superior properties. As usual in optics, there is more than meets the eye. The optical thickness of a coating is different from its physical thickness, as we have to account for the index of refraction. All references to the thickness of a thin layer are in fact to the optical thickness. It can be calculated that to be effective the thickness should be a quarter or a half of the wavelength. Since interference effects produce colours, just as in oil droplets on wet pavements, we might be able to judge the thickness of a layer by looking at the colour. If a single layer film has an optical thickness of one-quarter of a wavelength, any wave reflected from the second (bottom) surface will be one half of a wavelength out of phase with light reflected from the first (top) surface and both will cancel. We have however to take into account the index and it can be proved that to be effective a thin layer needs to have an index that is the square root of the index of the glass, on which the layer is deposited. The reflectivity of a coated surface will change with the wavelength. It is clear that the quarter wave coating only works for one specific wavelength. For all other wavelengths the layer is more or less thick than this quarter-wave thickness. A single layer coating does function therefore more or less efficiently in a broader region than only the specified wavelength. Often a coating will try to reduce the reflection for the yellow light as this is the most visible to the human eye, and that gives the characteristic purple colour of single layer coatings. The efficiency of a coating depends on index of refraction of the glass and of the layer, light transmission properties of the layer, angle of the incident light. All these components have to be looked at before one can make comments on a coating. With more layers of different properties, one can broaden the effectiveness of the coating over a wider range of wavelengths. It is possible to reduce the reflection over the visual spectrum to 0.2%, compared to 4% for an uncoated surface. Current Leica lenses are all coated with a multi-layer coating and sometimes the surfaces of the cemented glasses are coated when research has indicated its effectiveness, a not too common practice. The most common method of depositing a layer to glass is the thermal evaporation coating. The coating material is heated in a vacuum chamber as is the glass that will be coated. The length of time and the temperature control the thickness of the layer. If the glass surface itself is not absolutely smooth, irregularities will occur that diminish locally the effectiveness of the layer. Here we seen another hidden quality aspect. Leica takes great care to ensure that the glass surface is polished to a very low level of roughness, as this alone will degrade image quality. The cleaning of the lens, before the application of the layer has to very thorough. Leica uses often ultra-sonic cleaning procedures and sometimes a glass needs to be coated within hours after being cleaned as otherwise the air would already affect the surface. This coating technique does not deposit a really smooth, amorphic layer, but the surface is covered with a structure, consisting of rows of pillar like stakes, like rows of nails with the tip pointed upwards. Heating, cooling, depositing are time consuming and glass does not like the heating-cooling cycle. A new method has been introduced at Leica, developed jointly with Leybold: the plasma ion assisted deposition (IAD), where the growth of the pillar like structures is reduced and a much smoother surface area can be generated. The process uses a much lower temperature and in essence consists of a bombardment of ions onto the surface to be coated where atoms are set free that attach themselves to the substrate and form an amorphous layer.

4.6 The use of filters.

This topic will divide the Leica users in two camps, one stating that any filter will degrade the optical quality of the lens and the other one asserting that a filter will do no harm and will in addition protect the surface of the front lens. Filters are often an indispensable tool for the photographer. Many B&W pictures can be enhanced by the employment of filters to give a more natural grey value to the basic spectral response of the emulsion. A green filter will differentiate more between several green hues and an orange filter will enhance contrast. And slide film often needs a colour correction or colour balancing filter. So if the use of filters is unavoidable, what are the restrictions, if any? In addition the question most often posed is if it is a sensible act to have a UV filter permanently attached to the lens. The answer is simple, but has to be developed in two steps. IF a filter has absolutely plane surfaces (and I mean optically plane), then the degrading effects can be neglected in all but two situations. It is not to be assumed than any filter can be qualified as optically plane, without any defects or surface irregularities.

1. If the lens is a wide aperture one and/or a wide angle one, the oblique rays will certainly degrade the image quality of the lens, when a filter is put in front of the lens. There are two additional surfaces, which will inevitably deflect a very small part of the rays.

2. If the lens is used in high contrast situations or when strong light sources are in or close to the main subject, you can expect secondary images and some veiling glare. I will be practical here. Whenever the situation is not very demanding I will use a UV-filter for protection purposes. Just to make sure. I am aware that the front surface is quite scratch resistant, but there is always that nagging doubt that some nasty particle will scratch my lens. And if I use lenses with longer focal lengths, even in some high contrast situations, I will leave the filter on. But when the degrading factors accumulate (example: 24mm lens and a contre-jour situation or 90mm with light sources in the image area) I will remove the filter. There are no hard and fast rules here. None of the extreme positions (never a filter, always a filter) corresponds to the reality of filter use and image degradation. It is up to the individual user to choose carefully when to use or not use a filter. In most normal situations the theoretical image degradation of a filter can be neglected and is most certainly less than a slow shutter speed. Take a picture with 1/250 with a filter and 1/15 without and there is really no contest. The slower shutter will have more negative effect on the image quality than the filter. The use of a filter will have some effect on the lens performance, but one should carefully reflect if this element in the imaging chain is the most crucial for the picture to be made. If the use of a filter is required there is no option but to use the best filter quality you can find. The situations outlined above, that will magnify the degrading effect of a filter, should be taken into consideration when making the picture. If you habitually use a filter for protection purposes, you should remove it under the specified conditions. Current lenses have quite resistant coating. But every one has to make his own choices here.

4.7 Wide apertures and the geometric flux.

From a modern perspective a lens transmits light energy from an object to an image plane. If we take a picture with, let us say, 1/125 of a second, all light energy reflecting or originating from the object is integrally captured on film in a fraction of a second. The lens or optical system is in fact just a tube that transmits the light energy. This phenomenon is designated as the geometrical flux or in German "Geometrischer Fluss". In analogy: through a water pipe with a certain diameter, only a certain amount of water per time unit can pass through. If you need a larger flow of water, you have to increase the diameter of the pipe. The length and diameter of the pipe then do determine the energy that can flow through it. The strength of the aberrations is also dependent on this dimension of the pipe. The Apo-Summicron-R 1:2/180 is twice as voluminous as the Apo-Elmarit-R 1:2.8/180. The dimensions for the 2/180 are 176 x 116 (length and width) and for the 2.8/180 are 132 x 76. Simple calculations of the tube volume gives 32.053 and 15.750, that is the Summicron is twice the pipe volume of the Elmarit, which is correct, given the fact that the Summicron is twice as sensitive. This relationship with tube diameter and length also explains why the Vario-Elmarit-R 1:2.8/35-70 ASPH is twice the volume of the Vario-Elmar-R 1:4/35-70mm. If you prefer to reduce the dimensions, you will have to perform some elaborate optical juggling which often degrades the image quality. A 2/50mm lens seems to be a piece of cake to design, but a 2/35 is much more difficult as a wider tube is needed for the passage of the light energy and a 1.4/35 is twice as problematic and four times as problematic as a 2/50 design. Now aberrations do not conform to a simple extrapolation pattern. Some aberrations grow exponentially when the tube dimensions grow geometrically. There is much truth in the statement that it is easier to correct a lens when the physical dimensions may be allowed to grow beyond the minimally required optical relationships. Aperture and field angle are intimately related, as far as aberrations are concerned.

The following table illustrates the dependency.

Aberration	Aperture = r (radius)	Field (angle of view) = w
Spherical aberration	R^3	No influence
Coma	R^2	W
Field curvature	No influence	W^2
Astigmatism	No influence	W^2
Distortion	No influence	W^3
Chromatic aberration	No influence	W

This table tells you that the spherical aberration grows by a factor of 8 if the aperture doubles and that distortion grows by a factor of 8 if the angle of field doubles. A

2/50mm can be approximately be corrected as well as a 2.8/25mm, but coma is reduced by a smaller aperture, but at the same time enlarged by the wider angle of field. And while spherical is reduced, distortion grows disproportional and the balance may re-introduce some other aberrations. How this works out in practice is part of the designers' chemistry. The smaller the physical volume, the more difficult the correction. The law of the geometrical flux is always true. The improved correction of the higher order aberrations at the wider apertures demands a very high accuracy in matching of parts and assembly of components. It does not make sense to calculate an improved version of a lens and then specify production tolerances that nullify the advances made. It is not an over statement, that a large part of the price you pay for a Leica lens, has been invested in the performance at the wider apertures. It is really counter-productive to stop down to very small apertures, as image quality will degrade visibly, when enlarging the negative 10 times or more.

4.8 Vario lenses.

The basic idea of a vario-lens (in Leica parlance and zoom lens by many other manufacturers) is the possibility of different magnifications in one optical system, without changing the distance from object to film plane. A lens with a fixed or single focal length there is only one magnification ratio for the object at a certain distance from the film plane. Assume we take a picture of a person with height 1.70 meter and we want to have this person fill the frame of the negative without turning the camera, the magnification will be 24mm/1700mm = -0.014. If we want a different magnification, to get a more detailed recording of the face we have to move closer to the person and refocus. If we take a simple lens and move it towards the object, we get a larger image and when we move it away from the object, the image becomes smaller. This would be a variable-power (or vario or zoom) system, manually operated, but is shows the principles. An uncompensated single lens vario system, as outlined above, can only have two magnifications where the image is focused sharply. We will have to add more lens elements and a compensation shift of some of the other lenses in the system to get more points of focus. A real-life zoom lens consists of at least two groups of lens elements. If we change the distance between the two groups, we alter the effective focal length and thus the magnification. If we now use a mechanical device to slightly shift the location of one of the groups, during the zooming action, we can preserve the final focus position. This compensation movement is unfortunately not a simple linear change in distance, but a non-linear one and needs a cam arrangement, with a rather complex shape of the cam. In the early days of zoom lens design, such a mechanical compensation could not be manufactured with the required precision and an optical solution was searched for. The optical compensation employs two more lenses or lens groups, which are linked together and also move together and in relation to the other lenses of the system. Such a system is simple to manufacture and all early zooms are optically compensated. The early zooms had a remarkable property that is almost lost today: the constant aperture over the full range. Also the exit pupil was a constant, and as the older cameras had no Autofocus and Auto-exposure to compensate automatically for focus changes and illumination differences, that was a bonus. But these demands stressed the design optically and generally the earlier zooms were optically not that good. As the lens elements had to be located at specific positions, the designer was restricted in the ability to correct the system over the whole zoom range. In fact the correct focus could not be held and was replaced by a focus within the depth of field parameters. And last but not least, those systems were physically large. When the problem of the accuracy of the machining of the cam arrangement was solved, most zoom lenses became and are of the mechanical compensation type. A modern vario lens consists of three optical groups, the basic optical unit, that defines the general properties and where resides the bulk of the aberration correction, the unit that adjusts the magnification (the compensator for constant back focal length) and the unit that adjusts the focus position (the variator for focusing movement).

Figure 74: 4.8.A 105-280 See picture 4.2/105-280.

Some earlier lenses had two groups, only a variator and a compensator unit, which as a whole also functions as the basic unit. See 3.5/35-70mm. When the designer can employ many lens elements and is relatively free to move lens elements, a macro function can be built-in too, as with several current Leica Vario lenses. The Vario-Elmarit-R 1:2.8/35-70mm ASPH is a special case, as here the non-linear cam movement has been replaced by a linear movement, with the same possibilities but easier manufacture. Generally a designer will correct the vario-lens for three positions, the extremes and the geometrical mean of the extreme positions, on the assumption that the intermediate positions will be corrected automatically. Here much sensitivity and feeling of the designer is expected in order to create a really excellent lens. As we noted in chapter 1.1, the more lens elements you have, the more possibilities for aberration correction you have. But it is easy to lose track of all combinations. It is a hallmark of good design to accomplish more with less elements: most Leica vario lenses are within the 9 to 11 range, where the competition uses 16 to 20 elements.

Figure 75: 4.8.B 4/35-70

Figure 76: 4.8.C 2.8/35-70

The obsolete idea that vario lenses can never be as good as fixed focal length lenses is presumably based on earlier experiences of optically corrected zoom lenses. It is however not possible to work from pre-conceived notions. The Vario-Apo-Elmarit-R 1:2.8/70-180mm as example has better imagery than the fixed lenses from 80 to 135mm focal length, but is at 180mm not as good as the Apo-Elmarit-R 1:2.8/180mm. The same statement applies to the Vario-Elmar 4/35-70 and Vario-Elmarit 2.8/35-70 ASPH, when compared to the same range of focal lengths and comparable apertures.

4.9 Bo-ke, unsharpness and circle of (least) confusion

When we record a three dimensional (or solid) object with our Leica, we will have to accept that the image will be flat. The solid object will be represented on the film plane, that is in itself extremely thin and for all purposes can be considered dimensionless. The film emulsion has a thickness of 3 to 10 micrometer, but we can neglect this. It is, by the way, interesting to note that a film like Agra APX25 (one of the best to explore the Leica lens quality) has an emulsion 'thickness' of 3 micrometer. This is ten times smaller than the diameter of the circle of confusion, that is fixed at 1/30mm or 30 micrometer. Assume we take a picture of a person at two meters in front of the camera. Focusing on the eyes, will ensure that the focus plane, the vertical slice through that solid object will be sharply recorded on the film plane. All object points, in front and beyond that focus plane will be defocused or unsharp, and the more so as the distance from the focus plane becomes larger. Most photographers will have had the experience of a slightly defocused picture. But when looked at from a larger distance, the picture looks acceptable sharp to most viewers. Or the other way: we have enlarged a picture to a 20x30cm print and find the image sharply rendered. Then we try a bigger enlargement, say 40x50cm and now we are heavily disappointed, as all object points are blurred a bit. These experiences allow us to remark that the eye will regard image points as sharp points when the viewing distance and/or the diameter of the point is below a certain limit. We know (see chapter 1.1) that a very small object point, like a star will be recorded on film, not as a point, but as a small patch of light, with a core of high intensity of light energy and a series of concentric bands or rings of ever diminishing intensity. The core is surrounded by a blurred edge, but we will not see a blurred disc of light but a sharp point of light. Unless we enlarge sufficiently and are able to discern the pattern of irregular light distribution. The ability of the eye to see 'clearly', is simply stated the ability to differentiate detail at some distance from the eye. If we do an eye test, we are asked to identify letters or shapes of ever smaller dimensions. When we can no longer identify a letter as a "V" or an "O", we are beyond our minimum visible resolution. It has been established that this happens when the eye subtends an angle of 1' (minute) of arc. Using an angle means that the resolution limit is dependent on the viewing distance and the size of the object. Using this criterion and the normal viewing distance of 25 cm, it has been established that any object, smaller than 1/16mm (0.0625mm) will be seen by the eye as a single point. And two small objects, separated by at least 1/16mm, will be identified as two single objects. When two objects are closer together, say 1/50mm the eye will only see one (bigger) object and not two smaller ones. These figures are obtained under ideal laboratory conditions, so it is reasonable to use lower figures for the photographic practice. Often the figure of 1/6mm (0.1667mm) has been proposed, which translates to 6 lines in a millimetre or six points on a line, one millimetre long, every point having a diameter of 0.1667mm. All these figures are related to the print that we are looking at. What does this mean for the dimensions of the points on the film plane. Let us assume, that we will enlarge a negative 5 times. Then we have to divide the diameter of our smallest visible point by 5, thus 0.1667/5 = 0.0333mm. As long as points on the film are smaller than 0.033mm, we will see them clearly as a point. If we use an excellent lens, with very well corrected aberrations, the points in the plane of sharp focus may be as small as 0.005mm. If we defocus a bit, these extremely tiny points become blurred and larger, let us say twice as large, that is 0.01mm. That is still below the limit of 0.033mm and even these unsharp patches will be seen by the eye as sharp points. If the true (sharp) focus plane would be located at a distance of 2 meters, that is the plane we are focusing on, we have image points of dimension of 0.005mm. The object plane at a distance of 1.90meter, will be defocused (out of focus) and generate larger image points of dimension 0.01mm, but still within the limit of minimum visible resolution. An object plane at 1.70meter will have defocused image points of 0.03mm and now we start seeing a defocus blur. The same reasoning can be applied to all object planes behind the plane of sharp focus. In this example, we will be able to se all object points that are located in the object from 1.80meter to 2.20meter as acceptably sharp points and we say that the depth of field in this case is 40cm. The position of best focus is of course 2meter, but all points within the sharpness limit, calculated here as extending from 1.80 to 2.20meter are seen as sharp. The depth of field (DoF) is related to the limit of minimum visible resolution, which in photography is called the circle of (least) confusion (CoC). The enlargement factor we have used (5 times) to calculate the CoC of 0.03mm has been established long ago when films and optics were in their infancy. If we enlarge 10 times, which we will often do with our small Leica negatives, we will quickly notice that this CoC is too large and that the DoF shrinks considerably. It is not well known that the DoF extension (distance before and after the sharpness plane) only depends on the reproduction factor. That is, when two objects are photographed such they are of equal magnification, irrespective of the focal length, the DoF is identical. In practical terms, an object taken with a 35 mm at 3.5 meter and the same object taken with a 180mm at 18 meter will have identical DoF. So if we wish to compare the unsharpness impression of two different lenses, or make any general statements. we should take care to compare pictures taken at equal magnifications.

The idea of bo-ke

Most discussions of the concept of Depth of Field are based on the unsharpness criterion of 0.03mm and argue from there. It makes more sense, and in my view is more correct too, to interpret the DoF as a result from defocus blur. A more appropriate definition of the depth of field is this: the range of defocus within which the image appears to be correctly focused. This is what we do when we use zone focusing or the hyperfocal distance. Or even when we try to focus accurately and assume that we have a safety margin for some defocus or out-of-focus range. Any out-of-focus point will be represented as a defocused blur disc and we know, at least by experience, that any defocus decreases image quality as it blurs out fine detail, reduces contrast and makes sharp edges fuzzy. The shape of the blur disc is that of the aperture stop and its diameter is dependent on the size of the aperture stop and the distance between the in-focus and out-of-focus planes. We are familiar with the shape of the aperture stop when we see a circular or hexagonal out-of-focus spot in the fore- or background of the image, indicating the number of blades in the aperture stop. Less blades give a hexagonal shape and more blades a circular shape. Apart from this easily recognized phenomenon, you can note that the out-of-focus objects gradually become blurred when they are located farther away from the plane of focus. The change from focus to out-of-focus blur patterns is not gradual, but depends on many factors, such as the structure of the out-of-focus image itself and the distance from the plane of focus. It is therefore not easy to make comparisons between the shapes and structures of out-of-focus images between different lenses. Generally one can assume that a blurred fore- and background will help to set the main object, correctly focused, clearly apart and also gives a clue of depth. The out-of-focus shapes have been studied recently and the character of these shapes is designated by the Japanese word “bo-ke”. “Bo-ke” originally means being obscure. The Japanese often use this word to express absent-mindedness or dotage of the elderly. The word itself has no positive connotations. A lens which is interpreted as having good bo-ke has a certain level of image degradation, that retains the original shapes and details of the out-of-focus object planes. One might say that the difference between the in-focus and out-of-focus images is relatively small, which provides a very smooth transition from focus to defocus. The concept of bo-ke is a subjective one and it is a matter of personal opinion if a certain kind of out-of-focus blur is pleasant or not. The concept of bo-ke has been interpreted as a criterion of image quality and a discriminating characteristic of lenses. The artistic interpretation and emotional connotations of an image are beyond the scope of this book. What I can discuss is the fact that there are indeed differences in the way lenses reproduce the out-of-focus planes. The presence of aberrations decreases the ability to detect a defocus, as the result of aberrations is a loss of contrast, blurring of sharp edges and of fine details, just as the effects of defocus, we described above. A lens that shows less image degradation in the out-of-focus areas, (has good bo-ke) must be, therefore a lens with a higher level of residual aberrations. Some Leica lenses are described as having good and bad bo-ke. The older lenses invariably get high marks for good bo-ke and the current lenses get low marks. As we noted, the higher the optical correction of a lens, the more easier it is to detect the image degradation of the out-of-focus areas and that is interpreted as bad bo-ke. New or recently redesigned Leica lenses are more highly corrected than older lenses and therefore have a steeper transition from focus to defocus areas. A lens in case is the Summicron-M 1:2/35mm (3) from 1979, which is credited with very good bo-ke and the current Summicron-M 1:2/35mm ASPH, which is supposed to have a different kind of bo-ke. The aberrations still present in the older version do indeed decrease the effect of the out-of-focus blur .The use of aspherical surfaces has no direct relation to the perceived presence of good bo-ke. It is the level of aberration correction which is instrumental, and not the use of aspherics. A lens without aspherics, but highly corrected, as several apochromatically corrected lenses, exhibit the same bo-ke fingerprint. When one stops down, the differences between the definition of the in- and out-of-focus areas of several types of lenses do diminish of course, but do not disappear. It is a matter of optical progress that the new designs have a more easily recognizable out-of-focus blur and that a defocus is more visible. The definition of the in-focus part of an object is the most important part of a picture. Leica designers use all their creativity and expertise to design wide aperture lenses with outstanding in-focus imagery. A more pronounced out-of-focus area helps to concentrate the visual attention to the correctly focused plane. See examples in the colour section. Colour slide 4a shows previous type of correction, 4c shows current type of correction. Slides Girl a and Girl b, show real pictures. Both at aperture 1:2 and identical situations. Note the smoother background of the older lens. Generally the older Leica lenses exhibit out-of-focus blurs that are quite soft and retain the outlines of object shapes. The shift from in-focus to out-of-focus is gradual and smooth. Current lenses have a more abrupt transition and the out-of-focus blurs have a different character, notably a cleaner definition of the defocus rings, which breaks up the structure of the outlines.

5 5 Chapter 5: image evaluation

5.1 Introduction

The reader should be aware, after reading chapter 1.1 and 1.2, that a photographic lens rarely delivers a perfect image of the object. There is always a certain magnitude of aberrations left in the optical system, that will degrade the quality of the reproduction. In the end there is only one valid criterion for the acceptance of the performance level of a lens, and that is user satisfaction. If a user is happy with the images (s)he sees, the lens is accepted and its performance is judged as sufficient. This acceptance is purely based on personal considerations and so purely subjective. From the individual viewpoint, this does not pose a problem. The personal judgment is most often also influenced by the subject matter and the content of a picture. Again this is fine for any individual photographer. The acceptance of a certain performance level by personalized criteria, however, is hardly transferable to another person. If we want to make comparisons between lenses on more objective terms, we should disregard the content if the picture and look solely at the image structure as a technical issue of image recording. The optical designer too needs quantifiable criteria for image quality, as it is unknown who will buy the lens, in what circumstances it will be used and what the level of individual acceptance will be. The optical designer will ask this question: "In what way will the image quality be degraded if a given amount of aberrations is present in the optical system?" And the second question would be: "How can we interpret the results of our optical computations?". There is not yet any direct link between the numerical results of a computation and the subjective interpretation of a picture by an observer. A number of criteria for image quality have been proposed during the long history of the photographic lens. The oldest one and still popular today is the resolving power, which defines in effect the smallest detail that can be detected or discriminated in an image. It is a very simple measure to use and interpret, which accounts for its popularity. Its elegant simplicity is deceptive, however, and it is a most dangerous and defective measure. It is specified in lines per millimetre and a lens that resolves 60 lines p/mm is considered 'better' than a lens that resolves 55 lp/mm. In all optical design programs and all books about optics, the Modulation Transfer Function is designated as the best single merit function for the assessment of image quality. And its use is increasingly adopted by manufacturers and magazines as a measure of optical performance. It measures the loss of contrast that occurs when the lens reproduces an object. If the test target is a chart with a black and white space, we say that the contrast is 100%, as the black part does not reflect any light and the white part will reflect 100% of the light falling on its surface. If the same pattern is imaged by the lens on a transparent screen, we can measure the contrast again and we would note that the white part now has received most of the light and the black part some light). The contrast has dropped or changed and in modern parlance we call this change a 'modulation'. The value might be 0.8 and this tells you that 80% of the original contrast of the object has been transferred to the image. Such a figure is intuitively unappealing as it does not relate to any photographic experience in the way the resolution figure does. I will explain the background of both measures, indicate the value and help you understand and interpret the data. Off record I will mention here that the MTF data are widely accepted in the optical industry as a representative measure of optical performance, but is a derived or secondary measure. The true nature of an optical system as far as the aberration content goes, is being evaluated with the ray intercept curves, the Strehl ratio, the point spread d function and the optical path differences.

5.2 Resolution

5.2.1 Resolving power.

On first sight it makes sense to look at the finest possible detail that a lens can reproduce, as a measure of optical performance. We certainly want to capture every aspect of the object in front of our lens. A well-known example is the proverbial portrait of a girl, where we would want to record every single hair of the eyelashes. The image structure of an eyelash is representative of the idea of fine detail and looks like the test pattern we can find on the resolution test charts. There are many versions of this chart, and all are essentially the same. A pattern of alternating and equally spaced black and white stripes (bars or lines) of some length and width are grouped together in blocks of three or five bars. Every block has smaller dimensions than the previous one, representing a spatial pattern of higher frequency. Five bars with a width of 1mm occupy a space of 5mm, and five bars with a width of 0.2 mm each occupy less space and are said to have a higher frequency per millimetre. In the first case the frequency would be 1 line per millimetre and in the second case 5 lines per millimetre. See illustration. If we would wish to do a resolution test for a 50mm standard lens, we have to set up a camera in front of such a test chart at a certain distance, because we must know the 'magnification' of the lens in order to count the number of bars that are recorded on film. Let us assume that we use a 'magnification' factor of 50, that is we record on film the chart scaled down (reduced) with a factor of 50. The larger pattern would now be quite small on the negative, in fact 1/50 line per mm (or 50 lines per mm)and the smaller pattern would now be 250 lines per mm. These structures on the negative are too small to be seen with the unaided eye and we use a projection or an enlargement or a microscope to look at the patterns. Ideally we should enlarge the negative 50 times to reproduce the original pattern. For the sake of argument, let us assume that the larger pattern is clearly identifiable and every bar can be individually recognized, but the smaller pattern is completely blurred and we do not see 5 individual bars, but an undifferentiated patch of grey colour. With this procedure we can say that this lens under these conditions resolves 50 lines per mm.

5.2.2 Resolution described.

Resolving power values specify the number of lines per millimetre that can be separated visually. The ANSI/ISO standard defines resolving power as "the ability of a photographic material to maintain in its developed image the separate identity of parallel bars when their relative displacement is small". Note that resolving power/resolution is a visual, not a measurable standard. Basically resolution is a very simple idea. It is based on the visual acuity of a human observer and here trouble starts. The ability of the eye to distinguish small objects that are very close together changes substantially depending on the shape of the object, on the illuminance level of the location where the observer resides, on the fatigue of the observer and many more. There is also an element of 'judgment' and psychology involved. Observer A may judge two objects to be detectable as separate, while observer B may judge the two objects too close together to be separate.

Figure 1 shows such a pattern of parallel bars and these patterns are used by all resolution charts in one version or another. Resolution then answers only this question. What is the minimum distance between two very small objects for them to be detected as separate entities. There is no rule that asks the observer to distinguish between 'just detectable' and 'clearly detectable'. In fact this difference is quite important.

Figure 77: 5.2.1.A bar chart

5.2.3 The shortcomings of the resolution test .

The process of photographing the bar test chart at a certain distance, developing the film and finding the smallest group of lines that can be distinguished is a relative straightforward operation. But here the trouble starts. First of all it is difficult to translate the raw numbers into meaningful and comparable figures. The test target elements consist of the groups of six bars in several sizes. The object spatial frequency is related to the image spatial frequency by the reduction ratio. Assume that the real test chart has six bars (three white and three black) over a distance of 10mm and you have chosen a reduction ratio of 100 times. Then the image resolution is 60 lines per mm. The groups of lines are always arranged in a vertical and horizontal direction and with almost all lenses you will note that the resolution figure for the horizontal and vertical lines is not the same. After exposing and developing the film optimally (a 1/3 stop will ruin the results) you need to study the negatives under again ideal photographic conditions. But you can never be sure that you focused absolutely spot on and so you have to repeat this series of pictures with focus settings that are changed by very small focus increments and decrements. Then you have to select the negatives with the best values. As your eye is not to be trusted here (due to physiological and psychological factors), the results are subjective and should be accepted with at least 10% margin. Even if you did everything right, the resulting figure of say 74 lines per mm will have to be interpreted as having a margin from 67 to 81 lines. Selecting which block has just discernable bars is a highly subjective act and two observers will differ here again by at least 10%. Even if the resolution figures would be related in meaningful way to the real optical performance of a lens, these four groups of margins, set up errors, focusing errors, interpretation errors, and individual judgments, will produce figures that have a latitude of 30% and more. A simple check in the magazines will tell you that the Summicron lens (7 element) as been credited with anything from 60 to 300 lines per mm as a resolution figure. Even when the test is done competently, the results are fully inconclusive if not wrong. A lens with an established resolving power of 100 lp/mm does not necessarily have higher image quality than a lens with under the same procedure has a resolving power of 80lmm. Resolution figures do not correlate well, if at all with real optical performance. This is a serious defect of the resolution test for photographic lenses. In astronomy and microscopy the concept of the resolution limit has more validity as here the ability to separate two closely spaced objects (like double stars in astronomy) is a more important criterion. It is best to relegate the resolution test to find the maximum number of lines a lens can resolve, to the dustbin of history and I have to strongly advice you, not to look at resolution figures as a serious tool for the evaluation of optical performance and not to try to do your own resolution tests, as there are too many unchecked variables involved.

5.3 5.3 Spatial frequency and contrast

5.3.1 Spatial frequency.

While the concept of the maximum resolution is of no relevance for photographic image quality, the basic idea of spatial frequency is not. The alternating pattern of black and white bars of equal width is used as a target to be imaged (recorded) by the lens to be studied. Sets of patterns with different spacings in a continuous range from 1 to 100 lp/mm are used as a target. The number of lines per mm are designated as frequency of N lines per mm, where N is any number between 1 and 100. Lower frequencies have the lower numbers. and higher frequencies the higher numbers. Lines/mm and line pairs/mm do not refer to the same measurements. This is a very confusing, but relatively simple topic. A line is a black stripe of a certain width and length on a white background. Or a white stripe on a black background. We need the black-white contrast, as we are unable to detect a white line on a white paper. Assume we draw 10 black stripes on a white paper over a distance of 10cm. To be able to differentiate between any black line, there must be a small white space between two lines. We see a pattern of 10 alternating black and white stripes. Such a repeating pattern of black-white lines is called spatial frequency and has a clear analogy with the temporal frequency: the pattern in time of sounds and silence, as with the old mechanical ticking clock. The metronome, used in music training, is a device that can be set to different temporal frequencies of sounds, to help you stay tuned. These 10 black lines can be designated as having a spatial frequency of 10 lines over a distance of 10cm, or 1 line/cm. Over the distance of 10cm, we can distinguish 20 different lines, 10 black and 10 white. Engineers are down to earth people and they refer to this pattern as having 10 lines/mm, as they know that to see white, you need black. Normal people, like photographers, find this confusing and would say that there are 20 lines. To settle the matter, we define a black/white pair as a line pair and so our pattern can be described as having 10 lp/mm or 20 lines of alternating white and black colour or 10 l/mm (if we are engineers, assuming that a line is always a line pair). When dealing with photographic emulsions or optical aberration theory, a black-white pair indicates a wave pattern, a wave being a phenomenon that has a top and a trough. (Black equals the top of the wave and white the trough or the other way around). Such a top-trough combination is called a cycle and one line pair is identical to one cycle. Datasheets of film emulsions show MTF graphs as measured in cycles/mm.

Figure 78: 5.3.1 A lens MTF

Figure 79: 5.3.1.B film MTF

When reading resolution data, we should investigate what is referred to: single lines (black or white) or line pairs and who is talking. Leica MTF graphs and resolution data are always in line pairs and that is the convention I will follow in this book.

5.3.2 Contrast.

In chapter 1, I have drawn attention to the blur circle. To summaries, an object point is represented in the image as a disc of light with a core of high intensity (where most of the light will be concentrated) and a rim of diffuse light of diminishing intensity. If we represent this structure in a three dimensional diagram, the area of the disc on the x- and y- axis and the light intensity on the z-axis, we see an illumination mountain (Lichtberg in German). If we defocus, the area of the disc is enlarged and the intensity of the light in the core is reduced. That is logical, because the same amount of light energy from the object point is now spread over a larger area. This structure is called the point spread function and is defined as the light distribution in the image of a point. Literally the way (function) the light is spread out over the point.

Figure 80: 5.3.2 Illumination mountain

Contrast is defined as the difference in light intensity (luminance)between two areas. If we have a black and a white area, the contrast is 100%, as all light is reflected from the white area and none of the black. A bright star against the deep black sky also has a 100% difference in contrast. If we take a Kodak grey card which has a reflectance value of 18% and hold it against a white background, the contrast has dropped significantly. The border between both areas is still quite visible. Would we juxtapose a grey card with 18% and one of 20% reflectance, we have great difficulty in detecting the border line.

Figure 81: 5.3.2 A ideal pattern high contrast

Figure 82: 5.3.2.B pattern as recorded by real lens

In an ideal lens/film system all light energy reflected from any white stripe (however small) would be concentrated on film in a corresponding white stripe. No light energy would reach the black stripe next to it. Again contrast would be 100% whatever the spatial frequency. But lens aberrations will spread out the light energy a bit and light scattering in the film emulsion will do the rest. So part of the light energy (aimed at the white stripe) will reach the black one, and is therefore lost for the white part. This scattering of energy will affect the high spatial frequencies to a higher degree as the distances between the white/black patterns become progressively smaller and the scattering relatively wider. In a real lens then we should find the maximum contrast or overall contrast at the low frequencies (1 or 5 lp/mm). With higher and higher frequencies the contrast will inevitably drop. This contrast value at the finer spaced patterns we call the micro contrast, which is shorthand for contrast value at the higher frequencies. By now the reader should notice that contrast and resolution are more tightly coupled than has been suggested in the past.

Contrast and spatial frequency are related to each other through the point spread function. Note that the following example uses real optical data. An excellent lens will record an object point as a small circle of light with a diameter of 20 micron or micrometer. That is equivalent to 0.02 mm which is really small. Due to residual aberrations this circle is not of uniform intensity, but has the distribution as described above as a defocused blur circle. Specifically, the central core has a diameter of 8 micron and the surrounding diffused rim has a total diameter of 20 micron. We now take a spatial frequency of 100 lp/mm, that would amount to 200 alternating black and white bars on the negative. The dimension of every bar would be 0.005mm or 5 micron. But the smallest spot our lens can record is 20 micron! A white bar with a width of 5 micron cannot be represented with a circle of 20 micron. It is clear that there are several white bars that will all fall within the space of one circle of light that ideally represents only one single white bar. The resulting image will be blurred and we are unable to detect the individual white bars. We could say the contrast is zero. If we want to see the individual bars there should be a one-to-one relation between a bar and a image circle. When we use a spatial frequency pattern of 25 lp/mm, that is 50 lines in a millimetre, every white line now has a width of 0.02mm, that is exactly the diameter of the blur circle. All light reflected from a white bar is now recorded in one circle and between two white bars there is deep dark one, where there has been no light on the film. We see the alternating pattern quite clearly. Now for the tricky story. If we use a spatial frequency of 75 lp/mm, that is 150 lines in a millimetre, every white bar has a width of 0.0067mm or rounded 7 micron. The central core of the light circle will occupy the location of the corresponding white bar, but the rest of the blur circle will illuminate the black bars. Now we have a pattern of white and grey bars, with a reduced contrast and it now much more difficult to see the pattern as clear as before.

Let us look at figures above. This is again an ideal pattern, showing from bottom to top spatial frequencies from 10 to 100lp/mm. Note the fuzzy edges at the 10lp/mm. As a matter of interest, look at the 0 lp/mm bar (very bottom: a grey line, because there is zero contrast.) Note that the 100lp/mm are recorded with clarity because there is good contrast between the black and white lines. In print the 100lp/mm might be unresolved, Then look at the 80 or 70 lp/mm. The argument holds at every frequency. If we record this pattern by a Leica lens, we get figure xx. (Note: these pictures are computer simulations that are as realistic as possible. They show more clearly what happens). We now note that the lower contrast makes it very difficult to detect the spatial structures of the 70 lp/mm band. Even the 50lp/mm has a contrast loss. Most importantly and this is of utmost relevance, we see in figure 5.3.2B that a reduction in contrast does not lead to a higher resolution. If contrast drops so does resolution. These two figures prove that the old maxim that low contrast combines with high resolution and low resolution presupposes high contrast ,is simply not true. If you want a high resolution that is detectable by the eye, you get it through a high contrast and a good acutance. There is no way that you will see a high resolving power without good contrast in the photographic world. In astronomy where astronomers are used to detect the faintest signals, a signal to noise ratio is used, which is the same as a spatial frequency to contrast ratio.

The size of the blur disc and the distribution of light within the area then determines the contrast of the higher spatial frequencies and their visibility. The same argument works for the lower spatial frequencies too. When the lens records a white line with substantial width against a black background, the definition of the border line is still made with these small discs of light. If the core coincides exactly with the borderline, the rim of diffused light will spill over in the dark side and generate a small edge of lower contrast. We do not see a sharply delineated edge, but a slightly blurred edge. It is evident from this mental and visual exercise that spatial frequency and contrast are related to each other by the dimension of the blur circle. And we argued and demonstrated that the higher spatial frequencies will be of lower contrast, depending on the size of the blur circle or as it is called the geometrical spot size.

5.4 The Modulation Transfer Function.

The reduction of contrast from object to image is called the modulation of contrast and the relationship between modulation and spatial frequency is graphically represented as the MTF graph, where the vertical axis depicts the level of contrast transfer, the horizontal axis the location of the image point in the film area and the lines of the graph represent the spatial frequency.

Figure : 5.4.A-MTF at different apertures

The value of the MTF graph, compared to the procedure for finding the maximum resolution of a lens, is its firm foundation in optical theory. The effect of aberrations is to increase the blur circle, change the shape of the circle to an irregular patch and change the light distribution over the patch of light. These effects are comparable to the defocus blur, described above. The effect of the aberration of field curvature or astigmatism is like a defocus, as the image plane is curved and not flat, and if you locate the (flat) image plane at a certain position along the optical axis, the point's being imaged at the curved surface, automatically appear as out-of-focus. The bigger size of the blur circle and its uneven light distribution reduce the contrast. There is then a direct relationship between the optical errors in a lens and the size and shape of the blur circle, or which is almost the same, its level of contrast. The logic is simple: a lens that is highly corrected will reproduce object points as very small circles with a focused (concentrated) light energy and thus a high contrast. If we can look at the performance of the lens over the whole image area from centre to corner (or axis and several field positions) for several spatial frequencies, we can infer from these values the state of the aberration correction and its related image quality. We need to study this performance not only for one aperture but for all apertures. Any MTF diagram gives the information for one aperture only. Quite often the validity of the MTF graph as an indication for optical performance is questioned. It is stated that real life objects are solid three dimensional structures and the test object for an MTF graph is a two dimensional flat pattern of alternating black and white bars. Such an argument does not take into account that the image quality is based on the size of the blur size and its encircled energy. The representation of a three dimensional object is made possible through the concept of depth of field and this effect is related to the defocus blur, which is measured with the MTG graphs too. A solid object is reproduced in the flat image plane by a successive series of slices through the object, of which one slice is the focused one and all the others are more or less defocused. The image points in all slices are correctly defined and measured by the MTF graph as a series of blur sizes of growing size.

5.4.1 The generation of MTF graphs.

Two methods are being used to get these MTF figures. One method does measure the values by using equipment for the determination of the contrast transfer. An illuminated target, almost always a very narrow slit of 0.02mm is projected through the lens on a detector (a sensitive surface, nowadays a CCD chip) , and the brightness difference at the edges of the slit (illuminated and non-illuminated part) is recorded. This can be done because the scanning slit is much smaller than the target slit and we are able to record the brightness variation along the edge. Ideally we would see a square shape as the transition from dark to white is abrupt. Due to aberrations we see a slightly rounded off top with a gentle slope. (see Figure:).

Figure 83: 5.4.1.A two dimensional slice

Figure 84: 5.4.1.B broader base

These measured values are transformed by a mathematical technique of differentiation into the point spread function (the illumination mountain) and from there into the MTF graphs. The second method calculates the values from the optical data, describing the lens. The computer program calculates the spot diagram (see chapter 1.1) and the intensity distribution of the light over the blur disc. From these data the point spread function is derived. A line can be mathematically defined as an infinite number of points and from one spot we can generate a line spread function, which is a summation of an infinite number of PSF’s. From the line spread function we can, through integration and Fourier Transforms, generate the MTF again. Theoretically both methods should deliver the same results. In reality they do not. The measured values may differ from the calculated values, because of production tolerances during manufacture. But more importantly, the calibration of the measuring equipment may be different. The results depend on the accuracy of the measurements, the quality of the white light used, the number of wavelengths used and their weighting, the defined focus location and several more variables. Therefore it is very dangerous to compare results obtained by different tests, as all of these variables may be different and so results cannot be compared. 80% in one graph is not 80% in another one. With the calculated graphs, we have the same variability. Wavelengths used, weighting of wavelengths and other parameters generate different results. Again: a meaningful comparison is possible if you know that all parameters are identical. As these are not published, you should restrict yourself to a comparison between data from the same manufacturer and do not compare results between manufacturers. The published graphs by Leica are computer based graphs. As the production tolerances are very small, we can expect the results between the calculated and measured values to be quite close. Leica computes the values and then uses these values as an acceptance criterion when a lens is measured with MTF equipment.

5.4.2 The interpretation of MTF graphs

The interpretation of MTF diagrams is not easy. The graphs represent the spatial frequency of 5, 10, 20 and 40 line pairs/mm over the whole image area from centre (0) to the edge (21.6mm). The diagonal of the 35mm negative is 43.2mm and as a lens is symmetrical around the axis, we need only to look at one point on a line from centre to edge. Every spatial frequency is represented by two lines, a tangential one and a sagittal one to show astigmatism and field curvature. If the curves for both orientations (horizontal bars and vertical bar are wide apart, we may assume that the overall contrast is low and the fine details quite blurred. Generally the line for the 5lp/mm represents the contrast of the outlines of the larger object shapes and the lines for the 40lp/mm the ability to record very fine detail crisply, that is with clean (high contrast) edges. For general photography the lines of the 5 and 10 lp/mm are the most important. The higher the curves, the straighter the curves and the less difference between the tangential and sagittal lines the better the overall contrast and image quality. As example look at the figures here for an old Summarex 85/90mm lens a new Summicron 90mm lens. These differences are very visible in practical photography. One should be aware when comparing these graphs that a difference in contrast values of even 1 percent point is significant: a contrast transfer of 90% at 10 lp/mm is a visible degradation when compared to a contrast transfer of 92% at 10 lp/mm. When one looks at the higher frequencies, the margins are larger: 50% at 40lp/mm will deliver the same results as a lens with 55%, but not as good as a lens with 60%. Use the MTF graphs with caution. They are the best representation of image quality we currently have, but some optical and mathematical background is useful to prevent the observer to make the wrong inferences.

5.4.3 Trade off between contrast and resolution?

The relation between contrast and resolution is basically inverse. The real MTF graph generated for the Apo-Telyt-M 1:3.4/135mm for the on-axis position produces a downward slope, giving 100% contrast at 0 lp/mm less than 10% contrast at 400 lp/mm. Both of these extremes are only limiting values. More important is the midrange between 20 and 100 lp/mm. Leica lenses are optimised for maximum contrast at 20 lp/mm and this will automatically give the best results for the higher spatial frequencies. There is of course some trade-odd between contrast and resolution, but it is limited to a change of the distance of the flange focal length and the effective focal length. You cannot compute a lens that has high overall contrast and at the same time a low resolution. You will find in the literature many references to a dramatic trade-off between contrast and resolution, as with the Noctilux, a lens that is supposed to have been optimized for high contrast at wider apertures at the expense of a lower value for resolution. In fact the Noctilux 1:1/50mm has low medium overall contrast and low values for the 40 lp/mm too, indicating that contrast and resolution are related. Sometimes you will read or hear that Leica has optimized a lens for maximum contrast or maximum resolution. If one assumes a dichotomy, this is not the case. The Leica designers will optimise for a small size of the blur circle with as much light energy concentrated in the core as possible, given the state of the aberrations. And they will match the fixed location of the film plane to the selected position of the focal plane to maximize contrast. The story goes that

Leica has made small changes in the life of the several Summicron 2/50 versions, specifically the Dual Range version where they are supposed to have slightly reduced the resolution to make possible a slight increase in contrast. Such stories are part of the many myths around the Leica products. There is no evidence at all to substantiate this statement and it is most certainly false. The idea behind this story is the quest for maximum resolution, which is irrelevant here and never was nor is part of the design criteria for the Leica lenses.

5.4.4 Are 40lp/mm enough

We have seen that high contrast and high resolution work together to get good clarity of very fine details. A perfectly sharp picture would have a contrast transfer of 100% at all spatial frequencies within visual range of the eye. In Figure 5 we can note that about 70 to 80 lp/mm are still resolved with good contrast and should be visible in a 20 to 30 inch enlargement. Every optical company produces MTF graphs that relate spatial frequency (resolution) to contrast. The highest spatial frequency that will be graphed is 40 lp/mm. This is kind of an industry norm. This figure is partly based on the research by Zeiss that showed that this figure of 40 lp/mm represented a limiting case for image quality. Many experiments by Zeiss, but also other optical companies and academic research institutes have clearly indicated that the higher spatial frequencies have no influence at all on the perceived image quality. The best image quality is assured when the contrast in the region from 5 to 40 lp/mm is as high as possible. Resolution figures from film companies indicate much higher resolution figures. A 100 to 150 lp/mm are quoted as maximum resolution (or to stay in the parlance of the emulsion characteristics: 100 to 150 cycles/mm (where a cycle = one linepair). There is a danger in referring to maximum figures without taking into account what they really mean. One of the films best known for best sharpness and resolution is Fuji Velvia. The official company specification sheets show a resolving power of 160 l/mm for a high contrast subject and 80 l/mm for a low contrast subject. Two remarks here. The high contrast subject is 1:1000, which is extremely high in practice and hardly ever encountered. So let us settle for an average between the two figures. That is 100 or 120 l/mm. But 100 or 120 lines/mm is identical to 50 or 60 lp/mm, quite close to the relevant spatial frequency figure for lenses. Looking at the MTF graph of the Velvia we see that the maximum spatial frequency in the graph is 60 cycles/mm (linepairs/mm) with a contrast transfer of 30%. All Fuji and Kodak films, even the most recent ones I checked on this and they all are close to this figure, So the optical industry and the emulsion industry are reasonable close in the maximum or limiting values for their products. There is one exception. Some black and white films (Kodak Technical Pan, Agfa APX25 and Ilford Delta100) can record spatial frequencies above 100lp/mm. If the utmost care and technique is lavished on these films and the photographic equipment (camera, tripod etc.) is up to the task we can record these finest structures. Can Leica lenses cope with this as they seem to be limited to 40lp/mm. Here again we should not be lured into a simplistic conclusion. Figures 4 and 5 show clearly that a lens covers the whole bandwidth from 1 to 100 lp/mm (and even more). The 40lp/mm as we have seen, are a very good measure for image quality if the contrast is high. But no lens will stop abruptly after the 40 lp/mm line. Lenses just go on recording finer and finer levels of details (higher and higher spatial frequencies) till the limit of film, lens or the lens/film-combination. Many current Leica lenses, among them the Apo-Elmarit-

Macro 2,8/100, the Apo-Summicron-M 2/90 ASPH, the Apo-Telyt 3.4/135 and the Summicron-R 2/180 and 2,8/180, can resolve 100lp/mm and more with high contrast. So the 40lp/mm norm does not indicate that a lens cannot resolve more than 40 lp/mm. It indicates that if a lens can handle a spatial frequency of 40 lp/mm with high contrast it is a lens very well corrected and certainly capable of recording higher spatial frequencies.

Measurements of the resolving power of the eye (and for once all scientists agree) give a maximum value of 10 lp/mm at a viewing distance of 25cm. (Values for a young child). When you grow older, the minimum viewing distance is larger and by definition the resolving power of the eye lower. Or the maximum spatial frequency we can detect is 10lp/mm. This maximum value is of theoretical nature as degrading circumstances always exist in practical situations. (A 100% contrast for instance will never be attained). So we need a lower value to be realistic. Again there is a remarkable consensus that a spatial frequency of 5 to 6lp/mm is realistic, but still in quite ideal circumstances. Now we are in for some number juggling. The unaided eye at a distance of 25cm can resolve 6 lp/mm, that is fine detail in textures. So every line has a width of 0.08mm. Where you read line, you may substitute point, so points smaller than 0.08mm in the print will not be detected by the eye. Think about this for a while. A 20x30 inch print on a wall is unlikely to be viewed at so close a distance as 25cm. Assume 75cm, which is reasonable if you would have a vies of the full picture area. But at this distance resolving power is reduced by 1/3, so we are left with 2lp/mm on the print or a point 0.25mm in diameter. Now a 20x30 inch enlargement for 35mm is even for a Leica quite demanding. That is an enlargement factor of 20 times. Accepting the 2lp/mm on the print at normal viewing distance as reasonable, we end up with a resolution figure of 2 times 20 (enlargement factor) is 40 lp/mm. So the industry norm is a practical one, good enough for very big enlargements for exhibition prints. Now let us be very demanding. We want to record the finest textural details possible at a 20 times enlargement when looking at the print from a close distance, the 25cm. Then we need 6lp/mm times 20 (enlargement again) and we end up with 120 lp/mm on the negative, far above the 40lp/mentioned above. We will see that for this requirement we need Technical Pan or equivalent films, and the very best of Leica lenses. But it can be done. Most films however break down at 50lp/mm, so we could not even record this level of detail on film, even if the lenses would allow us to do it. If we look at slides, we are in a very different position. Assume we look at slides from a distance of 5 meters, which again is reasonable. At this distance, the eye can detect 0.3 lp/mm. The projection screen is 3 meters wide, which is quite a screen, which gives an enlargement factor of 85. Again 85 times 0.3 lp/mm gives us a maximum resolution of about 30 lp/mm, below the 40lp/mm norm.

5.4.5 The limitations of the MTF analysis.

While MTF diagrams are very important, they do not tell us all about a lens. Flare is not accounted for, as is colour transmission, close up performance (MTF data are measured or calculated for the infinity position), distortion and vignetting. The MTF graphs do give you a clear indication of the performance to be expected from a lens, but the personal situation and the material used are of decisive influence. If you take pictures with high speed film at shutter speeds of 1/8 of a second, you are less interested in the representation of the 40 lp/mm. But more in the flare characteristics. If you aspire high precision photography, the 20 and 40 lp/mm may be of prime importance. If you take pictures with a lens with very good MTF values and your results are disappointing, you should analyze your technique and try to find the weak spots. The MTF has one advantage: it is objective and value neutral. It is the user who has to find his own personal limits of performance. You should also be aware of the fact that lenses may be only compared with the same focal lengths. A 28mm lens may have a contrast value of 60% at 20 lp/mm, compared to 50% with a 90mm lens. As the reduction of the object is higher with a 28mm lens, the level of details that can be reproduced is also lower. To get a realistic comparison one should photograph an object at a distance of 2.8 meter for the 28mm and of 9meter with the 90mm. Than we have the same reproduction scale. As the MTF-data are all based on infinity, the observer should be aware of this.

6 6 Chapter 4: LEICA lens reports

6.1 State of the art designs.

Leica lenses have been produced since 1925 and somewhere in the year 2000 the 4.000.000 mark will be reached. The durability of these lenses is so high that many of them are still available on the second hand market. Most of the lens types (aperture/focal length versions) can be bought new too. The Leica user then has a bewildering choice or "embarrass de riche" from more than 150 different types and versions. The Leica afficionado will identify and discuss with great enthusiasm the differences in character that every lens design is presumed to possess. In a sense that is true. Every lens has its specific aberration correction, as this is derived from the overall characteristics, aperture, focal length and physical dimensions). In the individual reports I will describe and explain the character of the lens, mostly based on the measurable properties. It is possible, when closely looking at the performance profile or fingerprint, to identify groups of lenses, which share many characteristics. It is well known that any lens, when stopped down to 1:5.6 or 1:8.0 will deliver image quality that is commendably good. Of course, when the negative is enlarged more than 8 times and/or the picture is made under heavy duty circumstances (strong highlights, high contrast and oblique light rays striking the lens) big differences can be detected without much effort. For many a Leica user, there is a fun factor involved when using older lenses. And it gives indeed much satisfaction, to use an older Elmar or Summar for photographing those typical Parisian scenes, and getting fine images, that are a pleasure to look at. Lens performance and manufacture has improved over the years and so a Summar is not as 'good' (optically and mechanically) as the current Summicron. If you look critically at comparison pictures, the difference is evident. How you appreciate or value this difference, is an entirely personal matter. The chapter about image evaluation (Page xx) will help you to develop your own approach to this topic. Sometimes, Leica photographers contend that the improvements are not visible in practical picture taking and can only be detected in artificial situations, like photographing the proverbial paper page on the wall. Such an approach lacks substance and knowledge of the real optical progress made over the years. It is a fact of life, however that the capabilities of the photographer are becoming the limiting factor in exploiting the quality of Leica lenses. Older Leica lenses performed very well at the frequency of 10 lp/mm and if your demands for image detail is modest, you may not see a great advantage in the new lenses which perform outstandingly well at the same frequency and excellently at a frequency of 20 to 40 lp/mm. Let us say that the ideal lens has a performance level of 100%. Then older Leica lenses have a level of 70% and the newest ones reach on average 90%. If you use 40% of its maximum level of quality, the classical lenses will give you 28% and the current ones 36%, not as much difference as when you would exploit both generations to the full extent. This analogy should not be taken too far, but it illustrates the point. To appreciate the high quality of current lenses, you need to invest more energy and time in mastering it. It is worth the effort, and I am sure you will enjoy the photography with Leica lenses more when you look at the progress that is possible. A perennial topic is the comparative evaluation of lenses from different manufacturers. I would prefer to discuss this issue in a balanced way. There are two polarised views, both of which I think are unproductive and not true. One states that Leica lenses can never be challenged by other marques and the other assumes that there no differences of any importance. In the chapters on optical design I showed how a designer or a team analyses the task, defines the goals and finds a solution. I also exposed to some length that aberrations and their control are universally discussed and studied. In fact many design departments all over the world use the same design program (Code V). It is rational to assume that, given the same set of requirements, the solutions will be found in the same direction. And in the past, it would not have been different, even if the methods and tools were different. As lenses are manufactured for a long period, they reflect the state of the art at the beginning of the design, some exceptional designs excepted. It would be difficult to improve significantly on the Noctilux lens, even today, as long one has to stay within the parameters set by that lens. But generally designs do improve. This progression is not orderly, but happens in bursts and jumps. Sometimes a design is a quantum leap ahead of the predecessor and competitor, sometimes the differences are more subtle or the balance of characteristics is different. At every point in time, you could make a cross-section of designs and note that a particular lens is better or not as good as the comparative lens. And this applies to the lens lines of all leading marques. I noted that a lens can be evaluated at 30 or more parameters. It is a bit naive to assume that all parameters of all lenses of one manufacturer at all times are above all the others. The question if Leica is better or as good as other leading marques, should be rephrased to what specific lens at what period are you referring to. Today as in the past, Leica has produced lenses whose performance profile is comparable to others on the market and it would be most unbelievable if that were not the case. Leica has always stressed the importance of the image quality at the wider apertures and tuned the design and manufacture of lenses (aberration control, mechanical tolerances) to this goal. Their definition of optical quality has progressed through the years and so have the designs and the lenses. Lenses like the Apo-Summicron-M 1:2/90 ASPH, the Elmarit-M 1:2.8/24mm, the Apo-Elmarit-R 1:2.8/180mm and Apo-Telyt 1:4/280mm, to cite only a few examples, redefine the notion of image quality at wider apertures in 35mm photography. The optical performance in itself is not the only aspect to look at. Leica can design a lens with 9 lens elements, with about equal performance to a lens from another manufacturer, who needs 16 lens elements to accomplish the same. The Leica lens will have more consistent performance at wider apertures, sample for sample, as tolerances are smaller and the chances for error are less. We should enjoy the quality of Leica lenses, evaluate the performance with an appreciative, yet critical eye and at the same time admire the accomplishments of the optical industry as a whole.

6.2 The question of focal length

The choice of the specific focal length of a lens is sometimes a mystery. Leitz used for its medium telephoto lens the 90mm, but only once the 85mm. In photography we are used to series of numbers like shutter speeds and apertures, which generally obey a factor of 2 for its progression. The aperture series of 1.0; 1.4; 2.0; 2.8; 4.0; 5.6

is well known and we see clearly that the numbers itself double in two steps. The increment here is the square root of 2, which is ±1.4 or an addition of 40% per step. These steps are quite large and so we can imagine a series of numbers with smaller increments. For photographic purposes an increment of 26% or even 12% will suffice, but for increments in focal length a step of 6% is customary. With such an increment (for the mathematically inclined: an increment of 1.059 or log 0.025) we can generate a series which covers all possible focal lengths.

focal length

1000100950959009085085800807507
570070710716706764064600605605653053470 47450454204240040
3803835035340343203230030280282702725025240242202221021200
2019019180181701716016150151401413513,512512,5120 121101110510,510010

If we look at this table carefully, we will find any focal length that has been chosen by Leica. It is clear that the choice of a focal length is governed by a table like this. It is also interesting to note that the value of 50 is not part of the series, but 53 is. And the true focal length of many 'standard' lenses of 50mm (indicated) is 52mm! Why a designer would choose 90mm or 85mm is not clear. Presumably the calculations dictate a certain physical volume or a certain front lens diameter, which is convenient or necessary. A second consideration when discussing lenses is the angle of view or angular coverage. I would like to draw attention to the fact that the negative format is 24x36mm, which gives three different angles of view. As any lens produces an image circle, in which the rectangular format of the negative has to be fitted, we have a diagonal, a horizontal and a vertical angle of view. For a 50mm lens the diagonal angle of view is 45, but the horizontal angle is 41 and the vertical only 28. For the 35mm lens the numbers are, 64, 56 and 37. It is evident that the horizontal angle of view is more important than the diagonal, so the next table gives these figures for the Leica lenses. When taking photographs, we habitually look at the horizontal line to see what part of the scene is covered by the lens. This intuitive gaze, corresponds to the horizontal angle, which is invariably smaller than the quoted diagonal and can explain the disappointment sometimes noted with the covering power of a wide-angle lens in practical situations.

Focal length Horizontal angle Diagonal angle 15 97 110 19 87 96 21 79 92 24 74 84 28 63 76 35 52 64 40 48 57 50 39 45 75 26 32 80 25 30 90 22 27 100 20 25 105 19 23 125 16 20 135 15 18 180 11 14 200 10 12 210 9.5 12 250 8.5 9 280 7 8.5

The horizontal angle of view of 90°, is particularly interesting as you can cover a rectangular courtyard or room with such an angle in one picture. The focal length needed to cover this angle is approx. 18mm and if we would build a series from here in equal steps, we would get 18mm, 25mm, 35mm, 50mm, 70mm, 100mm, 140mm, 200mm, 280mm, 400mm, 560mm, 800mm. The lenses for the M-body are quite close, with the exception of the 21mm and the 90mm: we have 24, 50, 75, 135, and with Visoflex lenses: 200, 280, 400, 560 and 800!. The R-series is 19, 24, 50, 100, 180, etc: here the 80 and 90 are the odd ones. A second option would be to use a 10o increment, so starting with 90o the series would be: 80o, 70o, 60o, 50o, 40o, 30o, 20o, and the focal lengths would become: 18mm, 21mm ,25mm, 31mm ,39mm ,50mm, 67mm,102mm. If a 90o angle is the base angle, it is not surprising to imagine that half that figure (45o) has also some relevance. Now a full frame 35mm negative has a diagonal of 43mm, which covers an angle of 53o. We can calculate that a coverage of 45o needs a focal length that is 20% larger, or 43 + 9mm = 52mm! Here lies a partial explanation for the choice of .i.; for the 52mm focal length for the Elmax/Elmar.

6.3 50mm

The focal length of 50mm has been designated as the “standard” for the 35mm format. There are however, no hard or fast rules here. The statement is derived from the notion that the standard lens should have a focal length equal to the diagonal of the negative area. For a 24x36mm negative the diagonal is exactly 43.27mm. In reality most standard lenses of 50mm focal length are closer to 52mm. That is a difference of almost 10mm and too large to be inconsequential. A second, related explanation, has it that the angle of view of the standard lens (about 47 degrees) corresponds with a natural viewing angle of the human eye. That again is a myth and cannot be supported by research. The angle of view of the eye where good discrimination of details is maintained, is about 20 degrees. And the total angle is 140 degrees. The angle of 45 to 50 degrees has no special significance for the human eye. There is a psychological and a technical argument that can explain the preference for the 50mm length. If we look at a print with dimensions 15 x 20cm (diagonal 25cm) at the closest normal viewing distance (25cm) the eye is located at the so-called centre of perspective, corresponding to the optical centre of the taking lens. From that location of the eye , we look at the picture as if we were standing in the centre of the negative at the sharpness plane. At this distance the eye can capture the whole print area without eye movement, providing for easy viewing. Technically the focal length of 50mm is a very good compromise between high speed, small dimensions and excellent optical correction. In the world of the microscope lenses, where Barnack looked for a suitable lens, the focal lengths of 42mm to 60mm were available with good corrections. This might have inspired .i.; to search for a solution within this range. The 50mm focal length, combined with an aperture of 1:2 has been the workhorse of all Leica photographers since the early thirties. It is quite amazing to reflect on the enduring popularity of the 1:2/50mm lens, when one considers the big advances in emulsion sensitivity. When the Summar was introduced a film with a nominal speed of ISO 50 (Kodak Verichrome) , was the fastest that could be bought. In the mid-fifties the ISO400 speed barrier had been broken by the Kodak Tri-X, which was rated at 200ASA at first, but here a safety margin had been built-in. Since then this combo: the ISO400 film and a 1:2/50mm lens covers most demands and has recorded the most compelling images in photography. In the early fifties and sixties the ultimate object of desire for any 35mm photographer, who liked or needed to practise the art of the artless snapshot (HenriCartier-Bresson-style) was a standard lens with an aperture of 1,4. Any additional photon that could be captured on emulsion while shooting in ‘available darkness’ was most welcome.

The slender depth of field at that large aperture added quite often impact and drama to the image. The need for such a large aperture became imperative after the candid pictures of Erich Salomon of Ermanox-fame. The 35mm worker got what he demanded in the early fifties as coated 1,5/50 designs from several manufacturers, including Leitz became available. These lenses indeed did capture some of the additional photons. But the photons on their way through the many glass elements wandered around not fully controllable. Aberrations abounded and the image quality, to be polite, was just acceptable. The Leitz Summilux 1,4/50, introduced in 1959 for the M series camera was the first to offer a higher level of image quality. A redesign , offering very good quality, was introduced in 1961 and is still in production. The Leicaflex user had to wait till 1970 before she could capture scarce photons. A redesign in 1978 improved the quality. In the meantime the emulsion technology made some quantum leaps in speed/granularity relationship and the ubiquitous electronic flash lessened the need for high speed optics. Some even predicted the demise of this type of lens. More so as the 50mm fixed focus lens is nowadays often being replaced by a 'standard zoom' of 28/35mm to 70mm focal length.

The 50mm focal length has lost a bit of its status as the premium lens for 35mm photography. The 35mm focal length will cover a horizontal angle of 53o and as the format diagonal has also a full angle of 53o , there seems to be a natural match. Some would regard this 35mm medium wide angle lens as the best suited for Leica RF photography. In my personal view (no scientific arguments involved here), the 50mm lens is still one of the most versatile lenses to use. It is well suited to a wide range of subjects and situations, from environmental portraits, to documentary photography and landscapes. In fact hardly a subject exists that cannot benefit from being recorded by a 50mm lens.

6.3.1 3.5/50,Anastigmat/Elmax,1925 ,

The first lens, designed by Max Berek for the "Barnack-Leica". The original sheet with the calculations have the signature of with a date of Oct 7, 1922. That is some years before the actual production. In those days, that is a customary time lapse. (see page xx). The intriguing fact is the construction of 3 lenses and 5 elements, the last lens, composed of three elements. The usual explanation for this design is the avoidance of the Tessar patent. But this patent expired in 1921 or 1922. So with a presumed introduction date of 1924/1925, would not find himself in legal trouble, if he would adopt a 'classical' construction. The number of lenses produced (Anastignat and Elmax together) is well below 2000. And less than a year later the Elmar was computed and produced. It is most unlikely that if a patent problem would exist in march 1925 (introduction of the Leica camera), it would have been solved a few months later and could be anticipated by . The remarkably quick introduction of the Elmar, after the short production run of the Elmax, is a mystery that will probably never be solved. The patent issue, if one existed is only part of the answer. The Elmar delivers different image quality, and that may be the true answer. The complex three- element last component is difficult to produce and may not have been the solution looked for.

Figure 85: diagram 43

At full aperture the overall contrast is low to very low, with coarse detail rendered a bit softly. The performance from centre to corner is very even, but there is evidence strong astigmatism and field curvature. Quite fine detail is detectable and especially in the centre is of very good quality. Stopped down to 1:5.6 overall contrast improves visibly and now we have a remarkably good image quality over most of the picture area. The difference between the tangential and sagittal structures is quite large, which does soften the rendition of fine detail in the zonal areas. The Elmar has a more balanced performance in this respect. This behaviour might have provided Berek with the argument to redesign the Elmax.

6.3.2 3.5/50,Elmar,1925, 3.5/50,Elmar,1932 and later years

This lens is part of the Leica legend and myth too. The original drawings of Max .i.; have a date of May 6th, 1925 for this lens. The Elmar has been in production for more than 35 years in countless versions, that make it a collector's delight and nightmare. Almost half a million have been produced, which is more than 12% of all Leica lenses ever produced till 2000. Optically the lens has had minor updates, which did not change its overall character. Changes recorded are differences in radius of surfaces, differences in distance from position of aperture to first lens, etc. The application of coating did not enhance the performance very much as its moderate aperture and low number of air-glass surfaces could control flare and unwanted reflections very well. The serial number, quoted often as the start of the coated versions (581501) is not fully correct. While Leica could use the coating technique from October 1941, (from serial number 580401) it is most likely that this technique has been reserved or lenses, issued to military organizations. In an internal note we read that coated lenses will not be made available for amateur users, only for "Kriegsberichterstatter". (war correspondents and official war photographers).

Figure 86: diagram 44

Figure 87: diagram 46

On axis and till an image height of 6mm, object outlines and coarse detail are rendered with low to medium contrast. In the field, outside this circle, the performance drops significantly. Finer detail is reproduced quite softly, caused by a fair amount of astigmatism, curvature of field and chromatic aberrations. When stopping down to 1:5.6, the image quality improves markedly and now the lens has medium contrast over most of the image field. The zonal errors however remain and reduce the definition of fine detail in the outer zones. Overall the Elmar is a fine performer and is quite able to defend its reputation, at least when stopped down moderately. We should however put the performance in its proper perspective. Compared to the current Elmar-M 1:2.8/50mm it is of low contrast and it lacks the crisp and transparent recording of very fine detail.

6.3.3 2.8/50,Elmar,1957

This lens was redesigned with the new Lanthanum glasses, used also in the Summicron version and the LaK9 glass can be found in the first and last element. Analysis by modern computer based design programs of the original Elmar configuration show that the basic design is difficult to improve upon. A tribute to the old masters no doubt.! If advances are to be made, the only route is the glass selection. Inevitably, older glass types were removed from the catalogues and so the designers were forced to adapt to these circumstances. But modern optimization analysis also shows that the gains are relatively modest and so it may be no surprise that the image quality of this lens is quite stable over the years. Of course newer glasses and specifically the coating of surfaces give a modest gain under adverse conditions. In many situations, the use of new glass types will not improve the basic performance of a lens, as the designer will adapt the lens specifications to the characteristics of the new glass in order to preserve the original image quality. The classical four-element/three group design of the Elmar can just cope with the most important aberrations. And we know that doubling the aperture will increase the effect of aberrations by at least 6 to 8 times. The designer has however limited optical means to correct this higher level of optical errors. The Leitz designers used the new glass to improve the lens, but the progress is modest. The moving tube for the collapsible mount made the lens mount a bit unstable and Leitz indeed designed a newer rigid version with much better image quality. This elusive Elmarit 1:2.8/50mm never went beyond prototype status, but should have been an excellent design.

Figure 88: diagram 47

At full aperture the lens has a low overall contrast, lower than that of the Summicron and the Elmar 3.5 version. Coarse detail is reproduced with soft edges and finer detail is blurred in the outer zones (beyond image height of 8mm). The aperture of 1:2.8 does overstretch the design and spherical aberration and flare (due to coma) do lower the contrast. It delivers however an even performance over most of image field, which improved rapidly when stopping down. At 1:4 the performance is very good and better than that of the original Elmar 1:3.5/50mm at 1:4. Overall contrast becomes medium and now we have a very good centre quality, with he outer zones still trailing behind. Compared to the Summicron (I), there is an interesting difference in fingerprint. The Elmar has the edge in the centre of the picture and the Summicron is better in the field. At 1:8 we find very fine imagery (as good as that of the Summicron (II) from 1957). The performance characteristics show the limit of a four-element design with the glass types then available. Vignetting and close-up performance.

6.3.4 2.8/50,Elmar-M, 1994,

Introduced in 1994 as a special lens, only to be sold in combination with the M6J body, it has evolved into a normal , but underrated, catalogue item since 1996. Production however was continued during 1995. The image quality of this completely redesigned lens is amazingly good and now the position of the stop is between the second and third element. One might assume that the 4 element design has been fully explored and in a sense that is the case. Still the Leica designers could extract more performance out of the design, showing that improvements are always possible, . The ergonomics of the Elmar-M do limit its use. The external design very closely resembles the previous version, and inherits its small aperture ring and distance ring, presumably necessary for the compact size when collapsed. The lens mount is non-rotating.

Figure 89: diagram 48

At full aperture the Elmar-M adds medium to high overall contrast to the image. Fine detail is rendered crisply over most of the film area and fine detail is recorded with great clarity and sharp edges. This behaviour is interesting when compared to the Summicron (III) from 1969, at aperture 2.8. The overall performance is comparable, with the Summicron having an advantage in contrast. But in the field (zonal areas from image height 9mm) the Elmar has clearly the edge. The Summicron has better imagery in the centre (contrast and rendition of fine detail), but the Elmar records fine textures with greater clarity in the field. Stopped down to 5.6 or 8.0, the Elmar improves visibly with a higher contrast and consequently better rendition of (now) very fine detail. The fingerprint difference with the Summicron holds at these apertures too. Only in the extreme corners the Summicron has an advantage. Compared to the older Elmar, we see the progress when we look at the capabilities of recording fine detail, which is excellent with the new version and moderate with the previous version. Vignetting is more visible with the Elmar-M than with the previous version and identical to the current Summicron (IV), stopped down to 1:2.8. Close-up performance, even at full aperture is excellent with the Elmar-M, but less so with the previous Elmar-version.

6.3.5 2,5/50,Hektor,1930

The Hektor is the first attempt by .i.; to design a high speed lens, with minimal means. A 'compounded triplet' as this one has six air-to glass surfaces and should reduce unwanted reflections and flare. The three cemented doublets are introduced to create glass types with characteristics, that were not available then. called this an 'Anastigmat', and he reserved the term for a lens with relative small field curvature, and good correction of the astigmatic image planes (saucers). This design generates a moderate form of spherical aberration, what can be noticed when stopping down. The plane of sharpness shifts because of this effect, which may be noticed when taking pictures at closer distances at different apertures. The Hektor is very interesting in its use of a so-called Merté surface, a special optical design employed with the cemented surface in the centre doublet. Zonal spherical aberration is reduced by this solution and gives the lens part of its character. The patent description of this lens identifies it as a 1:1.8 design. however presumably would not go this far and reduced the aperture to 1:2.5. The Merté-surface is very sensitive to fabrication errors and when even higher speed lenses were required, the Summar was introduced.

Figure 90: diagram 49

The design is also very sensitive to production tolerances. One might be tempted to regard this lens as a bridge between the Elmar and the Summar and provided the Leica user with a higher speed lens to cope with slow film speed and low light. The Hektor 50 and 73 were designed in parallel and the Hektor 50mm could be a cost-effective derivative of the 73mm version. Aperture stops went to 1:18. At full aperture overall contrast is low with coarse detail reproduced cleanly on axis and quite soft in the field. Stopped down to 1:4 improves contrast substantially and in the centre (image height of 9mm) fine detail is clearly defined, albeit with blurred edges. In the outer zones performance drops visibly. At 1:5.6 the outer zones start to improve and at 1:8 we find really good quality, comparable to the current Elmar-M 1:2.8/50mm at 1:3.5. As a more apt comparison we may say that the Hektor from aperture 4 is better than the contemporary Elmar 1:3.5/50mm. Specifically in the field, the image quality is of a higher level. Field curvature and astigmatism are corrected to a higher degree, and the Hektor has a gentle drop in performance when traversing from centre to edge. The Elmar has slightly higher overall contrast, but a weaker performance over the whole picture area. Vignetting of the Hektor is high with 1.5 stops, as compared to the Elmar with 1 stop.

6.3.6 2.0/50, Summar, 1933

The first high – speed lens for the Leica, again designed by .i.;, closely followed the pattern set by the 6 element Cooke design, and gave the Leica truly available light capabilities. The aperture of 1:2 was 1 2/3 stops faster than the Elmar 1:3.5/50mm and now the Leica user could truly 'fix the shadows' as a famous and accurate definition of photography has it. The Summar has been produced in collapsible and (rare) rigid versions, both with the same optical cell. In 1938 the Summar had a price tag of 157 Reichsmark, against the Elmar 3.5/50 of 77 Reichsmark. A 1:2/50mm is still the workhorse under the standard lenses and it may be amazing that after 70 years many photographic situations can be handled with this aperture.

Figure 91: diagram 50

The Summar 1:2/50mm exhibits a low contrast image at full aperture, with a strong presence of astigmatism in the outer zones and a fair amount of veiling glare. The edges of the fine detail outlines are blurred, which give the impression of a slight unsharpness. Coarse detail is clearly visible with good edge contrast. The performance on axis (till an image height of 4-6mm) is quite commendable. The rendition of fine detail in the image field (zones and edges) rapidly becomes fuzzy and very soft. On axis we can detect 80 to 100 linepairs/mm, a Figure that appears quite high. Here we may note another general topic. Performance on axis has never been a big problem for lens designers since the early '30s, as the axial area is almost aberration free, by nature so to speak. References in the literature to high resolution Figures in the centre of the lens/image are not a very useable measure for real-world optical performance. Introduce a lower contrast , add some flare and some zonal aberrations and the centre performance, as recorded on film, will drop dramatically. Stopping down to 1:4.5 the image quality improves a bit , but reluctantly, and at this aperture the overall contrast is slightly higher and now we have very good imagery spreading into the outer zones. Quite fine detail is clearly detectable, but still with a shade of fuzziness. The amount of vignetting is on the high side with 1.7 stops. Allowing some vignetting is a well-known tool of the lens designer to improve the image quality as the extreme corner rays are excluded form the image formation process. At 1:5.6 overall contrast improves another step, but rendition of fine detail in the outer zones of the field hardly improves, a sure sign that the residual aberrations are still large. At 1:8 we have excellent performance till image height 9mm, after which quality drops visibly.

6.3.7 2.0/50,Summitar,1939 ,

Leitz however, kept on studying and improving the design and so gained valuable experience, which they used to good effect when they introduced the Summitar 1:2/50mm in 1939. With he Summitar, Leitz designed its first seven element- four group design, that shows many characteristics with the early Summicron version. Aperture stops went to 1:12.5, as with the Summar. Later versions went to 1:16. There is some discussion if this restricted range of stops has any relation to the level of aberration correction. It is presumed that a lens with small aperture diameters would show diffraction and other errors. There is no factual basis for such a assertion. It is possible that problems with the mechanical accuracy of the aperture stop to cover a range from 1:2 to 1:16 are part of the answer. The Summitar is supposed to have a large front diameter to reduce vignetting, but read the test.

Figure 92: diagram 51

This lens has somewhat higher contrast and noticeably less vignetting, partly due to a bigger front lens . Its general characteristics wide open closely follow the Summar. Its central area of good definition is larger as is the reduction of astigmatism. Most importantly the Summitar improves rapidly on axis on when stopping down and at 1:2.8, we get medium overall contrast and clearly visible recording of fine detail, but edges stay on the soft side. The outer zones are flare prone and of very low contrast with blurred corners. At 1:4 we find very good imagery in the centre, but the outer zones improve very reluctantly when stopping down. At 1:8 the optimum is reached and fine detail is recorded with good clarity, albeit soft edges. After 1:11 performance drops as contrast is reduced. Compared to the Summar, the improvements are a higher overall contrast, very good quality in the central area of the image and a more powerful rendition of coarse to fine detail. The definition of finer structural details is on the same level as that of the Summar. The alleged improved colour correction is difficult if at all to detect. Vignetting is about 1.5 stops at full aperture, only slightly lower by the way than with the Summicron (I).

6.3.8 2.0/50,Summicron collapsible, 1953

After the introduction of the Summitar, the “Leitz Rechenbüro” continued to explore this design as it was clear that the competition would not sleep and a high quality 2/50 lens was of utmost importance for the critical Leica user. In those days the limits of the diameter of the lens mount of the current models became painfully clear. When wider apertures were needed or a higher level of correction , the diameter simply was too small. The patent literature of the four-tap bayonet mount for the later M-models, specifically mentions the reduced vignetting as one of the prime characteristics. The first Summicron version closely followed the design parameters of the Summitar and the increase in image quality was slight. It is a low contrast lens, and shares the optical ‘fingerprint ‘ with its predecessor

Figure 93: diagram 52

As suitable glass types seemed to be the biggest obstacle for the advancement of new designs, Leitz set up its own glass laboratory and around 1953. The first fruit of that effort was the introduction of the Summicron 1:2/50mm (collapsible). Its design was completed in 1949 and employed the new lanthanum ('rare earth') glass, which was being offered by the British firm Chance Brothers Glass and a new computation became necessary in 1952 when Schott glass had to be incorporated. The Summicron design was first 'tested' in a Summitar* disguise. Two small batches were produced, one from 812242 to 812323 and one from 812341 to 812360, both series are from September 1950. The first batch, assigned to the Summicron is from #920.000, is dated late 1951. This lens employed LaK9 glass for three of its seven elements. Leitz documentation show that the lens was designated as SummiKron too, implying that 'cron' might be derived from Kron-glas (Crown glass). At full aperture overall contrast is low to medium, and coarse detail is rendered with good clarity over most of the image field, corners excepted. The fingerprint of this lens is almost identical to that of the Summitar. Very critical inspection will reveal some finer differences. The Summitar has slightly better centre performance, whereas the Summicron has a more even performance over the whole image area. One might assume that the designers paid more attention to an even coverage as this lens was supposed to be the prime lens for the Leica system. Stopped down to 1:2.8 the Summicron clearly distances itself from the Summitar at the same aperture. Contrast improves, and the even coverage of coarse and finer detail is crisper. At 1:4 very fine detail is resolved over most of the image area with good clarity and very fine detail becomes visible, but with fuzzy edges, due to a trace of astigmatism and field curvature. At 1:5.6 a faint improvement in the outer zones can be detected. The lens is sensitive to flare and bright light spots have extended blurred edges. Vignetting is about 1.6 stops at full aperture and is gone at 1:5.6.

6.3.9 2.0/50,Summicron, 1957

This Summicron version has a slightly different optical cell than the collapsible one and improved performance. Now 4 lens elements are from the LaK9 type. The distance between the first and second lens element (the air lens) has been increased form 028mm to 1.52mm and the shape of the second element is different too. It has been build it two versions, the standard version, designated as the Rigid version to distinguish it from the Collapsible version. The minimum focusing distance is 1 meter. A second version with an extended close focus range (from 88cm till 48 cm) and an removable spectacle rangefinder attachment has been produced. This version has the designation DR (Dual Range) or NF (Near Focus). Both the Rigid and the DR version have identical optical cells and so have absolutely identical performance.

Figure 94: diagram 53

The rigid version of the Summicron 1:2/50mm arrived on the market in 1957, but was on the drawing board several years earlier. It utilized the optical improvements that were made available with the wider throat for the M-body. Increasingly Leitz realized that the inherent instability of the moving tube of the collapsible types was a negative factor for the required optical improvements. The rigid version of the Summicron is the first Leica lens with image characteristics pointing into the future direction. The designers now were free to use the wider bayonet throat of the M-body and did not have to compromise for the use on the thread-mount bodies. Overall contrast at full aperture is medium and fine detail is recorded with crisp edges over a large part of the image area (till image height 12mm). Most noticeable difference with the collapsible version is the greater transparency and clarity of the image and a marked improvement in the definition of fine to very fine detail , after stopping down one or two stops. The aperture of 1:4 brings a quite visible improvement in contrast and the centre performance now spreads into the zonal areas. Very fine detail is rendered with quite crisp edges and extremely fine detail is visible, but a bit blurred by flare and low contrast. At 1:5.6 we get excellent performance with only the outer zones and corners lagging behind. Close-up performance is acceptable at full aperture, but for best results one should stop down to 1:4 or smaller. This also helps extend the depth of field, often necessary when photographing at close distances when the subject has depth in space. This Summicron captures a level of very fine detail that is beyond the recording capabilities of the predecessors. Vignetting is at the same level as the first version.

6.3.10 2/50,Summicron-R, 1964

The first Summicron for the Leicaflex, introduced in 1964 was a Canadian design, as was the Elmarit-R 1:2.8/90. (the 35mm, the 135mm and he 180mm were of Wetzlar origin). This Summicron could be focused till 50cm, a must for a reflex lens and can be compared to the 1 meter limit with the rangefinder version. This additional focusing range asked for a different type of correction. Curvature of field had to be small at full aperture and focus shift should be contained as well. The higher contrast of this lens, when compared to other lenses, including the competition, was quite noticeable. Research had indicated that film-emulsions could deliver a higher sharpness impression and a higher level of recording of fine detail if the acutance (or micro-contrast) was enhanced. Lenses that could use this characteristic with success had to be of higher contrast than was customary in those days. The introduction of the Summicron-R with enhanced contrast was the result of reflection and study of these imaging characteristics.

Figure 95: diagram 56

With its lower level of astigmatism, spherical aberration and field curvature, this lens has a medium to high overall contrast at full aperture, more so than the RF-version at that time (the then current Summicron (II) for the M-system). Stopped down however the M-version gave better results. This comparative evaluation indicates that any lens is a compromise between several competing demands. It is true that today, designers with a different approach, expanded theoretical understanding and sophisticated tools are able to balance these conflicting characteristics to a higher degree. The reader will become convinced (I do hope at least) that any lens (at least in the Leica world) has its own unique personality. A global merit Figure for the evaluation of a Leica lens does not suffice to get to the finer points that characterizes and differentiates the Leica lenses. Some of the lens elements for this lens have been produced by the Leitz factory in Rastatt, where spectacle glasses were also made.

The Summicron-R (I) has better overall performance than the Summicron (II) for the rangefinder system: generally we note a higher contrast in the field and a much better reduced level of flare. At full aperture we note a medium to high overall contrast, and a crisp definition of fine detail over a large part of the image area . Stopping down improves the performance somewhat. From 1:4 the Summicron (II) for the M improves more than the Summicron-R (I) and might be the better performer as this lens had a more favourable optical response to the aperture becoming smaller. The improved image quality at the wider apertures, however, gives the R-version a wider usefulness. Here again we note as so often, that it is not so easy to give one overall performance measure to appraise a lens. Too many variables have to be balanced and the compromise will be different from lens type to lens type. The bad guys with high speed lenses are flare, low contrast, coma and spherical aberration and the design history of the high speed lens is a battle on many fronts.

6.3.11 2/50,Summicron (III), ,1969

The seven-element Summicron 1:2/50mm was followed in 1969 by a six element version. It shared many design characteristics with the first Summicron-R 1:2/50mm, which was introduced in 1964. The sixties were a period of rapid changes in photography and the criteria of lens evaluation evolved. It was established that good contrast at the limit of the resolving power of the film-emulsion provided better image quality than a high resolving power with lower contrast. The Leitz Summicron-R and the Nikkor-H 2/50mm were probably the first lenses to be designed according to this rule. Both were six element lenses and these designs replaced the previous seven-element constructions, which were generally of lower contrast. The lens elements 4 and 5 are separated by an air lens with a thickness of 0.07mm!

Figure 96: diagram 54

At full aperture overall contrast is high; outlines and coarse detail is rendered with good edge contrast over most of the image field, the corners excepted. Crisp definition of very fine detail is visible on axis, but becomes soft when going to the outer zones of the image. This performance at 1:2 is better than of the 7-element version at 1:2.8. Effectively the user wins a full stop. As astigmatism and field curvature are better controlled, close up performance is very good and better than with the previous version. One of the reasons of the improved correction is a slightly larger diameter of the last lens element. The DR-version had a mechanical construction, that needed a smaller diameter of this lens, and this caused some edge rays (with a beneficial effect on the performance) to be cut off from the image plane. At 1:2.8 the contrast improves significantly, but the rendition of very fine detail trails a bit behind. This characteristic holds when stopping down further: excellent quality on axis with a clear definition of very fine detail and a more restrained rendition of the very small textural details in the outer zones of the image. At 1:5.6 the previous Summicron (II), is at the same level of performance, but the impression of clarity and high contrast of the newer one, gives it the definite advantage. Vignetting is slightly higher, when compared with the second version. Distortion is absolutely zero, making this lens good for recording of plane surfaces with scientific precision.

6.3.12 2/50, Summicron-R (II), f, 1976 & 2/50,

Summicron-M (IV, 1979 Both lenses are identical in design and (almost) in performance. The small differences can be attributed to the mount that is dedicated to the use of an automatic diaphragm in the R-version and a rangefinder coupling in the M-version. Both are Canadian designs as were the predecessors. Both versions share the same glass types and design. The lens diagrams do show some differences in shapes of the rims of the lens elements, but these are necessitated by the different mounts and have no significance for the image quality. Many modern lenses after 1950 are based on the six-element double-Gauss design, and without any doubt, this lens-type is the best studied type in the world. It has excellent potential for high quality imagery, but as with every design it has its limits, due to a fair amount of oblique spherical aberration (a fifth-order aberration). This error is very difficult to balance with third order aberrations, let alone to correct completely. The wider the aperture , the more disturbing this error becomes. Around 1980, this design type reached its current zenith and I may add, that significant improvements are unlikely, unless the designer departs form the basic layout.

Figure 97: diagram 57 (R)

Figure 98: diagram 55: M

Five surfaces are flat, a measure, that reduces the ability for aberration correction and at the same time simplifies the production and assembly of the lens. Both lenses have improved imagery and this is an outstanding tribute to design optimization, that would have been impossible in the pre-computer period. The improved performance has been made possible through a higher correction of coma, and field curvature. At full aperture the M-version has the same overall contrast as the previous one, but the most visible improvement is the crisp and clear rendition of the extremely fine details on axis, which give the definition of the image a sparkling clarity. At 1:2.8 the contrast of the fine details improve, as do the outer zones and at 1: 4 we have an outstanding image quality, with only the outer zones a trace behind the centre. The Summicron (III) at the same aperture exhibits a softer image in the field. At 1:5.6 the overall contrast is slightly reduced, and the definition of the fine textural details in the field has improved a bit. Here we note that the user of these lenses should study his subjects and demands very carefully: for best overall contrast the optimum aperture is 4, but for best definition of very subtle textural shades of grey or colour, 5.6 might be more appropriate. Scientific tests can indicate these differences as measured values, but the user may or may not be able to see or appreciate them. Photographic technique is the limiting factor here. I will note this aspect often in the course of these reviews. Vignetting is at the same level as the Summicron (III). Close up performance is much improved as is flare reduction (the lower amount of came helps here a lot). Drawing (distortion) is non-existent. Most of the above remarks apply to the R-version too. The R version at full aperture has somewhat lower contrast over the whole image field than its M-version. One should however not overestimate these differences. I made careful comparisons with both lenses and saw a fractional difference when shooting in normal day light situations. When taking pictures in twilight and similar low contrast environments the difference may be of more importance. At 1:5.6 the situation is reversed. Now the R-version has the higher contrast and gives a truly outstanding performance on axis (up to an image height of 9mm). The outer zonal areas have a somewhat lower performance as one looks at the very fine textural details. The M-version has a somewhat more even performance over the whole image field, but with a lower overall contrast. Both lenses offer sparkling clarity of extremely fine details, but if one wishes to differentiate the R version has a slightly flatter definition in the field. Stopped down to 1:5.6 the R-version shows that typical dip in performance in the outer zones, that many Leitz lenses of these generations share. R- and M-version deliver outstanding performance at a close-up distance of 1 meter, when stopped down a bit. This phenomenon does show, as so often, that many classical legends, are no longer valid. The old adagio , that a lens can only be corrected for infinity and therefore should drop in performance when closer distances are used, has of course a theoretical justification, but not always a practical relevance. Many current Leica lenses do prove that at closer distances, performance can be as good as at infinity, which by the way is not true mathematical infinity, but a value like 100 times the focal length. (See design chapters).

6.3.13 1.5/50, Xenon, , 1935/1936 & 1.5/50, Summarit, 1954

Most lens aberrations grow disproportionatetely when the aperture is doubled. When designers were still struggling to get decent performance out of an 1:2/50mm design, it seemed a bit rash to introduce a 1.5 lens. Remembering the slow film speeds of those days and the advent of the colour slide films with even lower sensitivity and the drive of the Leica photographer to capture scenes, illuminated by the faintest trace of light, a 1.5 lens makes sense, even if it is a designer's nightmare. Why Leitz have opted for the Schneider lens and did not wait for the Berek solution that was being created in the same period, is a mystery, but it might be that the introduction of the Zeiss Contax RF with a good 1.5 lens, was seen as a commercial challenge. It is sometimes asked why a designer would choose a 1.5 aperture and not the 1.4 aperture, as there seems to be only a small difference between both apertures. First of all, we have to realize that aperture stops and their values are subject to issues of tolerance, just like focal lengths. Secondly, a difference in aperture of 5 or 10%, is for a designer sometimes the borderline between a good and a bad design, as this additional amount of rays might introduce aberrations, that are very difficult to correct. To give a practical example: the diameter of a 1.5 aperture is 21.3mm and for a 1.4 aperture it is 22.7mm. Such a difference might be quite large in the world of optical design. The Leitz Xenon allowed the user to expand his practical picture taking opportunities into hitherto uncharted realms. Apertures till 1:9 only. Weight is 300grams.

Figure 99: diagram 59

The performance of the lens at full aperture is however barely acceptable for the intended use. Finer detail in the centre area (about 5 mm image height) is recorded with good visibility, but the very low contrast and strong presence of coma, especially in high contrast situations reduce the useful recording capabilities. A high speed lens with 10 air-glass uncoated surfaces has a high level of internal flare, that tends to lighten the deeper shadow areas in a picture, and thus give the impression of being able to penetrate the shadows, where in fact the only effect they have is a bit higher density in the otherwise blank areas of the negative. On the other hand the coma introduces flare patches around specular highlights. The quite dreamy and romantic atmosphere of pictures taken with high speed lenses at wider apertures in those days visible in many picture examples. Stopping down improves the image quality very reluctantly. At 1:2.8 we find an overall performance that will bring in the finer details within visible range, but with soft edges. In the outer zones definition of fine detail is quite soft. At 1:5.6 performance evens up and quite fine detail is rendered with still blurred edges. Close distance performance at the wider apertures is very weak and one has to stop down to 5.6 and smaller to get good results.

The Summarit 1:1.5/50mm is a coated version of the Xenon. The anti-reflection coating as a tool in the lens designers toolbox is effective when the design is trimmed to the use of coating. Coating can reduce reflections and enhance the effectiveness of transmission, but only to a certain extent. The overall contrast at full aperture is very low. The centre area (image height about 4 to 5 mm) has the (usual) familiar high resolution from 80 to 100lp/mm, which is, however, a theoretical figure as flare and the residual zonal aberrations degrade the recording capacity significantly. Stopping down improves contrast and after 1:5.6 we see a quite good image quality that invites sympathy , but is not equal to the contemporary lenses of lower speed. The inherently higher correction of aberrations in the lower speed designs does show. Generally the image quality of the Summarit is close to that of the Xenon, which should come as no surprise, as both share the identical formula. Apertures now till 1:16. Weight is 300grams

6.3.14 1.4/50, Summilux (I), 1959

The first Leica lens in the 1.4/50mm category was a redesigned version of the Summarit with newer glass types. This lens was introduced in 1959, designed by ELW and had the shortest life span of any Leica lens as it was replaced in 1961 by a much improved version, the still current Summilux-M 1:1.4/50mm. The first Summilux has low overall contrast at full aperture, quite visible vignetting (more than 2 stops) and on axis coarse detail is rendered with good clarity but soft edges, rapidly becoming blurred when approaching the corners of the image area. At 1:2 the contrast becomes medium and fine detail is now quite visible, albeit with some fuzziness. The outer zones , from image height 6mm, stay soft and fine detail is recorded with fuzzy edges.

Figure 100: diagram 60

This characteristic of good on axis and weaker performance in the field holds till 1:8, where the performance evens up over the whole image area. At 1:4, contrast improves again and the definition of the major outlines becomes crisp as is the rendition of finer detail on axis. Stopping down to 1:5.6 brings some marginal improvement. At apertures 8 and 11, we have optimum image quality of a high order. For serious close-up performance you have to stop down to 2.8 – 4. Flare is present at the wider apertures and produces the well-known blurry patches of light around bright light spots. Compared to the Summarit, this Summilux has visibly higher contrast and definition of fine details. At 1:2.8, the Summarit has improved, but the Summilux is at the same aperture still better. These remarks are relative and I also have to remark that the contemporary Summicron (II) at all apertures, including 1:2, has the better imagery overall. Everything is more relative than one might care to know about and, as a comparison the other way around, we may say that the Summilux (I) is at all apertures better than the Summitar.

6.3.15 1.4/50,Summilux (II), 1961

A truly excellent 1:2/50 lens can be realized relatively easily with a double-Gauss design, as we noted during the Summicron discussion. Often it is assumed that the one additional stop to the aperture of 1:1.4 is a matter of smooth transition. Add one lens element to correct the increased level of aberrations, tolerate somewhat more image degradation at the wider apertures and all is well? In fact the jump from 2 to 1.4 is a step into another dimension, as going from the molecular to the atomic level. As the aperture increase with a factor 2 , all aberrations will grow with a factor of 22 and 23 . The battle with this new level of optical errors would be easier to win, if the volume of the lens were of no importance. But it is and especially with the M-series large lenses are not feasible ergonomically and presumably economically too.

Figure 101: diagram 61

This second (Canadian) design has a higher overall contrast at full aperture and on axis very fine detail is rendered with high edge contrast. This second version has excellent image quality on axis, but performance takes a visible dip in quality when going to the outer zones. Coarse outlines and medium fine detail is crisply rendered, but finer detail becomes progressively softer and fuzzier when extending into the outer zones. Stopping down to 1:2.8 improves overall contrast. Image quality in the field is however visibly lower and the outer zones stay weak, with very fine detail below the threshold of recording capability. This behavior is typical of very wide aperture lenses and is an indication that there are some nasty aberrations operating at this level. Stopping down to 1:4 and 1:5.6 bring small improvements and the overall characteristic of excellent on-axis performance, combined with a weaker performance in the field does not change. At apertures 1: 8 and 1:11 the performance becomes first class and extends over the whole image area. This second version shows its advantages specifically when the wider apertures are used. Stopped down the differences are quite subtle. Vignetting is on the same level as the first version. Close-up performance is very good from 1:2.8. Strong light points are recorded with fuzzy rings of halo and high contrast scenes generate a veiling glare over the whole image area, lowering micro-contrast and thus soften the definition of the finer details. Compared to the Summicron-M (III), its contemporary, we may note the same general fingerprint. The Summilux verson performs as a Summicron (III) lens opened up one stop.

6.3.16 1.4/50,Summilux-R (I), 1970

The Summilux-R 1:1.4/50mm has been introduced at the Photokina 1970. It constitutes a Wetzlar design and has an interesting performance profile. At full aperture it is of slightly lower contrast than the M-version and its on axis performance extends over a wider area. It also shows reduced astigmatism and field curvature, giving it improved image quality. The M-version shows better flare reduction thanks to the better correction of coma. On this level the designer has clearly to balance requirements against possibilities. At 1:2 the Summilux-R improves and is now as good and even a bit better than the Summicron-R (I) (higher contrast, crisper rendition of fine details). Stopped down to 1:5.6 its overall performance is improved visibly, thanks to a high contrast. The definition of very fine detail in outer zones of the image field is a bit weak and brings in very fine detail with good clarity .

At this aperture the Summicron-R (I) has a larger focus shift, that reduces the definition of small details at very big enlargements. During its production, the Summilux underwent several detail changes in glass type, without altering its fingerprint.

Figure 102: diagram 62

Around 1980 there is a change in production method, and lenses are no longer classified in groups of focal length (as with the M-lenses), but a compensation method is used to adjust the correct focal length with lens thicknesses and distances. Elpro-close-focus attachments can be used with the Summilux-R without problems.

6.3.17 1.4/50,Summilux-R (II), 1998

This eight-element design shows a significant improvement over all previous 1.4 designs. The performance in the field is quite visibly enhanced and this is the first 1.4-Leica lens, that delivers outstanding image quality when stopping down. In this respect it is better than the current Summilux-M-version and even brings current Summicron quality and more to a 1.4 design.

Figure 103: diagram 63

At full aperture the new Summilux-R exhibits medium to close-to-high contrast that is visibly above the lower contrast of the seven element predecessor. This is quite a performance as conventional wisdom will tell you that more lens elements will degrade contrast. The additional eight element was needed for correction of field curvature. Fine detail is very clearly rendered with crisp edges with only a faint trace of astigmatism and field curvature in the centre over an image area with image height of 9mm. From there the quality very gradually drops, as compared to a drastic drop in previous designs. At 1:2 overall contrast improves and the optical performance is as good as that of the current Summicron lenses at their full aperture. In fact performance from 1:2.8 to 1:4 is almost identical to the current Summicron. Very fine detail is recorded with excellent clarity and crisp outlines from centre to well into the outer zones. In the far corner area a slight drop in performance can be noted. Stopping down from 1:2.8 to 1:4 gradually brings in exceedingly fine details that are now recorded with that lucid clarity that characterizes modern Leica designs. At 1:5.6 the Summilux surpasses the level of image quality of the current Summicron. From f/11.0 diffraction starts to lower the contrast of very small image details. Close-up performance (±1 meter distance) is at all apertures excellent. Deliberate two stops underexposure failed to bring out strong vignetting. Veiling flare at full aperture is negligible. Suppression of light halos around small subject details is excellent and careful comparison shots with the Summilux-M 50mm showed the R version to have a slight edge. The sharpness-unsharpness gradient is quite smooth and subject shapes are very well preserved in the unsharpness zones.

The new Summilux-R 1:1,4/50 offers excellent image quality and Leica R users can now shoot in available darkness and fully exploit the capabilities of modern emulsions. For my comparison shots I use Kodachrome 25 and 64, as these films still give the best microcontrast (read edge contrast) for the definition of extremely fine image details. Stopped down one stop and the new Summilux-R has that enviable balance of lucidly rendered crisp detail and smooth gradient of colour hues within small subject areas that is Leica's current . The image recording capabilities of this lens far exceed the one offered by all current ISO400 films and are on a par with the best of the ISO100 films. Kodachrome 64 would be an excellent companion.

In comparison to the Summicron-R 2/50 the new Summilux is a better lens. Optical aberrations(especially curvature of field and astigmatism) are tightly controlled, and from 1:2 the Summilux jumps ahead of the Summicron-R. Compared to the current Summilux-M the differences at full aperture are quite visible. On axis performance is more or less equal, but the R-version wins in the field, ad significantly so! And when stopping down forges ahead with superior performance in the field

Summarizing: the 1./50 Summilux-R (II) defines the current state of the art of large aperture standard lenses. It outclasses the 1.4/50 Summilux-R (I) by a comfortable length. It edges ahead of the Summicron-R (II) and visibly improves on the Summilux-M (II) 1.4/50. Non-scientific comparison pictures with the Summicron-M (IV) show comparable performance in most picture taking situations. If you need to record the finest possible details and shades in small textures, the Summilux-R (II) has to be stopped down to 1:2.8 and at medium apertures, the Summilux-R (II) has no competition.

6.3.18 1.4/50mm Summilux-M ASPH, 2004

The evolution of the high-speed standard lens came to a virtual halt in the late seventies. The reason is quite simple: the classical design for most 35mm lenses was a derivative of the double Gauss lens, as exemplified by the Biotar lens. In my report of the new Summilux-R 1: 1.4/50mm (II) in 1998 I noted that the era of the Double Gauss lens was not yet over. We were encountering a certain plateau however. In 1980 Dr. Mandler had written the definitive book about the stare of the art and the potential of the DG class of lenses. His conclusion was that for most lenses for general photography with focal lengths from 35mm to 90mm, the DG type was eminently suited and could not be improved upon within normal economical and manufacturing constraints. But the design has its inherent limitations. Very high-speed lenses could not be corrected fully for the oblique spherical aberration in the sagittal direction, astigmatism and curvature of field. These aberrations produced a low contrast reproduction of fine details and a soft edge contrast for subject outlines in the outer zones of the image area. The wider the aperture, the more pronounced these effects could become. In addition the improvement of performance at smaller apertures was quite modest because the balance of the aberration correction was naturally focussed on the image quality at the wider apertures. In addition, the focus shift could lower the quality of the image in the centre of the image.

These limitations made the design of a truly outstanding high-speed lens, based on the DG design an enigma. And in fact development of wide aperture lenses stopped around 1980. With eight elements the development potential was exhausted. The choice of glasses and especially the modern glass types could be beneficial, but not enough to give a radical improvement. The Canon FD 1: 1.2/55mm Aspherical design did demonstrate this, but with eight elements, one grounded aspherical surface and a floating element, it was very bulky and outrageously expensive. Wide open the overall definition showed the faint softness of the image that is the main characteristic of all very high-speed lenses at full aperture. If you look critically at the image, you have the impression that you just missed the critical focus plane. However good the mage quality wide open, there is always a visible improvement when stopping down to f/2 and f/2.8. It is as if the image snaps into focus with high contrast.

To be fair, it should be noted that most users of high-speed lenses do not use the wide apertures quite often and when then in conditions where the finest optical quality is not the overriding concern of the photographer.

In recent years we have seen only two new designs that show a marked improvement on the predecessors: the Leica Summilux-R 1:1.4/50mm (II) from 1998 and the Voigtländer Nokton 1:1.5/50mm Aspherical for Bessa and Leica cameras.

The new Summilux-R 1:1.4/50mm showed a significant improvement in the stopped down performance, based on a higher level of correction of the secondary spectrum and the reduction of astigmatism and curvature of field. The thick centre element (behind the stop) functions as a field flattener. The sharpness impression at the wider apertures was also improved, especially in the middle zones of the image. The overall performance wide open did follow the pattern described above and high contrast imagery can be expected from f/2. From 2.8 the quality is better than what can be expected from the Summicron-R. 2/50mm. Wide open the Summilux-R is remarkably free from veiling glare, flare around bright light sources and secondary reflected images

The Nokton has the classical double Gauss design with six elements and two aspherical surfaces on the last lens element. This lens shows improved performance in the outer zones when stopping down and a fair to modest contrast wide open. Excellent performance can be expected from f/3.5. At wider apertures we see a tendency to veiling glare and overall contrast is fair to medium. As a corollary the definition of fine detail is on the soft side, but quite evenly distributed over most of the image area. Astigmatism and curvature of field are partly responsible for this behaviour.

It has however the edge on the Leica Summilux-M 1:1.4/50mm, a design from 1962, modelled on the classical lines with seven elements and an air spaced lens between the second and third element. This lens has good contrast wide open, but the performance in the outer zones there is a fair amount of astigmatism and there is also some curvature of field. Definition in the centre of the image is very good, even wide open, but on stopping down the outer zones cover the finer details with low contrast. The intended use for this lens is the reportage and documentary photography with high-speed film, as the Kodak Tri-X (in this year 50 years old incidentally), where the coarser grain does boost the edge contrast and suppresses the reproduction of really fine detail.

Contrast versus resolution

There is a persistent story that one can optimize a lens for high contrast or high resolution. There is a certain truth in this assertion, but one has to understand the facts. The choice is only relevant for systems with a high amount of spherical aberration. In this case the rays from a point in object space do not converge to a point in image space, but the bundle of rays forms a pipe of light that is converging to a certain location on the optical axis where the waist of the pipe is smaller and then starts to widen. It is obvious that the location with the narrowest waist has the best contrast, but this is not the location of the film plane. Around the film plane we find a wider bundle of rays, but more dispersed and here we find the location with best resolution. In the past high-speed lenses al had a fair amount of spherical aberration and then the designer could select the back focal length such that the film plane was near the location of best resolution or best contrast. But the difference between both choices was quite minor in practice. Currently all Leica lenses have a very low amount of spherical error and then the choice is not relevant: all lenses have automatically a high contrast and a high resolution.

New approaches and a new vision

The first fundamental departure from the DG design was introduced with the Summilux-M 1:1.4/35mm Aspherical in 1989. In the patent literature (#5.161.060) the designers stress the fact that the new design gives a markedly improved performance in the outer zones of the lens. They also note that the employment of aspherical surfaces must be fully integrated in the whole design and must be part of the basic specifications. Here we detect the design principles of Mr Kölsch: you need to understand the basic problem of a lens first in order to find a sensible and fruitful solution. If a lens exhibits astigmatism as example, it makes no sense to let the computer find solutions, but you must first understand on a theoretical base why this astigmatism occurs, what lens surfaces are responsible for its magnitude and what is the best and most simple solution. This approach: to find the best and most simple solution for a design problem is the basis of all current Leica lenses. It is better to search for one special glass type with the required characteristics in one of the many lens catalogues and to understand it's potential for the solution for the problem at hand, than to use two separate elements whose combined power might provide a solution too.

When I discussed future trends in optical design with the Leica designers in 2000, the natural question to ask was whether a future 1.4/50 design for the M series could be derived from the Summilux-M 1.4/35 ASPH. The answer was that it might be possible, but not at that moment. The Summilux design transposed to a 1.4/50mm lens would become too large and require a level of tolerances that was impossible to hold in series production, even with the high level of careful manual assembly and frequent inspections that is the hallmark of the Leica Manufaktur. Two years later the optical cell with the eight elements and some exotic glass types was ready and delivered breathtaking performances on paper. At that moment in time it was not yet feasible for production as the mechanical problems were not solved and the size of the lens was an additional hurdle to take. It was a clear design goal that the new lens should be as compact as the current Summilux-M 1.4/50mm. But the designer had an ambitious vision: this lens was to become the best high-speed standard lens in the world, a true demonstration of Leica's optical ability in this field. For this goal the lens needed to perform above normal requirements in the near focus range and a floating element would be necessary. We know that a lens can be optimized for one distance only. This distance is normally the infinity position or in more practical terms one thousand times the focal length. But even at a distance of one hundred times the focal length (in this case 5 meter), the performance has not dropped to a level that is detectible. But at a close range and particularly at wider apertures one might begin to see a drop in contrast and a very slight haze that seems to reduce the clarity of the image. High-speed lenses in particular are prone to this effect, due to the presence of spherical aberration, astigmatism and curvature of field. If you are not a professional optical designer, there are many aspects you take for granted, but are a nightmare for the designer. The performance of a lens can be fully described by looking at the aberration distribution in the entrance and exit pupils. Here distortion and spherical aberration are two sides of one coin. Improve one and automatically degrade the other. But near distance performance needs to be distortion free and also deliver a crisp image. For a designer this is quite demanding a task.

The size problem

But the most demanding of all tasks is the combination of a small size with excellent image quality. I am now seriously designing lenses, as this is the only way to start to understand the problems and challenges of the optical designer. Modern optical design programs are extremely capable and you can ask the program to find the best lens design for a certain level of performance and selection of glass types. But invariably the optimization program will create a lens that is large and as soon as you restrict the physical dimensions of the lens, the performance drops significantly and all your work is for nothing. Then there is only one option: to make manual adjustments and very slowly proceed to a practical solution. As photographers we are justified to have simple demands: small size lenses and superb performance. But we do not appreciate fully the achievements of the designer when we do not have a clue how difficult it is to combine size and performance. The image quality of the new Summilux-M 1:1.4/50mm ASPH would be outstandingly good when fitted in a big mount, but is spectacularly good when one considers the size.

The addition of a floating element in the same space of the previous Summilux-M can be regarded as a triumph of mechanical engineering. The task here is twofold: find a mechanical solution (in this case finding the correct specifications for the pitch and thread of the mating parts: you need to combine accuracy and smoothness) and find one that can be manufactured in a consistent way. In the past, the prototype stage is the platform to find out if the lens can be manufactured at all to the required specifications. But it is up to the manufacturing department to find a way to manufacture and assemble the parts in a cost effective way. This did not always function in the past: and many lenses had to be changed during series production to accommodate to the harsh realities of the limits of he workers at the assembly stage. The famous wooden hammer, often seen as the symbol of superior craftsmanship at the assembly stage is in fact the remedy for the shortcomings at the prototype stage. The current approach within the Leica optical design department is to order parts from the series production to be used during the prototype stage. So they accommodate to the realities of production tolerances and not the other way around. This is a most sensible approach and explains why the period between finalizing the prototype and the start of the series production is very short. Normally it takes Leica a long period to go from prototype to series production, a delay that was acceptable in the old times, but now is no longer an option, given the aggressive pace of new developments.

On test.

Let me be clear and honest: it is impossible for a 1.4 lens to deliver at that aperture the same image quality as what we can expect from the best 1:2 lenses at f/2. The increase in magnitude of aberrations and the additional types of aberrations (fifth and seventh order) forbids this level of quality. In particular the spherical aberration in the

sagittal direction is a bad guy. This said, I have to note that the performance at 1.4 that we get form the new Summilux-M 1:1.4/50mm ASPH is very, very close to the performance of the best f/2 design (read Summicron).

At full aperture the overall contrast is high, with a faint hint of softness still hovering over the image. Astigmatism is very well controlled and the curvature of field is very flat, bringing a visibly enhanced image impact in the outer zones of the picture area. There is a small amount of coma detectible in small bright spots and specular highlights, but much less than in the previous design.

I made the test pictures with Fuji Provia 100F and 400F. Colour rendition of the new Summilux is outstandingly good. Especially in areas with dim light, the colours are bright and clean and quite saturated. With other high-speed lenses the colours in low light illumination look a bit underexposed and flat. They lack the sparkle of bright light illumination. Here the new Summilux sets a very high standard. And in combination with he excellent reproduction of high lights and reflections in bright surfaces, the images with this lens have a very fine and subtle three-dimensional effect that enhances the lifelike quality of the pictures.

Flare suppression is outstandingly good and even better than that of the Noctilux or the Summicron. It is almost impossible to create secondary reflections, even with bright sources in the picture or even worse, just outside the picture but shining into the front surface of the lens. In this last situation, you may see some smeared out bands of light in the outer zones, Of course, no lens with this aperture and front lens diameter is fully immune to flare and veiling glare but this lens is quite close to being for most intents and purposes flare free. You can see this when you make pictures where very bright windows figure prominently in the scene and the windows are decorated with small objects. Normally these objects are washed out and over saturated, but with the Summilux ASPH they retain shape and colour fidelity, a most remarkable performance.

Definition of very fine detail is quite good, but still has a somewhat soft edge. In night scenes the images retain their contrast and outlines of small subjects are clearly reproduced, but very fine detail is lost in the very low micro contrast of the subject textures.

Stopping down to f/2 adds crispness to the very fine detail and from this moment on the Summilux is ahead of the Summicron-M 2/50mm. The jump in quality when going from 1.4 to 2 is however a subtle one and not as visible as with all other high-speed designs. It is easy to assume that a picture made at 1.4 was made at smaller apertures. In this respect this is the first lens where you do not have to accept a compromise quality because of the high speed. The visible advantage of the Summilux is the excellent quality over the whole image area, where very fine detail is reproduced with clarity and crispness.

At f/2.8 the micro contrast of the extremely fine detail is enhanced, because now the effects of the higher order aberrations (residual errors are extremely small now) are neutralized. From here to f/8 image quality is extremely high and comparable with the best Leica lenses in the range (24, 90 and 135). The inevitable drop in contrast at smaller apertures is due, as always, to the effect of diffraction.

Vignetting is on paper on the high side with 2 stops at full aperture, but in practice the darkening of the corner-edges is not so pronounced that is should be a problem. Distortion is just visible, but not of relevance for most scenes, unless you do reproduction.

The floating element improves the quality in the near focussing range. Reduction in image quality will normally occur around the distance of 3 meters and less with high-speed lenses. The floating element does correct this reduction quite effectively, but to a certain limit. When you are in the close up distances from 0.7 to about 1 meter, the floating element can improve matters quite a bit, but then at the wider apertures we get soft images. For best quality in this focusing range, we need to stop down to /5.6 or smaller to get good imagery. We should not imagine that with the floating element, we get a high-speed lens with near macro capabilities. We should stay realistic in our demands. What the floating element accomplishes, is a visual improvement of the quality in the outer zones and a contrast improvement from 1 meter to 3 meters, where the wider apertures will now perform at the optimum of the lens.

Bo-ke aficionados will have mixed feelings about the performance of the lens. The unsharpness gradient is relatively smooth in the near focus range when the fore- and background planes are close to the sharpness plane. But when the distance between main subject and fore-/background increases the unsharpness subjects lose shape and form. Especially when the unsharpness areas are backlit, the shapes become very harsh and rough. This behaviour is due to the reduction of the astigmatism and curvature of field as is a small price am gladly willing to pay. With careful selection of the background and at full aperture, you can produce very intriguing natural portraits.

Conclusion

The new Summilux-M 1:1.4/50mm ASPH is the best high-speed general-purpose lens in the Leica range. Its wide-open performance is outstandingly good (in some respects like flare even better than the Sumicron at f/2). Stopped down it is better than the Summicron 2/50mm. It can be used as the universal standard lens and can be deployed without any restrictions in image quality at all apertures and over the whole image field. If you want only one lens for your M camera, this one should be the prime choice. I still have the opinion that the focal length of 50mm is the best single lens for the M (I am an old fashioned M3 user with 50, 90 and 135mm as the prime lenses) and offers a wide range of possibilities for picture taking.

Handling is superbly smooth and the size of the lens fits in well with the camera and the finger controls of the average user. The screwed finger grip allows for one finger fast focussing and the telescopic lens hood has a lock to prevent accidental moving. This is nice to have but not essential. The smoothness of the focussing mount is the most important aspect. Using the prototypes, you could notice some rough spots, but in the production versions, these are gone. The finish is of a very high standard and the aperture click stops match the quality of the rest of the lens.

This lens has optical qualities second to none and is a triumph of optical and mechanical engineering mastery. It even adds some new pictorial tools in the plasticity of the reproduction and the fine colour rendition in dim light and shadow areas.

Comparisons

The previous Summilux-M is clearly outclassed on all counts. As the Nokton is a small improvement on the older Summilux-M, this one too is not a serious competitor to the new Summilux-M 1:1.4/50mm ASPH, except on the matter of price. More interesting is the comparison to the current Summicron-M. The close up performance of the Summicron is definitely better than that of the new Summilux and if you do not need the high speed, it still has its virtues. The Noctilux-M is more difficult to profile. If you look at the objectified performance criteria, the Noctilux at the wider apertures is no match for the new Summilux-M. But then we have the more subjective considerations. Here the Summilux offers the real life dimension, where the Noctilux is more dreamlike and painterly in its reproduction of the scenes. The Nokton colour rendition is leaning to the pastel colours where the Summilux is more saturated. The drawing of the Noctilux is with a thick pencil where the Summilux uses a very thin tipped point. It is up to every photographer to make the choice. I can only try to describe the differences, objective as well as subjective,

What about the Elmar-M 1:2.8/50mm, This could be the perfect companion to the new Summilux-M: it offers excellent close up imagery even at full aperture, it is very compact and has excellent overall performance.

I often get questions like this: if you only had to use one lens, which one would you choose. The answer was not that easy. But now it is: the Summilux-M 1:1.4/50mm ASPH.

Glass types

The glass selection for the new Summilux is very interesting. There is one glass element in the new lens, whose cost is higher than the cost of all seven glass elements in the previous model of the Summilux. One may ask whether the mechanical parts have been reduced in engineering quality to compensate for the high glass cost. There is indeed a persistent story among Leica aficionados that the new generation of lenses may be optically superior, but the mechanical quality is inferior to older generations. This is not the case. In the new Summilux, there has been advanced engineering to account for the additional movement of the last lens group, the floating group. The total movement is about 2 mm and the effect can be seen from 5 meters. The employment of automated machining is the reason that the lens can be in the same price league as the previous version. And as the lens elements, in combination with the mechanical components, can be made to a higher level of precision, the costly manual adjustments during assembly can be forgotten.

The new glasses used in the new Summilux are very sensitive and very difficult to machine. In fact, the glass is very soft, which makes it difficult to get a smooth surface on nanometer level. The glass is also very sensitive to atmospheric influences and after being polished may not be in the open air for more than a half hour. The manufacturing process has been adapted to this requirement and the glass is coated immediately after the final machining. This also implies very good and thin coating layers. In fact the new Leica process of 'cold' coating is needed to accomplish this.

One of the new glasses has an interesting story. The original glass lab of Leitz was very productive and creative and has produced numerous receipts for special glasstypes. But the glass lab was a research facility and not a production factory. When glasses were needed in substantial quantities, Leitz had to persuade glass manufacturers to adopt the glass in their catalogues. In the past Schott was often the partner in this business. Later that role was adopted by Corning, a company that almost became the main supplier of Leitz glass. But Corning has stopped making the Leitz glasses.

Leica however needed that special glass, formulated by the old Leitz lab in order to get the required optical characteristics. Leica approached Schott and they agreed to manufacture that glass type. It can now be found in the regular Schott catalogue.

As a matter of interest, it may be noted that almost every glass now employed by Leica is eco-glass, or lead-free glass. The change from old glass types to newer eco-glasses implied in many cases a reformulation of the optical formula to hold the required image quality. In normal practice this change is not important, as one does not notice any difference.

If you take a good look at the lens diagram, you will note that the rear diameter is not very large, less indeed than with the Summicron 2/50mm. Therefore the first lens element needs to be of high refractive power to bend the rays sufficiently to get through the aperture opening. Lens elements two and three correct the color aberrations and are also responsible for the flat field of the image. The color correction is excellent, but not of APO calibre. Some red and green color fringing can be detected at high magnifications. The aspherical (fourth) element does correct the fifth order spherical aberration (oblique spherical in the sagittal (horizontal) direction). Element five and six are needed to get the rays to enter the last group almost horizontally. This is a requirement to enable the last group to become 'floating'.

One question that may be asked is why the original layout of the Summilux 35mm asph has not been used. The negative front element will disperse the rays to such a wide angle that the diaphragm opening cannot capture them. Therefore a strong converging lens was needed as the first element.

Performance issues.

Some comments have been made why I did not compare the Summilux 50 with the 35mm version. The obvious answer is that the angle of field of the 35mm is so much wider than that of the 50mm, that a real comparison is not possible. The design choices are totally different. But many persons consider the 35mm wide angle as the true standard lens for the Leica. I declared the Summilux 50mm ASPH as the best Leica standard lens. This does beg the question. The verdict is difficult as the Summilux 35mm ASP is an outstandingly good lens. But with a gun pointed at my head I would say that the new Summilux 50mm is slightly ahead at the widest apertures, especially in the zonal sections of the lens. The image area is normally divided in four sections (the centre, a circular segment from centre to the vertical edge of the negative format, an other segment from the vertical edge to the horizontal edge of the format and lastly the corners. Everything from the centre to the corner is designated as the 'image field'. Or as the 'Feld’ in German

To avoid confusion with the normal photographic parlance where the field is interpreted as the location where you take the photographs, I will use the concept of the zonal sections of the lens. The question has also been asked where the new Summilux-R stands in the performance league. If we set the previous Summilux at the beginning of a line and the new Summilux ASPH at the end of the line, the current Summilux-R would by on a point, located at about two thirds of the line segment from the start point.

What are the more subjective differences between the old and new versions of the Summilux-M? If you are familiar with Dutch painting, one could say that the older Summilux paints as Rembrandt, where the new one paints like Vermeer. This is an especially apt comparison as both painters lived in the same period. Rembrandt has been famous for his atmospheric and emotionally charged paintings. Vermeer on the other hand has been called the first optical painter as he painstakingly captured the finest possible detail with his fine brushes and used special techniques to bring the specular high lights to life.

On a more quantitative level, I made pictures with the older version of the Summilux at 5.6 and with the new version at 1.4. Even experienced users could not see a difference. I did check this again at the optical bench and indeed here the same conclusions holds. The new one is almost four stops ahead of the previous version. This is an incredible result, given the fact that the older Summilux got very high praise in the past for its performance. There is on the other hand a fair amount of discussion in the newsgroups, whether the performance of the new lens is not hyped-up or sexed-up (to use the language of the spin doctors in the political arena). Many people were and are very happy with the image quality of the seven-element Summilux-M. So what is the fuss about? Just marketing speak from Leica and some overcritical zealots?

Let me say this: the original Porsche 911 sports car was and is a great driving machine. Driving one is a fine experience and may recall the glorious days of the real men, who could handle an unpredictable beast and knew exactly where the limits were of cornering and road holding. The newest Porsche 911 is a vastly improved car that still captures the original atmosphere, but is improved in every screw and detail. Now road holding and cornering and braking are impeccable and the important performance parameters have been significantly improved. The older one is a very fine vehicle, but the newer one is simply better. You can be very happy with the older 911, but the new one out-engineers and out-performs the older one

In photographic terms: the older Summilux can deliver fine images, and if you are happy with them, stay at all means with the older version. If you however wants to take pictures at f/1.4 with the uncompromising quality, previously associated with an excellent f/2 lens, there is no way but to buy the new Summilux. I did an additional, special check between both versions on the bench to try to find the important differences that are relevant for picture taking in real life. First of all there is a major difference in the edge contrast at the low frequencies: where the older one at 10 linepairs/mm has a quite soft representation of the black line pattern, the new one shows lines with excellent edge definition. The overall impact is an image that is really crisp and powerful, where the older lens delivers an image that is more modest, more reduced in its drawing and contrast. At the finer frequencies, let us say, 30 to 60 lp/mm, the older one has a quite fuzzy representation of the lines in the sagittal direction and even become blurred. The new one has very good micro contrast and shows the fine lines with good clarity and separation. With hand held shooting, one is hardly able to capture these fine details and so one does not see them in the picture. And what you do not see, does not exist; that is the adopted view!

If you were to use the new lens only and exclusively at shutter speeds of 1/30 and less, the chances are high that vibration will blur the edge contrast and reduce the impact of the image. When using a good high speed film, like the new Kodak BW400CN, that has excellent fine grain, and allows a higher shutter speed, the difference is easier to see, if you do your own printing. (the natural gradient is not steep to allow printing on color paper!). Best is of course a medium speed film, like TMax100 or Delta100. And if you are a fan of slow speed films like Technical Pan, the differences between the old and new version are quite easy to see. But even with Tri-X 400, the new version delivers images with much higher impact and tighter grain. You will not see this clearly when you concentrate on the small circle in the centre of the image. But when you look for significant details at a location half way the axis point and the edge of the vertical delineation of the negative format, the older one will disappoint you, where the new one will show quite fine texture in the subject details.

The current view of a high-speed lens is to use it only at low shutter speeds in scare ambient light. Under these circumstances any performance advantage may be lost, depending on the workmanship of the photographer. If you do care for the best images, even in adverse conditions, one would yearn for the highest quality lens. Indeed if you use the lens at widest apertures to be able to use a slower speed film or a higher shutter speed or to take advantage of the limited depth of field, one is not inclined to compromise.

The 1.4 lens has always been the lens to judge the standing of a lens line. If you read the older literature of a fine manufacturer like Canon, you will notice that they regard the 1.4 design as the pivotal lens for the photographer, but only if the quality is uncompromisingly good. As a matter of interest, I checked the current Canon 1.4/50mm AF design for comparison. Overall this is an excellent lens, very close in performance to the current Summilux-R. The drawback is a quite high level of distortion, even more than that of the Canon 1.4/35mm ! There is also a trace of coma and the oblique spherical aberration in sagittal direction (the killing aberration for all high speed Double Gauss designs). The Canon philosophy then allows a higher level of distortion to compensate the other lens errors. For the intended use of the 1.4 lens, this is good thinking. But Leica engineers would not agree, as they know things can be done better. The new Summilux-M ASPH is the proof.

6.3.19 1.2/50, Noctilux, 1966

In 1966 the Noctilux 1:1.2/50mm was presented to the market and this lens, with two aspherical surfaces became famous at the same moment. It was not the first lens with such a wide aperture, but all previous efforts to construct a lens with a truly useful aperture around 1:1.2 or wider did fail. Some manufacturers tried the route of many lens elements, but the nine element designs were heavy and of very low contrast. The more sedate seven element designs were often 1.4 designs, opened up a half stop. The Noctilux was the first lens, that specifically had been created to provide a high contrast mage at the aperture of 1:1.2. As spherical aberration and coma are, among others, responsible for low contrast on –axis, the Leitz designers tried two different routes: new glass types or even special glass constructions (see picture of Marx) and/or aspherical surfaces. (see chapter 1.2).

Figure 104: diagram 64

Figure 105: Marx pictures on CD

The grinding of a non-spherical surface was extremely difficult and in those days (without CNC-equipment) had to be done manually. We must realize that the amount of asphericity is very small and the deviation from the spherical surface is measured in microns) To get to this level of precision by manual means is close to impossible and even with a specially trained operator Leitz had to accept a fair proportion of out-of-tolerance lens elements. And at the assembly stage, the narrow tolerances and precision required to put this lens together were additional cost enhancing factors. Commercially the Noctilux was not the success Leitz had hoped for.

The Noctilux is quite remarkable in its characteristics. At full aperture it delivers medium to high overall contrast with coarse detail rendered quite crisply. Comatic flare is also very well suppressed, but in the field the astigmatism is not. Finer details are not resolved at all and you have to stop down to 5.6 and smaller to get outstanding imagery, that is even better than that of the then current Summicron 1:2/50mm. There is a widespread misunderstanding concerning the characteristics of the Noctilux. This lens is supposed be tuned for good performance at full aperture exclusively and in the (assumed necessary) design compromise, stopped down performance is supposed to be of lower quality. The Figures and my tests do not support this description. Stopped down the Noctilux is excellent and from 5.6 to 11 we have imagery of a very high order and very fine textural details are now rendered with good clarity. At full aperture the lens exhibits a medium to high overall contrast on axis with a fairly rapid drop in the field, where only subject outlines and coarse detail is rendered with good visibility. When stopping down from 1.2 to 1.4 and 2 overall contrast improves visibly . On axis the image quality increase rapidly , but in the field performance improves more reluctantly. At 1:2.8 we find almost the same performance as with the Summilux 1:1.4/50 design, which has a slight advantage. In fact we may say that from apertures 1:2.8 the Noctilux and the Summilux are equal in performance. At 1.4 the Summilux is on axis, a bit ahead of the Noctilux and this comparison shows the very great challenge the Leitz designers had to face. To increase the aperture by half a stop, they had to accept a much higher level of aberrations that could only be checked by a very creative use of optical design and technology. The understanding of the complexities of aspherics in design and production was greatly enhanced by the Noctilux, but the production problems made it a challenging lens for the Leitz factory. Given the much higher aberration content, is no mean feat to design a lens that performs as good as an excellent 1:1.4 design as the Summilux is. Vignetting is more than 3 stops, distortion is visible and for good close-up performance, the lens has to be stopped down at least 3 stops. The Noctilux has a lower level of flare than the Summilux at the wider apertures, giving pictures in high contrast situations and when strong point sources of light are shining indirectly into the lens, a particular clarity that might be referred to as the hallmark of the Noctilux. Leitz invested considerable research into the design of a Noctilux R 1:1.2/50mm in the early eighties. The physical constraints (throat diameter among others and the space needed for the mechanism of the automatic diaphragm) limited the usefulness of this lens, and the project was cancelled.

6.3.20 1/50,Noctilux,1976

In 1976 a new version of the Noctilux was manufactured, now of Canadian design and with the maximum aperture yet another half stop wider. Employing spherical surfaces and using a new Leitz designed glass type, the 900403, the 1:1/50mm Noctilux-M was the first lens to deliver useable image quality at this wide aperture. As with the earlier Noctilux, some myths around the lens have to be discussed and discarded. The comment that this aperture even surpasses the sensitivity of the eye is not very well researched. The maximum aperture of the eye is between 1:2 and 1:3 as the pupil of the eye has a maximum diameter of about 8mm. To find an animal with an eye, that has a really fast aperture, we have to turn to the cat, whose maximum aperture is 1:0.9!! . A second myth, we have already encountered when discussing the properties of the earlier Noctilux 1:1.2/50mm. The new Noctilux improves on stopping down and at apertures around 5.6 surpasses by a small margin the performance of the current Summilux-M and is close to the performance of the current Summicron-M. The inherently higher correction of the Summicron-M gives the pictures taken with this lens a higher clarity and an almost brittle edge contrast. Comparison pictures with the Noctilux show a somewhat softer definition at the level of very fine detail. The suggestion that the Noctilux should only be used at full aperture as this is the aperture where this lens should deliver its best, is not supported by the facts. The Noctilux at full aperture delivers a low to medium overall contrast (due to comatic flare) , and subject outlines are rendered with clear edges on axis. In the field, outlines are more blurred coarse detail becomes soft. Stopping down to 1:1.4 improves contrast substantially and now we see Summilux quality at its 1.4 aperture. At the edges the Noctilux-M is a bit below the performance of the Summilux, due to a higher level of field curvature. At 1:2 the Noctilux-M fingerprint is similar to the Summilux-M, but the Summicron-M has the best overall performance at that aperture. From 1:2.8 the Noctilux-M has excellent on axis performance with a smooth definition of fine detail and a gradual softening of details when going to the corners.

Figure 106: diagram 65

Vignetting is with 3 stops on the same level as the predecessor and distortion is slightly less. There is some evidence of colour errors : small bright spots show outer fringes that are blue, with an internal core that is red-yellow Close up performance (around 1 to 1.5 meter) gives good imagery when stopped down to 1:4 and smaller. The lens can cope very well at full aperture with strong light points in the image and secondary images are very well suppressed. This is a demanding lens to use at full aperture as its shallow depth of field (only 10 cm at a distance of 2 meter) asks for accurate focusing, which is not easy in the available darkness where the Noctilux will be employed often. Some users also have to adjust their expectation level for the image quality at full aperture which is impressionistic rather than scientific. Out-of-focus objects retain their subject outlines and a gradual transition from the sharpness plane to the unsharp fore- and background add to the illusion of depth.

6.3.21 4/28-35-50,Tri-Elmar, 1998, New version 2000

The Tri-Elmar lens for all M bodies, from the M3 till the most recent one, is a landmark design in optical and mechanical construction. The shift in focal length goes from 35-50-28, and this sequence is necessitated by the frame-selector mechanism. The use of the Tri-Elmar-M expands your style of photography into unknown territory and helps to refocus your vision, even when attached to a 40 year old M3. This is an engineering feat of daunting complexity. And last but not least, Leica M users now have a zoom lens with optical quality that challenges the best lenses in the world. It is obvious that a maximum aperture of 1:4 has its limitations. We should however note that subjects with deep shadows, illuminated by a heavy overcast sky require exposures of 1/30 at 1:4 when using 100ISO film. The Tri-Elmar-M still has some margin to go before hand-held shutter speeds prohibit picture taking. And then a small tripod or fill-in flash will assist us in expanding our limit. The three ring construction (ring for distance, ring for change of focal length and ring for aperture change) is a bit unfamiliar at first. The ring for distance setting is quite close to the body and your fingers almost naturally fall around the focal length ring so you are changing the focal length when you intend to adjust the distance. After a while you get the knack for it. The new version, introduced at Photokina 2000 has the same optical cell, but improved ergonomics, with a focusing tab and improved selection mechanism for the focal lengths. It is also smaller than the predecessor with a 49mm mount and a slightly shorter mount. Mechanical complexity. In order to grasp and appreciate the mechanical complexity of this lens, let us first review the basics of zoom lens design.

From its optical design the Tri-Elmar is a true zoom lens. A zoom lens alters the focal length of the optical system and thus changes the magnification of the image when you take pictures from a fixed standpoint. The designer accomplishes this by employing two groups of lens elements, a back and a front cell. When both groups are shifted relative to each other and relative to the film plane the focal length is changed. The front group also moves axially for the adjustment of the distance setting. The demands on the mechanical engineering are extremely high. The Leica M employs a mechanical linkage to bring in the correct frame masks when changing lenses. So the "zoom lens" must have a mechanical linkage too, in order to activate the correct frames when changing focal length. And this lens must be designed such that at the three focal positions the accurate focal length must be set. The designer has to take into account the demands of all M bodies, including the M3. Every M body has a coupling arrangement between the lens and the appropriate frame in the viewfinder. These frames are spring actuated with different tensions and the sequence is 35, 50, 28. As can be seem from the illustrations, the two cells move over a bigger distance when going from the 50 to the 28 position than when going from the 35 position to the 50 position. The relative movement between the two cells and with respect to the film plane is mechanically compensated by cams with different curves. The change from 50 to 35 and from 50 to 28 requires the same distance on the focal-length setting ring, but the internal movements are quite different, where the shorter distance requires a steeper curve. This results in different forces to overcome and these forces need to be linked to the tensions of the frame actuating springs. If we then think about the required precision as the lens needs to stay accurately focused when changing focal length, we can appreciate the quality of the precision mechanical engineering involved in the Tri-Elmar. Every one of the three focal positions is individually tuned to a very high degree of accuracy when the lens is mounted. It may be noted that the Tri-Elmar is the lens where the art and tradition of precision mechanical engineering and mounting is at its current zenith.

Figure 107: diagram 130 A, B, C The performance of the Tri-Elmar-M.

At 50 mm: on axis and over most of the image area the lens gives a high contrast image with very fine detail crisply rendered. In the outer zones (at an image height of about 12mm) the contrast drops a little and textural details become slightly softer. The corners are soft with fine detail just visible. Stopping down to 1:5.6 enhances the contrast and definition somewhat. This performance level holds till 1:11 when the overall contrast drops a bit. Close-up capabilities (1,0 meter) are very good with a high contrast image showing crisply rendered fine detail over most of the whole image field. At 35mm: at full aperture the contrast now is just a bit lower and very fine detail is a bit softer. Very fine detail is visible over the whole image field. Quite remarkable here is the uniform quality over the whole picture area. This performance level holds till 1:11 when the overall contrast drops a bit. The close-up performance again shows a high contrast image with excellent detail rendition over the whole film area. At 28mm: At full aperture fine detail is rendered with medium to high contrast in the centre and drops a little in the outer zone. Very fine detail is clearly visible and becomes somewhat softer in the outer zones. This performance level holds till 1:11 when the overall contrast drops a bit. At close-up distance the image is of the same high contrast and evenness of field as the other settings. Here as with the 35 and 50 setting stopping down brings in contrast but the correction of aberrations is already on such a high level that image outlines and fine textural details improve a little. The distortion at the 28 setting is more visible than at the 35 and 50 settings. It depends on the kind of subject area if the effect is acceptable. Vignetting for the 50 and 35 position is quite low (1 stop in the corners) and about 1.5 stop for the 28mm setting. Flare is very well controlled and its absence, especially when specular highlights are in the picture, enhances the clarity and crispness of the overall image and the rendition of depth and textural tonality. As a general statement one may conclude that the performance when compared to the current 28, 35 and 50 Leica M lenses at their 1:4 setting is outstanding. And like it or not the Tri-Elmar is better than most of the previous generations of the 28, 35 and 50mm Leica lenses.

6.4 6.4 15 to 21mm

The focal lengths from 15mm to 21mm offer many interpretative opportunities for interesting images. One should realize however, that an angle of view of about 100o, is quite challenging from the viewpoint of perspective and subject. Optically the design of a very wide angle lens, is equally demanding. The very wide angle introduces many daunting aberrations, that need attention and the cosine-fourth-effect brings lots of vignetting. To make the problem manageable, the designers at first opted for a fully symmetrical design, as in this case several aberrations cancel out each other, simplifying the task. But a symmetrical design implies that the focal length is the same as the physical lens, bringing the lens very close to the film plane. That is OK for a rangefinder, (within limits!), but not practical for a SLR-camera, where a swinging mirror needs space too. One does not realize often how cramped the space is behind the lens and in front of the film plane. Retro focus designs can be used to get more room behind the lens, but one has to leave the symmetrical construction, which introduces now problems from an aberration perspective. The change from symmetrical to retro focus for the Leica R dropped the maximum aperture from 3.4 to 4 in the case of the Super-Angulon and the change to a retro focus design for the Leica-M in the case of the 28mm, brought a slight performance drop at first.

6.4.1 8./15,Hologon,

1972 In 1972 the Hologon 1:8/15mm from Zeiss had been added to the M-lens line. It offered virtually distortion less imagery and a fairly even illumination. If necessary, a graduated filter can be used when the residual vignetting is really disturbing. On axis definition is very good with a crisp recording of outlines and coarse detail. The recording of the finer details in the field is on the soft side and its potential for high quality images is limited. As this lens will be used to record subjects close to the lens or for architectural spaces the excellent definition of coarse detail should suffice. If bigger enlargements (above 12x) are required, the limits of definition become visible and the overall image becomes softer. In those days, the creative potential for such a lens was quite limited and in my view still is. The learning curve of the lens is quite high, but if the user has familiarised himself with its characteristics, pictures with a high attention value can be produced. The Hologon has serial numbers from the Zeiss range and seems to have been completely outsourced as Leitz did not allocate serial numbers from their range for this lens. Only a few hundred have been produced.

6.4.2 3.5/15, Super-Elmar-R, 1980

In 1980 Leitz offered a new 15mm lens for the R-series. The optical cell is identical to the Zeiss Distagon-T 3.5/15 and has a floating element to improve performance at closer ranges. There is very good image quality at a distance of 50cm. This design has a correction philosophy similar to the 19mm lens. A deliberate amount of astigmatism above image height of 12mm is used to correct field curvature. The filter revolver has slight changes in the spectral characteristics of the filters, compared to the Zeiss version, to bring them in line with the other Leica lenses with the same feature.

Figure 108: 6.4.2.A Super Elmar

At full aperture overall contrast is medium and fine detail is crisply rendered on axis till an image height of 10 –12mm. Vignetting is relatively low with 2 stops, but distortion is quite visible. Stopping down to 1:5.6 improves contrast and the definition of very fine detail on axis. In the field there is a moderate performance gain. Due to the very curved front lens the Super-Elmar-R is flare-prone and sensitive to reflexes of secondary images.

6.4.3 1:2.8/15mm Super-Elmarit-R ASPH

General remarks

The very wide angle of this lens and its short focal length bring advantages and restrictions. The extended depth of field makes the concept of 'boke' obsolete for this lens. Even unsharp areas in front and beyond the sharpness field ('plane' would be the wrong word here) retain shapes and details and have a very smooth migration curve. On the other hand, the assumption that the lens is an easy one for pictorial representation is wrong. This is definitely not a convenient landscape lens. The large and extended foreground pushes main subject areas into the vanishing background. So you need to be careful when and where to deploy the lens. It is at its best when the sense of shape needs to be defined or when the overwhelming surroundings of some magnificent room or corridor or interior is to be visually communicated. In short a visually sensitive photographer with a keen and empathic eye can do wonders with the lens.

It is also very good for closing in on groups of people who share some activity. The lens has back element focusing and is indeed incredibly smooth in its movement. The internal filter revolver is the same from the previous Elmar 15 and must be used as the filter element is part of the optical design. It focuses to 18cm.

At full aperture we have a medium to high contrast image with excellent definition of very fine detail over an image circle of 12mm radius (24mm image circle in diameter). The outer zones and the corners are progressively softening but even in the extreme corners coarse detail is quite visible. When reading this one should reflect on the extreme angle of field. For this angle the definition over the whole image field is close to outstanding. A slight fuzziness at the edges of fine detail delineation softens the overal image a bit.

Distortion is very well corrected and even persons at the edges of the image retain their normal body contours. (Ever looked at the elongated faces and bodies of persons when using a 12 mm or some other 15mm lens). Architectural straight lines are straight lines with a just visible distortion in the outer zones of the image. Astigmatism and colour fringing are for all practical purposes non-existent. For really demanding work (above 50 times enlargements of slides, there is some colour fringing from 9mm radius). Vignetting is of course visible but not objectionably so. In darker grey areas it is not visible, but white areas or blue sky do show light fall-off.

Flare is commendably low: secondary images are not to seen and the veiling glare in contre-jour shots is confined to very small areas around the bright spots themselves. A good example is a picture of very fine telegraph or electricity lines against a light grey or white sky: if the lines are clearly differentiated and keep their own colour (no greying) then the lens is OK. There is absolutely no decentring, which is some act given the large diameter of the lens elements.

At f/4 the lens visibly crispens and the circle of best performance grows to 30mm, that is close to covering the whole format. Edges of fine detail now are clean-cut and overall contrast is high. The typical Leica sparkle in the highlights and bright spots is evident and the fine differentiation of the whitish hues (on Kodak E100VS) adds to the image.

Further stopping down is not necessary for image quality and or depth of field. Till f/16 the lens can be used, but at apertures from f/11 the overall image is softer.

At 5,6 and 8.0 the lens is at its optimum and hs that typical Leica fingerprint of crisp and clean details with excellent clarity of shadow and highlight hues and outstanding colour reproduction, with a high fidelity reproduction of fine gradation of hues in small subject areas.

At closer distances the contrast drops in the zonal areas outside a small center circle. But stopping down to f/8 brings the quality you need. So when using the lens at distances closer than 1 meter you should stop down to f/8 for best imagery.

Leica yes or no?

The lens is a Schneider design. It is worth stressing that Leica did not accept the design as Schneider provided initially but commented on the quality and wanted a performance that is in line with the Leica philosophy. So it happened. Whoever designed and manufactures the lens is of no importance. The imagery is as Leica wants it, given their own goals and aspirations.

Comparisons.

The inevitable comparison is with the previous (Zeiss) design. The Zeiss design has less overall contrast at all apertures and especially the definition of very fine detail is much lower. The new Schneider design is quite crisp and clean in its detail rendition, which is the result of a better mastery of the higher frequencies.

The Zeiss Super-Elmar 3.5/15mm

As example: At f/8 the older Elmar design has about 90% contrast in the centre for the 10 lp/mm. The newer Super Elmarit has above 95%, which is visible. Even more important is the 40 lp/mm: Elmar in the centre: 40% at f3.5 and 55% at f8 versus Super-Elmarit 65% at f2,8 and 70% at f8. That is clearly visible progress.

The other comparison is the Voigtlander 4.5/15mm. This is in fact a comparison that is optically and theoretically questionable. A compact symmetrical design for the RF scene with a modest aperture of 4.5 is not to be compared to a big retrofocus design with an 2.8 aperture. Even so, much interest does exist. So even if not allowable, I will stick my neck out.

The Voigtlander at 4,5 has a visibly lower overall contrast and general image quality is below what you can expect of the SE 15 at its full aperture of 2.8. The imagery of the Voigtlander is a bit dull, lacking the sparkle of the SE 15, an indication of a highly corrected lens even at the 30 and 40 lp/mm level of performance. Distortion of the V is a bit higher and so is light fall off. Where the SE 15 can be used for scientifically correct architectural pictures, the Skopar is best used for the more casual shots.

Overall

The best proof of the capabilities of the new SE 15 is the fact that slides taken with it do not show as taken with a 15mm. They are natural looking in its perspective and clarity. Fine details exude when enlarging or looking closer at the image.

But remember that a slight dislocation of the camera will introduce natural distortion. My usual trick is to ensure that one vertical and one horizontal line in the image align with the viewfinder frame.

6.4.4 2.8/16,Fish-Eye-Elmarit-R, 1975

This type of lenses has been designed at first for scientific and technical purposes where hemispherical recording is required. The Leitz version is identical to the Minolta version and has been built in Japan. The circular angle of view is 180o, which requires an extreme refraction of the rays. Eleven elements are needed to cover the full 24x36mm format with a horizontal angle of 137o and a vertical one of

86o. To stretch the circular image to the rectangular format extreme pincushion distortion has to be fed into the design. For best performance the large front element should be completely hemispherical to collect as much light as possible. A normal assessment of image quality is obviously impossible. For its intended application the centre performance will satisfy modest requirements.

Figure 109: 6.4.3.A

6.4.5 2.8/19, Elmarit-R, 1975

Leitz Canada computed the Elmarit-R 1:2.8/19mm , which arrived on the market in 1975. At full aperture contrast is low to medium, definition of coarse detail is very good, and very fine detail is rendered with slightly fuzzy edges in the centre of the image. In the outer zones performance drops as astigmatism is used to balance field curvature. Stopping down does improve contrast (which becomes high) and on axis performance, while the image quality in the field improves very reluctantly. At 1:5.6 and 1:8 performance is good with a crisp rendition of fine detail on axis and a quite soft reproduction of small detail in the field. Vignetting is high with 2.5 stops and distortion quite visible in the periphery and at close distances. The distortion type is a bit weaving and its changes direction abruptly. Close-up performance is not so good, as this design has no floating element. You need to stop down to 1: 11 to get an even performance over the whole image field. At the middle apertures this lens is better than the Super-Angulon-R 1:4/21, with less field curvature, visibly improved

rendition of fine detail in the outer zones and corners and better close-up performance. The lens is flare sensitive, as is the Super-Angulon. The large front lens of both these retro-focus designs does contribute to the occurrence of this phenomenon. In general picture taking situations, this 19mm lens offers good imagery.

6.4.6 2.8/19,Elmarit-R, 1990

The new version of the 19mm does include a floating element (rear lens focusing!)for improved close-up performance as this was one of the weaker points of the previous version The mechanical construction of a floating element is demanding. As example: the lens moves only 0.7mm from infinity to .5 meter. From 3 to 2 meter the lens moves 0.05mm! The mechanical movements are very small and need a high precision construction to function properly after many years of use. Between this version and the older one, there is a time span of 15 years.

Figure 111: diagram 5

Figure 112: 6.4.5 A floating

And a change in generation of designers. The new one has at full aperture high contrast and outstanding performance on axis with a clear and crisp rendition of very fine details. In the field the performance drops gradually to weak, with fine detail now recorded very soft and with blurred edges. At full aperture the new is as good as the previous one at 1 :4 to 1 :5.6. And at 1 :5.6 the current 19mm version reaches its own optimum with outstanding imagery over the whole image field. This lens shows the progress the Leica designers have made with retro-focus type of lenses.

6.4.7 4.0/21,Super-Angulon, 1958

Very wide angle lenses with acceptable apertures for the 35mm format were very difficult to design, as the oblique aberrations (coma and lateral colour)and distortion on one hand and the light fall off on the other hand challenged the designers beyond imagination. A wide angle of view could be created with a symmetrical design and a small aperture. The use of a symmetrical design was imperative as several aberrations cancel out with symmetry. It is clear that the aberrations, introduced in the front part of the lens, will be fully corrected by the same aberrations, but of negative magnitude, present in the rear part. The designer then was free to pay attention to other problematic errors. You could correct the natural vignetting (cosine-fourth effect) by allowing a strong amount of distortion, which is unacceptable. At about the same time, designers at Zeiss and Schneider found the identical solution. By using the properties and relationship between the entrance and exit pupil, one could enlarge the apparent pupil diameter for oblique rays and so reduce the vignetting. A large front and rear element is typical for this type of designs. Leitz adopted the Schneider version and used the same name. “Super-Angulon” sounds a bit heavy as it seems to refer to a super-lens, which the first Angulon was not.

Figure 113: picture from HOVE archive

The deployment of a 21mm is tricky, due to its large foreground and tendency to perspective distortion, when the lens is angled to the object. Artistically it is challenging lens and only a few photographers can really produce arresting pictures with such a lens. Jeanloup Sieff and Bill Brandt come to mind, both of which did not use the 21mm for landscapes or interiors, but for nude studies. I specifically mention these examples with the intention that the Leica photographer will break out of the conventional mould and use the lenses based on inherent characteristics and optical qualities. At full aperture the overall contrast is low and there is strong vignetting, with a hot spot in the centre of the image even at aperture 1:8. The definition of coarse to fine detail is on the soft side, but the performance is very even over most of the picture area, excepting the edges. Stopping down improves the definition of fine detail and at 1:8 we see a crisp rendition of fine to very fine detail over the entire field, with the excepting of the extreme corners. Flare is very well repressed and night shots with this lens show well contained halos around point light sources. After 1:11 we note a reduction of contrast due to diffraction. For best close up performance some stopping down is advisable.

6.4.8 3.4/21, SuperAngulon, 1963 & 3.4/21,Super-Angulon-R, 1965

In 1963 the Super-Angulon 1:3.4/21mm superseded the 1:4 model. The same optical cell has been used for the M and R versions. It is a complex design with 9 elements, each of which is made from a different glass type. This lens could only be used on the R-body with the mirror out of the way. Vignetting now is much less with this redesign and at 1:8 the picture area is now even illuminated. Flare is higher at full aperture than with the 1:4 version. Contrast is medium and coarse detail is rendered crisply on axis (image height 9mm) with the outer zones becoming progressively softer.

Figure 114: picture from HOVE archive

Very fine detail is just under the threshold of reproduction. Stopping down to 1:4 brings a visible improvement and now this lens is better than the predecessor and at 1:5.6 the rendition of very fine detail is quite clear, but with blurred edges. At 1:8 the optimum is reached and very fine detail is now reproduced over most of the image area with soft edges. As is typical of many lenses from this period, the textural details are recorded with a certain softness that gives the impression at bigger enlargements that the plane of focus has been missed. It is true that the extended gradient between sharpness and unsharpness gives a pleasing effect to the pictures at the detriment of a clearly defined plane of critical sharpness. This is part of the fingerprint that defines the Angulon lenses overall.

6.4.9 4/21,Super-Angulon, 1968

This lens is a new design of the retro-focus type and a half stop less than the symmetrical predecessor. This is a wise precaution, as even at this reduced aperture, the new design is not the equal of the symmetrical version of the same specifications. At full aperture overall contrast is low and the definition of coarse detail is soft , with the exception of the centre where we find a cleaner definition. At 1:5.6 and 1:8 performance is fair with a crisper rendition of fine detail on axis and a very soft reproduction of small detail in the field. Flare level is high at full aperture and for high quality in the close up range, we need to stop down a few stops. The designers evidently grappled with the intricacies of the retro-focus design, which was introduced only a few years earlier by Angenieux. The improved grasp of the design we see with the first and specifically the second version of the 19mm. The time span between the first retro-focus design and the state-of-the-art design is almost 25 years and is a good indication of the research needed to improve a design substantially. These rays of light are really stubborn!

Figure 115: 6.4.8 lens

6.4.10 2.8/21, Elmarit, 1980

he first retro-focus design from Leitz in the 21mm focal length class, is of Midland origin and shows family resemblance with the 2.8/19mm for the R, which is also a Midland design. The gradual change from symmetrical to retro-focus types for the M-body, was necessary since the introduction of the M5. The second, more disguised argument for the change to this newer type of designs is the optical potential of these designs. As soon as the designer has familiarized himself with the inherent characteristics of retro-focus designs, (s)he has more opportunities for correction. The M-version could not grow to the physical dimensions of the R-19mm and this restricted the designers somewhat. The M-21mm is of similar quality as the R-19mm, which has a still wider angle of view.

Figure 116: diagram 10

At full aperture the M-21 has a low to medium overall contrast, crisp rendition of fine detail on axis (image height 6mm), with a fairly rapid drop in the field. The lens is flare sensitive, has vignetting of 2.5 stops and visible distortion. Stopped down to 1:4 improves contrast slightly and so does performance in the field. At 1:5.6 the reproduction of very fine detail is brought within visibility range over most of the image area. The delineation of small textural details is fuzzy and we need to stop down to 1:8 to get a clear recording on axis. In the field the softness is retained however. This lens is a good performer, but it is not a leading edge design. .

6.4.11 2.8/21,Elmarit ASPH, 1997

The combination of aspherics and more insight into the principles of the retro-focus design, made possible a quantum leap in performance with the 2.8/21 asph. At full aperture overall contrast is high and very fine detail is rendered with crisp outlines over a larger part of the centre (till image height 9mm). In the outer zones performance gently drops and becomes very soft in the extreme corners. As comparison: image quality at full aperture is better than that of the previous version at 1:4.5. Vignetting is visible with 2 stops and distortion is measurably on the same level as with the M-21, but as the distortion curve has a different shape, it is less noticeable. Stopped down to 1:4 the field improves visibly and at 5.6 extremely fine detail is recorded over the whole picture area with high edge sharpness on axis and more softness in the outer zones. This lens offers clean definition of fine detail and clarity of small textural areas, which add to the pristine image quality.

Figure 117: diagram 11

The second version of the R-19mm offers the same level of performance and here we see the choices of the Leica designers. The R-version is physically larger which supports a better correction of aberrations. The M-version has to be smaller and here the employment of an aspheric surface makes sense.

6.5 6.5 24 - 28mm

6.5.1 2.8/24,Elmarit-R, 1974 11221/11257

The 24mm focal length is a relatively recent addition to the Leica lens lines. It seems to sit a bit uncomfortable between the 21mm and 28mm lenses. In fact it is a fine compromise. The horizontal angle of 74 that coupled to the main motive at closer distances, will wrap around the subject and enhance the feeling of being in the scene. The 21mm is often a bit to far-off and the 28mm has a too narrow perspective to really encapsulate the subject. As is the case with many lenses, a learning curve is unavoidable. The

Elmarit-R 1:2.8/24mm is often referred to as a Minolta lens. The true background is a bit more complicated. The original design is a Minolta computation with Minolta glass and glass from other manufacturers. The computation had been adopted by Leitz. The lens is completely built in Germany.

Figure 118: diagram 12

Figure 119: 6.5.1 A front floating

This lens has a medium overall contrast with clean rendition of the fine details on axis (image area of 6-9mm). In the outer zones the performance drops and now coma and flare become quite visible. Coma will always soften the details and lower the contrast. Most users assume that coma is only operative when strong light sources are present, but that is not true. Stopping down to 1:4 evens up performance to the edges, but the fine textural details stay soft, due to a strong presence of astigmatism and field curvature. At 1:5.6 the contrast in the outer zones improves a bit and this level of quality is available at 1:8 too. At the level of reproduction of coarse to fine details this lens offers commendable image quality, but stopping down does not reduce the residuals enough to bring high edge contrast to the really fine details. Vignetting is 2 stops, but distortion is pronounced. At the middle apertures the R-24 is better than the Angulon 4/21 or the first R-28mm. Performance is always relative. The R-24 employs a floating element, which brings excellent image quality to the close focus range.

6.5.2 2.8/24,Elmarit ASPH, 1998

Once in a while, all parameters fall into place with that indefinable fit, that characterises the presence of a successful creation.

Figure 120: diagram 13

Figure 121: 6.5.2 A aspheric element

The Elmarit-M 24mm is without any doubt a masterpiece of optical engineering and within the Leica M range a landmark design. At full aperture the lens exhibits a very high contrast image from centre across the whole field. Only the far corners drop in contrast and produce soft details. On axis (till image height of 12 mm) the outlines of subject shapes and details are delineated with superb edge contrast and extremely fine details are crisply and clearly rendered. In the rest of the field the very fine details are crisply etched in the emulsion with extremely fine details visibly rendered but with softer edges. Exceedingly fine detail is just rendered above the threshold of visibility, but with slightly lower contrast. Going from centre to corner the contrast drops a bit, but while a bit soft these details are still visible. Stopping down 1:4 overall contrast improves and exceedingly fine detail now is clearly visible. Corners still lag a bit but centre performance is at its optimum. This aperture can be called the optimum. Stopping down to 1:5.6 we see that the finest details crispens a bit on axis, but overall contrast in the field is lower. It is a matter of priorities which aperture is optimum. I would say that at 1:4 this lens is at its best At 1:8 corners continue to improve where the centre now drops in contrast. At 1:16 the overall image contrast is lower and very fine detail suffers as diffraction effects set in. At close range (around 1 to 2 meters) this excellent performance is preserved. A wide angle lens like a 24 is less usable if the close up performance would not equal the infinity setting. Due to aberrations we need to stop down to 5,6 to get the best of performance in the close up range. Flare suppression is perfect. Night pictures with Kodachrome 64 show excellent gradation in strong highlight sources and distance point sources are clear and without any halo Vignetting is about 2 stops and distortion is visible. There is some confusion about the effects of distortion in the corners. Flat objects will be rendered almost geometrically correct, but it is with three-dimensional objects that distortion becomes visible. The M-24 excels in his respect with a gentle transition in the depth-distortion. Pictures taken with the M-24 have outstanding definition of fine detail in the foreground, with an added sparkle and clarity for luminous pictures.

6.5.3 6.3/28,Hektor,1935

In the thirties, optical expertise with really wide angle lenses was limited and the focal length of 28mm was about the widest that could be employed with acceptable results in the 35mm format. A small aperture helped to reduce the effect of aberrations. Vignetting is quite high with 3 stops and most certainly is allowed as an aid in correction of optical errors. The current M-28 has vignetting of less than a stop at this same aperture. Progress in optical construction can be noted in many different aspects of lens performance. At full aperture overall contrast is low, and on axis (image height 3 mm) fine detail is recorded with soft edges. In the field image quality drops significantly, but outlines and coarse detail are clearly visible. Finer detail however is fully blurred and introduce a kind of background noise, that degrades the overall quality. Stopping down does not bring much improvement and we need to stop down to 1:16 to get a reproduction of detail and outlines that will stand bigger enlargements.

Figure 122: diagram 14

The rendition of fine colour hues in small detail is quite good and gives this lens in standard picture taking situations a pleasing look. As soon as light sources enter the front lens the veiling glare gives the overall picture a washed out look. This lens delivers remarkably good imagery when stopped down an/or used in not too demanding circumstances. The overall image is however a bit dull and fine detail is softly rendered without the clarity and bite we do note in current lenses.

6.5.4 5.6/28, Summaron, 1955.

Twenty years after the first 28mm design, the Summaron has a maximum aperture that is only half a stop wider. Image quality is however vastly improved. At full aperture we have high overall contrast and a crisp rendition of very fine detail over a large part of the picture area (till 12mm image height). In the outer zones performance drops rapidly. At 1: 8 we see identical performance and closing one more stop brings a drop in contrast and a further drop when going to 1:16. From 5.6 to 8 this lens delivers excellent image quality. Vignetting is 2.5 stops and distortion non existent. Flare is also well suppressed, but the lens is not immune to its effects.

Figure 123: diagram 15

6.5.5 2.8/28, Elmarit (1),1965 Germany and Canada.

Figure 124: diagram 16

Of symmetrical design, this lens has a bit more distortion and with 2.6 stops vignetting at full aperture looks the same as the predecessor. The full aperture is two stops wider however and then we can appreciate the raw figures. At full aperture the on axis performance is good with a clear definition of fine details, but going to the corners the image becomes progressively softer. At 1:4 corners improve rapidly, contrast becomes medium and fine detail is now crisply rendered over a substantial part of the picture area. At 1:5.6 quite fine detail becomes visible with somewhat fuzzy edges and now only the corners and edges of the picture lag behind. Image quality is comparable to the Summaron at full aperture. Performance levels off at 1:8.

6.5.6 2.8/28, Elmarit (2), 1972

Canada manufacture. This Midland design is a retro-focus construction and the change was needed for the M5. It equals, but did not surpass the quality of the previous, symmetrical design. The performance description of the first version is applicable here too.

Figure 125: diagram 17

Differences in fingerprint are the more pronounced difference between centre and field performance. The M-28 (2) is of lower contrast in the outer zones and even stopped down to 1:8 renders fine detail with fuzzy edges. Vignetting is reduced to 2 stops and distortion is very small.

6.5.7 2.8/28 Elmarit-M (3), 1979 (new focusing mount from # 3037401 Canada mnf)

Figure 126: diagram 18

A much improved design became available after only a few years. In 1979 the second Canadian Elmarit-M 1:2.8/28mm arrived on the market and this lens set the standard for the 28mm focal length for years to come. At full aperture overall contrast is medium to high and very fine detail is crisply rendered in the centre area (image height 9mm). Beyond that the definition becomes progressively softer. Outlines however are delineated with high edge sharpness till the corners and it is these image details that are responsible for the overall impression of the picture. At 1:4 and 1:5.6 performance improves slowly, with a higher overall contrast and a crisper definition of very fine detail over most of the image area. At 1:8 extremely fine detail is captured on film with very clean edges on axis and a more fuzzy look in the field. Two stops vignetting and negligible distortion are in the same league as the predecessor. Close up performance is very good when stopped down to 5.6. This lens has excellent overall image quality that will challenge many higher speed film emulsions.

6.5.8 2.8/28 Elmarit-M (4), 1993.

Figure 127: diagram 19

Primary goal of this redesign, now with Solms signature, was improved image quality and smaller physical dimensions. Both demands are in fact contradictory and it is slight surprise that in actual picture taking, the advance is readily seen. The front lens is unusual with its plane front surface , which might help reduce the flare tendency. At full aperture the lens is indeed sparklingly clear, even in high contrast situations. Generally this lens is one full stop ahead of the predecessor and at 1:2.8 is as good as the previous one at 1:4. At full aperture a high overall contrast is combined with a crisp definition of really fine detail over most of the picture area (image height 16mm). In the outer zones we detect a veil of softness that overlays the finest textural structures. At 1:4 the performance in the field improves, but now we note a slight reduction in contrast on axis. For all intents and purposes stopping down is only needed for extension of the depth of field range. The specific fingerprint of this lens is a high correction of the oblique sagittal rays, which does improve the rendition of fine gradations in tiny object areas. Close up performance has been improved too and now the full aperture can be used at 1 meter without reservation. Vignetting is a bit lower with 1.8 stops and distortion will be observable in critical work. This is an outstanding lens with a clear rendition of very fine details in deep shadows and highlights alike with a retention of crisp outlines in high contrast situations. The old myth that in high contrast lighting a lens with low contrast is of advantage, as this characteristic is supposed to compensate for the extended brightness range, finds its Waterloo with this lens.

6.5.9 2.0/28 Summicron-M ASPH, 2000

Leica designers, when creating lenses for the M-system, have to face two conflicting demands: the physical size of the lens should be small, as it may not obscure the viewfinder and should fit the size of the body and the image quality must be the highest attainable within the size limitations. A physically small lens puts constraints on the optical capabilities of the design. The use of aspherical surfaces has made the task of the designer somewhat easier. With the new Summicron-M 2/28 ASPH, the designer had to work within the physical dimensions of the Elmarit-M 1:2/8/28mm and fit in a full stop more and realize more performance. The result is a superb lens. A lens with an aperture of 1:2 with the same dimensions as a 1:2.8 lens is in itself a feat to be proud of and when the performance at full aperture is as good as that of the Elmarit-M at 1:2.8, we have an outstanding example of the Solms design philosophy.

The optical construction with one moulded glass (blank pressed) aspherical surface (the front surface of the last element) follows the lay-out as first introduced with the Summilux-M 1:1.4 ASPH. The front section of the optical system (before the aperture) is closely related to this Summilux. The first cemented group now has separate elements, which enables additional degrees of freedom for aberration correction. Based on the computed performance indicators, vignetting at full aperture is fractionally higher than with the 2.8-version, and distortion is very low. Given the small size this is a quite remarkable feat. The calculated MTF graphs do indicate that at full aperture the Summicron-M 2/28 ASPH is even better than the

Elmarit-M 1:2.8/28 at 2.8 and has better on axis performance than the Summicron-M 1:2/35 ASPH at 1:2. As with the Elmarit-M 1:2.8/90 – Apo-Summicron-M 1:2/90 pair, the newer lens at its full aperture has better performance and a full stop gain in light transmission. In the past, a faster lens at its widest aperture would not be as good as the less fast lens at its full aperture, but this rule of thumb no longer is valid with the new generation of Leica designs. The Summicron-M 2/28 ASPH and the Summicron-M 2/90 ASPH redefine the classical Summicron image quality and both are the benchmark lenses for the M-system. When current thinking indicates a levelling off in optical quality, these new Leica designs forcefully demonstrate that the creativity of optical designers defies this view.

Introduction and background

A few years ago in Solms, I was shown a certain lens, a compact 1:2.0/28mm lens for M. It was a prototype, to be sure, but it was ready for production, all optical computations and tests were done. On my question why this lens never made it to the production stage, Mr. Kölsch answered, that he expected more performance from a new lens of these specifications. So a new design was created from scratch: the Summicron-M1:2/28mm ASPH., scheduled for delivery early in 2001

The optical prescription of the lens is quite fascinating. It fits in the genealogy of the seminal Summilux ASPH, a design that decisively departs from the classical Double-Gauss formula. This design-type, now more than a 100 years old, has been stretched to the limits and a performance plateau has been reached. The new Summilux design, incorporates the negative front and back surfaces and the aspherical surface. It is probably the first lens that has been designed specifically around the use of aspherics. Retrofocus designs are a second approach to step out of the shadows of the Double-Gauss formula. More lens elements can potentially improve performance, as more parameters can be controlled. The new Summicron-M 1:2/28mm ASPH picks up design elements of both: the lens group in front of the aperture is an enhancement of the Summilux (front group) design and the lens group behind the aperture fits into the retrofocus family and is a derivative of the 2.8/28 formula. We should not press the point, however, as a lens design is a creative whole and not a mix of ready made components. The message should be that the new Summicron is based on the best design principles currently available in Solms thinking. The location of the aspherical surface is different and probably decisive for this design

The ergonomics.

The new 2/28 is indeed a very compact lens, comparable to the current 2.8/28 version. Measurements are (2.8 version in parentheses): length from flange: 41mm (41.4mm), overall diameter: 53mm (53mm), front diameter: 49mm (48mm). Both lenses use filtersize E46.

For a lens with twice the speed this is a remarkable feat. This design indicates the direction of future Leica M designs: compact and high speed and high performance. The somewhat weak performance of the old Summilux 1.4/35mm could be excused with reference to its compactness, which forced the designers in those days to find a compromise between size and performance. Now the circle has been squared.

The lens operates very smoothly, and the aperture ring clicks with just the right amount of resistance and fluidity. When taking pictures with the new Summicron 28, I was amazed how quickly I could focus with the focusing tab and I have to confess that I hardly missed a shot, when focusing moving objects. The depth of field with a 28mm lens, even at an aperture of 1:2 exceeds of course the DoF of the Summicron 50 by a factor of 2, which brings real advantages in street shooting.

The performance

At full aperture this lens exhibits a high contrast with crisp definition of exceedingly fine detail over most of the image field, softening in the field from image height of 9mm. A faint trace of astigmatism and field curvature can be detected. Stopping down to 2.8 improves the center area (diameter 12mm) and also brings in a higher microcontrast in the outer zones. Corners however lag a bit and stay soft with a limited definition of coarse detail. Stopped down to 4, contrast becomes very high and the optimum is reached with a very even performance over the whole image area, excepting the extreme corners. At 5.6 we se a small drop in microcontrast of the fine textures and from 8, the overall contrast drops a bit. We have to put this in perspective, of course as we relate it to the optimum aperture. At 5.6 and smaller, the Elmarit-M 2.8/28 is a bit behind the new Summicron 28.

Distortion is about the same as with the Elmarit 28mm and vignetting is just visible with 2 stops in the corners at full aperture, about the same as the Elmarit at 1:2.8. In general use, this falloff can be neglected: even on slide film one has some difficulty noticing the darkening of the extreme corners.

Close up performance at 0.7 meters and full aperture shows excellent performance with high contrast rendition of very fine detail

Night pictures retain high contrast in the shadow areas, and (when exposure is right) finer gradations in the highlights are recorded as well. At least with slide film and Black and White. Bright light sources have cleanly delineated outlines, indicating effective elimination of halo effects. Coma cannot be detected in these situations (light points in the image field).

Flare is very well suppressed in daylight shooting too, in contre-jour situations and when the sun strikes the front lens obliquely. Of course: you can construct situations where secondary images and veiling glare is quite visible, but even here the images retain contrast and some saturation. A lens shade is needed, when the light sources may shine in or close to the front lens. I will give this topic a separate treatment. Leica has redesigned the front part of the lens where the shade is attached for easier handling. All wide angle lenses suffer the same problems here. It is a tribute to the design team that they have given this topic additional attention.

The transition from the sharpness plane to the unsharp areas is relatively smooth, but really out-of-focus areas show the tendency to break up details in coarse and fuzzypatches. There is a certain harshness in the out of focus rendition that is typical of modern Leica lenses. It is related to the level of aberration correction.

The comparison

The Elmarit 28 at 1:2.8 is slightly behind the Summicron at 1:2, specifically in the contrast in the field. At 2.8 the Summicron is ahead of the Elmarit at 2.8, again in the field and in the rendition of very fine details. This advantage is not lost at smaller apertures. So we may say that the Summicron at 2 is already ahead of the Elmarit at 2.8 and never loses this advantage. Given the very high performance of the Elmarit, these differences at the smaller apertures are not very great, but they are there for the discerning user to exploit.

Compared to the Summicron 2/35 ASPH, the new Summicron 2/28 wins in the department of definition of very fine detail, where the 35mm is of slightly lower contrast. The Summicron 35 however wins in the area of distortion. Stopped down the 35mm lens is a bit softer overall, but we are here discussing differences on a very high level of performance.

If we take a helicopter view of the Summicron line for the M, we can note that the Apo-Summicron-M 2/90 ASPH. is the best overall and at full aperture, closely followed by the new Summicron 2/28 ASPH. The Summicron 2/35 ASPH is third with a somewhat lower overall contrast and a softer rendition of very fine detail at all apertures. The Summicron 2/50 upholds its reputation at smaller apertures, but begins to show its age at full aperture performance. Well even Pete Sampras can be beaten by a younger player

Conclusion

With the Summicron-M 2/28 ASPH Leica adds a very potent lens to the stable of current M-lenses. Its a full stop ahead in performance compared to the Elmarit-M 2.8/28. The significance of this evolution is not to be underestimated. In the very recent past, it has been normal experience, when comparing lenses, that a faster speed lens would be not as good as the not so fast lens in the same focal length class, and would become better when stopping down, surpassing he less faster alternative because of its inherently higher level of correction. Now we have a lens in the 1:2 category that is even better, objectively, when compared to the 1:2.8 version. The same trend I noted with the Apo-Summicron-M 2/90 ASPH, a lens that is also better at full aperure than the excellent Elmarit 2.8/90mm. It is really progress when we now have transferred the outstanding performance of a 2.8 design to a 2.0 lens. It is to be expected that Leica will improve the performance of a lens, when introducing a successor version. The magnitude of the improvement however is such that we may note a new paradigm for Summicron-class lenses.

6.5.10 2.8/28 Elmarit-R, 1970

This lens is of Wetzlar origin, and should be one of the lightest lenses for the R-system with less than 300grams. It is also very compact and has vignetting of 2 stops.

It is of comparable performance of the contemporary M-28 (2), with a slight advantage for the R version in the field, where details are rendered with higher contrast. At full aperture we have low to medium overall contrast and the rendition of fine detail on axis (to image height 6mm) is quite clear, becoming very soft when approaching the corners. Stopping down enhances micro-contrast, but the definition of image details improves marginally.

Figure 128: diagram 20

There is a fair amount of field curvature and this limits the improvements when stopping down. At 5.6 the depth of field covers some of the detail softness in the zonal areas and fine detail is now rendered with clean edges. Close up performance is fair at best and stopping down a few stops is necessary for good imagery. Wide open the lens is flare sensitive and small bright spots have extended blur patches. During its course of life, there have been some changes in balance between centre and edge performance. For really critical work, this lens should be used stopped down to middle apertures.

6.5.11 2.8/28,Elmarit-R, 1994

A 1.4/28 has been designed around 184. B846. Problem is again the small diameter of the bayonet. Vignetting can be reduced by enlarging front lens. Test pictures show a nice quality in the centre. But bad in the corners.

Figure 129: diagram 21

Figure 130: 6.5.10A rear floating

The current R-28 has been introduced in 1994 and is a more advanced design. It has a floating element to improve close distance performance and also to assist the overall level of correction. Its level of performance is very close to that of the 1993 version of the M-28. At full aperture it is about equal to the M-version and almost two stops ahead of the previous R-28. .At 1:2.8 high overall contrast is combined with a crisp definition of very fine detail over most of the picture area (image height 16mm). In the field the fine textural structures are rendered with soft edges. In the corners coarse detail is blurred but detectable. At 1:4 the performance in the field improves and at 1:5.6 the on axis performance (image height 9mm) sets a new standard and surpasses even the M-28. As with the M-version we note a high correction of the oblique sagittal rays, which does improve the rendition of fine gradations in tiny object areas. Close up performance has been improved too and now the full aperture can be used at 1 meter without reservation. Vignetting is?????????? This is an outstanding lens, that in some areas even surpasses the M-version, which lacks the mechanically complex floating-element construction.

6.5.12 2.8/28, PC Super-Angulon-R,1988

With large format-studio cameras, it is very easy to control the perspective by changing and shifting the lens board and film holder relative to each other. The large format lens covers a wider image circle than is needed for the format to get good illumination and definition when shifting the lens relative to the film plane. The same principle is being employed by the so-called perspective-control (PC) lenses for the Leica R. The diagonal of the 35mm format is 43mm and most lenses cover an image circle, just sufficient to illuminate the full picture format. The Super-Angulon has an image circle of 62mm, which allows some shift in the position of the lens, relative to the film-area. (see picture here). The angle of view is effectively 93 is normal for a 21mm focal length. The trick of the lens is to have a larger angle of view for the effective focal length of 29mm. Movement in the vertical and horizontal direction is 11mm, and diagonally 9.5 mm.

Figure 131: 6.5.11 SA

The PC-28 at full aperture has medium contrast, less so than the current Elmarit-R 2.8/28. Performance is very good up till image height of 9mm. There is strong vignetting of more than 3 stops. Stopping down to 5.6, the contrast improves markedly and is now even better than that of the R-28mm. Definition of fine detail improves to an image height 26mm and on axis very fine detail is rendered quite crisply. This performance is partly due to a very good correction of the field curvature. necessary for the movements. Using the PC option forces the user to stop down to 1:11. Full aperture will be used mainly for focusing. There is the normal slight barrel distortion which grows when the PC option is used. The PC 28/28 employs a floating element for improving the quality at the closer distances.

6.6 35 to 40mm

Whatever the more philosophical arguments for the prima-donna role of the 35mm lens in the Leica RF world (natural perspective, angle of view suitable for intimate life-shots and story telling), the optical reason is quite simple. An angle of view of 64 relatively large aperture, small physical dimensions and modest optical lay-out and still ensuring good optical quality. The 35mm focal length has been produced in many variations and optical designs and has proved to be very demanding in its correction, if really outstanding image quality is required. The 1.4 aperture has been offered in 1961 already, but while delivering good imagery stopped down, at full aperture is was overstretched. In fact the 1.4 Summilux is almost identical to the later Summicron 2.0, and this lens can be seen as a Summilux with a smaller aperture. The first Summilux aspherical is a radically different optical design and delivers outstanding performance, beyond what is possible with a design based on the double-Gauss formula.

6.6.1 4.5/35 ,Elmar,1934/35

This snapshot lens had been announced as early as 1935, and officially postponed as a production model. A few samples have surfaced, probably as prototypes, as no serial numbers have been ever allocated for this lens. The optical cell is identical to the normal Elmar 3.5/35mm and all comments made for this lens, apply here too.

6.6.2 3.5/35, Elmar, 1930

This is the first interchangeable lens that Berek designed for the Leica, a year later followed by the 90mm and 135mm. It is also used in the Stereo attachment. It is a classical Elmar construction, but now the aperture is located behind the second element. It has vignetting of 2 stops and has visible light fall off, even at 1:8. Some distortion can be seen. At full aperture is has low overall contrast and a clear definition of coarse detail on axis, becoming rapidly very soft. At 5.6 the contrast in the field improves and the centre area of good definition expands to an image height of 6mm, where fine detail is rendered with fuzzy edges. In the field however, the fine detail is blurred and difficult to detect. At 1:8 the image quality improves markedly, with the outer zones still of low contrast.

Figure 132: diagram 25

The pictures that Paul Wolff produced with this lens are made mostly stopped down and at the smallest apertures this lens is a commendable performer.

6.6.3 3.5/35, Summaron, 1948

This lens is the first new design after the war. It is of double-Gauss construction and has been introduced in 1948. Many sources give 1946 as the earliest date, with serial # 601001, but the factory records indicate that this batch was reserved for the Elmar 50mm. See the Appendix for a more detailed discussion. At full aperture the performance is visibly improved when compared to the Elmar 35mm. Contrast is close to medium and on axis (till image height 6mm) fine detail is resolved with good visibility and only slightly fuzzy edges, but in the field the contrast drops rapidly and details become quite soft.

Figure 133: diagram 26

Stopping down brings some improvements, but gradually and we need to use aperture 1:8 to get a clear definition of the fine detail over most of the picture area, excluding the outer zones that stay soft. In the centre we now very good definition of the very fine details. For best close-up pictures, stopping down is necessary. Vignetting is 1.5 stops and distortion very well controlled.

6.6.4 2.8/35, Summaron, 1958

The first series have been produced in Wetzlar and later series in both here and in Midland. This Summaron is closely related to the previous one in design and adds a half stop. At full aperture we have medium overall contrast, vignetting of almost 2 stops and a more even coverage of fine detail rendition over the picture area. It is a visible improvement over the namesake at its aperture of 3.5, specifically in the field. At 1:4 the on axis performance improves with visible recording of very fine detail, but in the field we see no improvement. At 5.6 image quality levels off, as field curvature softens the details. Overall at this aperture the new version is better than the older one, but at 1:8 we see comparable quality.

Figure 134: diagram 27

Distortion is very small. Close-up performance is very soft at the wider apertures.

6.6.5 2.0/35, Summicron (1), 1958

In the same period of the introduction of the Summaron, Leitz Midland produced an 1:2 Summicron, which followed the classical double-Gauss pattern too, but added two lens elements. Sometimes one can read or hear the remark, that a 'true' double-Gauss lens, has to have 6 elements, grouped as two symmetrical halves. In fact any lens should not be analyzed by counting elements, but by analyzing the refractive powers and the path of the rays. The D-G lens is typically set up as follows: A positive (converging) meniscus element is followed by a second meniscus or convex element with lower refractive index and higher Abbe-number, the third element is of similar specification, then we have the stop and the fourth element is a bi-concave element of flint glass, and the fifth and six elements are flints too of biconvex shape. These rear glasses are of an higher index than the front elements. They are often more expensive and the smaller diameter of the rear elements offsets the price differential. In this case, the two additional inner meniscus lenses do not change the basic pattern.

Figure 135: diagram 30

The 8-element design has relatively large front and rear elements, presumably to reduce vignetting. In fact, at full aperture vignetting is 2.5 stops and at aperture 2.8 is 2 stops, about the same as the Summaron. At full aperture overall contrast is low and coarse detail is rendered with soft edges over most of the picture area. Fine detail is visible on axis (image height 6mm), but becomes blurred when extending to the corners. At 1:2.8 contrast improves markedly and now centre quality is better than that of the Summaron. At 1:4, we note a small improvement in the field and at 1:5.6 fine detail is defined crisply till the corners, which stay very soft. On axis very fine detail has good edge sharpness, but the contrast is lower. There is a pronounced tendency to flare at wider apertures over the whole picture area, due to the presence of coma. Close up performance is fair and one needs to stop down for good imagery. The lens is very compact and the balance between size and image quality is evident. Distortion is negligible.

6.6.6 2.0/35, Summicron, (2), 1969

The six element redesign, from Midland, is a very short lens, and has been produced as a more economical version of the 8-element predecessor. At full aperture overall contrast is medium and higher than that of the previous version. The new design has on axis (image height 5-6 mm) a good definition of fine details, rapidly becoming softer in the field. Here (in the field) the previous one has an advantage. AT 1:2.8 overall contrast improves, which in itself sharpens the recording of fine detail, even if we cannot see more of it. At 1:4 very fine detail is recorded with clean edges, but performance in the field refuses to improve.

Figure 136: diagram 31

Stopping down further spreads the circle of good definition to image height 9mm, but the outer zones stay soft with low contrast. At 1:8 image quality inches up another small step, but is still somewhat less in the field than the 8-element version. At close distances however this lens has a really high performance and could be used for repro-work, when stopped down to 1:11. Flare tendency is high at wider apertures, but only in the field. Flare pattern is different between this lens and the previous one. The light patches in the previous version are larger but the energy is more diffused, where the newer lens has smaller flare spots, but of higher energy concentration. There is a balancing act here again: flare is often generated by coma, but this can be reduced by allowing more vignetting. As so often, the overall character of a lens is more like a personality, than as a simple listing of resolution figures. Vignetting is high with more than 2.5 stops, but the lens is distortion free.

6.6.7 2.0/35, Summicron, (3), 1971

A Midland redesign of the six element version, still with the same number of glass elements, brought some improvement in overall contrast. specifically on axis. In the field the performance drops significantly and is somewhat below that of the previous six element design. The optical design uses different glass types and the second group has a very small airlens, where the first version was cemented. Flare tendency is reduced compared to the previous designs.

Figure 137: diagram 32

Vignetting is lower with less than 2 stops, but now some distortion is visible. Generally however, these differences in fingerprint are low and will be visible only in direct comparison. This lens has a few millimetres more length to make the reading of the numbers on the rings easier.

6.6.8 2.0/35, Summicron (4), 1979

The fourth Midland version with seven elements delivers a medium contrast image and much improved quality at full aperture, specifically in the field as field curvature is corrected to a higher degree. Overall contrast is higher than in the previous version, but the corners are still very soft. Coma is less visible in the middle of the image area, but the lens shows a tendency to flare in the outer zones, where one can detect coma spots around bright small points of light Fine detail is recorded with soft edges, becoming quite fuzzy in the outer zones. At 1:2.8 rendition of fine detail becomes quite crisp till image height 18mm, abruptly becoming very soft in the corners. At 1:4 very fine detail is detectible over most of the picture area, excepting the corners and at 1:5.6 this level of detail recording is visible. Stopping down further brings more edge sharpness to this level of detail and at 1:11 we have a medium contrast coupled to a good definition of textural structures, which can stand bigger enlargements.

Figure 138: diagram 33

Vignetting is high with 2.5 stops and distortion is not visible. This version however is often referred to as a bo -ke champion. (SEE DISCUSSION in chapter 2.1). Compared to the predecessors it is an excellent design and its compactness has its own advantages. Optically however it is limited by the principles of the DG-design

6.6.9 2.0/35, Summicron ASPH, 1997

The Summicron ASPH belongs to the same design family as the Summilux aspherical and ASPH and shares with these lenses the radical new design. (see the Summilux aspherical report). At full aperture the lens exhibits a high to very high contrast, with crisp definition of very fine detail over most of the picture area. Corners are softer, but the image structures are well visible. Stopping down to 1:2.8 extends this quality of definition to the level of the very fine detail. At 1:4 the optimum is reached with very clean outlines and a high fidelity reproduction of small surface textures. After 1:8 contrast drops and edges of fine detail become softer. As with all modern Leica lenses, stopping down too much diminishes the excellent quality visibly. It is better to use slow speed film, than to stop down to 1:11 with higher speed films.

Figure 139: diagram 34

Vignetting is lower with 1.8stops and distortion is only visible at the far out zones. Flare is very well suppressed, but the lens is not immune to it: there are situations where secondary images or a strong flare patch can be noticed. This is an outstanding design and exhibits the lucid overall clarity, that is one of the characteristics of modern Leica lenses.

6.6.10 1.4/35, Summilux, 1961 (11870 to 1 meter, 11871 to .65 meter).

In 1961 Leitz Midland computed the Summilux 1:1.4/35mm for the M -system as the world’s first 1.4/35mm lens. It stayed in production till 1993, when the (second) aspherical version appeared. At full aperture the overall contrast is very low . Coarse detail is recorded with clean edges, but becomes much softer when going to the corners of the picture. Fine detail is rendered with low contrast and even finer structures are lost in the image noise, as contrast becomes so low as to blur the small details.

Figure 140: diagram 37

The flare level is on the high side. Stopping down to 1:2.8, overall contrast quite markedly improves and from that aperture the performance characteristics are identical to the Summicron (3) 1:2/35. Indeed so identical is the performance that one could get the impression that both lenses share the same basic computation. The long production period of the Summilux is a clear indication how difficult it is to improve on a well designed lens when the parameters are really difficult (1,4 and an angle of 64o are heavy obstacles for a designer. (SEE ENERGY FLUX). Vignetting is high with almost 3stops and distortion is not detectible. The Summilux, when compared to the Summicron version of its day showed a much lower contrast at wider apertures, but when stopped down had better performance in the field.

6.6.11 1.4/35, Summilux aspherical, 1990

The Double-Gauss design had reached its performance limit when applied to high aperture, wide angle lenses. During the research it became clear that substantial improvement of image quality asked for a new approach. Field curvature, chromatic version of astigmatism and oblique spherical aberration are the limiting optical errors for the DG-type. The employment of aspherical surfaces could reduce the spherical aberration, but not the rest of the errors. So a radical departure had to be found. The DG-type has a symmetrical construction with a converging lens (+)-diverging lens (-) -stop-diverging lens (-)- converging lens (+) sequence. This + - - + sequence has been flanked by two lenses with negative powers (diverging) to become - (+ - - +) -, giving the designer much more power to correct the aberrations. It is simple, but as always with genial ideas, simplicity is the hindsight. The design goal was to significantly enhance the image quality in the field, while keeping the physical volume small. The lens employs two aspherical surfaces of the grinded type and is probably the first lens, where the design is structured around the use of the aspherics. The method of grinding the aspherical surfaces was technically closely related to the procedure used for the Noctilux 1.2/50mm. The production started around 1988, while the lens was introduced in 1990. The Summilux aspherical is generally two stops ahead of the previous Summilux from 1961. At 1:2 it is better than the older one at 1:5.6.

Figure 141: diagram 38

Figure 142: 2.4.1 A

At full aperture we note a high overall contrast and very fine details are recorded with fidelity and high clarity on axis (image height 10mm). From there the quality is reduced gradually and at the corners the details are fuzzy. At 1:2 contrast improves visibly and the definition of very fine detail is crisp, excepting the outer zones where these details are becoming softer, but still with good visibility. At this aperture it is ahead of the Summicron asph at 1:2. But the Summicron at 2 is ahead of the Summilux at 1.4, which is no surprise as there is a full stop difference. At 1:2.8 the very fine details are very crisply rendered over almost the full image area and at 1:5.6 extremely fine detail and subtle shades of grey and colour hues are reproduced with accuracy. Flare is well suppressed but at the widest aperture there is some internal reflecting that becomes visible as secondary images. Vignetting is lower with about 2 stops and distortion is visible.

6.6.12 1.4/35, Summilux ASPH, 1994.

This lens uses one aspherical lens surface of the blank-pressed type. Generally this lens performs in an identical way as the ‘aspherical’-version. There are a few very subtle differences: the ‘asph’ version has on axis slightly lower contrast, but a more even performance in the field at apertures 1.4 and 2. From 1:2.8 both are equal in image quality.

Figure 143: diagram 39

Figure 144 6.6.12

A aspherics Vignetting is slightly higher with 2.5 stops and distortion is visible. The fingerprint differences are really very small, if measurable and I would not be put to the test to identify which lens is used when presented with some pictures.

6.6.13 2.8/35, Elmarit-R (1), 1964

The 1964 version has low to medium overall contrast at full aperture, soft rendition of fine detail and a smooth reduction in performance from centre to corner. In the field there is low contrast and image details are outlined with fuzzy edges. Vignetting is 2 stops and distortion is just visible. Stopping down to 1:4 markedly improves the overall quality with a crisp rendering of fine detail that extends into the field until image height of 12mm. Stopping down further does not bring additional performance in the field, with the exception of the edges, that do improve. The lens is sensitive to flare, vignetting is 2 stops and distortion is well visible. Later versions had all metal mounts and a change in the optical cell, where the 2nd and 3rd element are no longer cemented, but have a tiny airspace. Performance does hardly change, so it is a matter of opinion if one would recognize this as a separate version. Sometimes optical changes are made for reasons of production technique and not necessarily to change and improve the performance. This lens is stopped down very good, but given its modest specifications, one would expect no less.

Figure 145: diagram 28

6.6.14 2.8/35, Elmarit-R (2), 1973.

The next version, from 1973, has much improved overall contrast at full aperture and fine detail is rendered with good visibility on axis (image height 6mm), becoming progressively softer when reaching the corners. Vignetting is slightly less with 1.7 stops. Stopping down to 4 brings marginal improvements and at 5.6 very fine detail becomes visible on axis, but in the field is quite blurred. At 1:8 performance evens over the whole image area and contrast begins to drop a little. In the field the definition of finer details is soft. Distortion is more visible. This behavior is typical of many older designs. Performance improves only reluctantly and is more governed by the natural effects of a smaller aperture (crispening of finer details as marginal rays are cut-off from the image forming process) than by the inherent correction of the lens.

Figure 146: diagram 29

Close up performance is excellent and if this is a required application, the Elmarit should be preferred over the Summicron-R 35mm.

6.6.15 2/35,Summicron-R (1), 1972 Wetzlar design and Midland production

The first version of a 1:2/35 lens for the R has the same fingerprint as the Elmarit-R 1:2.8/35mm (second version). At full aperture overall contrast is medium and while on axis (till image height 6mm) we see clear definition of fine detail, in the field the contrast drops sensibly and details are soft., becoming fuzzy in the edges. There is a tendency to flare and ghost images.

Figure 147: diagram 35

Vignetting is less than 2 stops. At 1:4 the overall contrast improves and this brings good edge sharpness to the outlines of larger subjects. At 1:5.6 the contrast in the field is enhanced and for the recording of fine detail is now as good as on axis. We need to stop down to 1:8 to record really fine detail over a larger part of the image field. At 1:4 overall performance is somewhat below the Elmarit, but from 5.6 the Summicron offers better imagery in the field, due to an improved correction of field curvature. For good image quality at closer distances, one should close down a few stops, as distortion is visible at wider apertures.

6.6.16 2/35 Summicron-R (2), 1977

Midland design and Wetzlar production. Relatively soon, in the Leitz world at least, an improved version has been introduced. It is more compact and also of less weight. At full aperture overall contrast is a bit lower, but the performance on axis extends farther into the field (till image height 12mm). The edges are not as good as with the previous version, which is more visible too as the field performance is better. Vignetting is 2 stops. Secondary reflexes are suppressed to a higher degree. At 1:2.8 contrast improves and brings the usual crispening of edge sharpness. From 1:4 we see comparable performance as with the previous version, which has lower contrast in the field. At 1:5.6 the newer version has a marginal edge and from !;5.6 both lenses perform on the same level.

Figure 148: diagram 36

The remarks on close-up pictures for the previous version are valid here too. This lens is specifically better at the wider apertures with higher contrast and less flare and improved rendition of finer details. If we look for family signatures, the Summicron-M 2/35 from 1979 is closest, with the M-version exhibiting more overall contrast and slightly softer detail rendition in the field.

6.6.17 1.4/35 Summilux-R, 1984

The design of a very high speed 35mm lens is not easy, as angle of view and aperture conspire together to allow a large amount of light energy to pass through the lens, with a corresponding boost in the level and amount of aberrations to be controlled. A very high speed lens for the R-system should complement the Summilux 1.4/80 and 1.4/50 from 1970. The first 1.4/35 design for the M was created in 1961 and it took the Leitz designers 20 years to get to grips with the same specifications for the R, with two additional requirements: very close-up performance and retro-focus design. The Summilux -R for the 35mm focal length was a Wetzlar design and a vast array of optical means was required to improve upon the M-version from 1961. The M-version had to be designed within the limits of a compact lens and it may represent what was then possible with conventional means. The R-version could be designed with more liberty concerning the size and so a ten element optical system with a floating element emerged from the drawing board.

Figure 149: diagram 40

At full aperture overall contrast is medium: on axis fine detail is rendered with clarity till an image height of 6mm and from there to the edges the definition becomes softer rapidly. Vignetting is less than 2.5 stops. Performance in the extreme corners does often improve because of vignetting, and this lens is no exception, especially if we look at the level of the rendition of very fine detail. At 1:2 overall contrast improves and fine detail in the field is now defined with clean edges. Stopping down further improves the contrast on axis and at 4 and 5.6 really fine detail is accurately reproduced. In the field the improvements are small and very fine detail is just visible with blurred edges. At 1:5.6 centre performance is excellent, with a gradual softening of the small textural subjects. In extreme light conditions the Summilux has good flare suppression and less coma, better than the 1:2/35 companion lens. Close -up performance is significantly enhanced thanks to the employment of a floating element. The extender however should not be used.

6.6.18 2.8/40 Elmarit-C, 1973

This lens was initially planned as the standard lens for the Leica CL. A few hundred found their way into the public domain, read the collectors. Its general performance is close to that of the Elmar 12.8/50mm At full aperture overall contrast is low, coarse detail is rendered with low contrast, but acceptable visibility. Finer detail is fuzzy and becomes blurred in the outer zones.

Figure 150: diagram 41

Vignetting is 1.5 stops. At 1:4 overall contrast jumps up, improving the definition of fine detail on axis, but in the field there is only a marginal improvement. Stopping down further brings in the clear definition of fine detail in the field. But even at optimum aperture, the performance is really below the standard of the day and it would have been bad for the reputation of Leitz if this lens had become the standard lens for the CL.

6.6.19 2/40 Summicron-C, 1973

This 6 element double-Gauss is better in all respects than the 2.8/40mm. A compact 6-element Gauss lens is not easy to design. A 5-element version is compact, but has disturbing chromatic errors in the field and a 7-element would be too long. For the front lens Leitz used a glass with high refractive index to partly address this problem of the aberrations. Some of the glass was created in the Leitz glass lab. (The Minolta version used Minolta glass). At full aperture the overall contrast is medium to high and fine detail is rendered with clean edges on axis only (image height till 3mm), with a fairly rapid drop in the field and edges. Vignetting is 2 stops. Stopping down to 1:4

improves on axis performance significantly till image height of 6mm, after which the contrast drops rapidly to low values and very fine detail is just recordable. At smaller apertures the image quality in the field slowly improves with excellent definition of very fine detail on axis and fairly good in the field. Distortion is detectible, but not disturbingly so.

Figure 151: diagram 42

Overall performance is between the Summicron 35 type 3 and type 4. The 6-element Summicron 35 has a slightly better performance at full aperture, but stopped down is a bit less good in the field. The 7-element Summicron 35 is better in the field, but it suffers more form strong zonal errors. So it would be horses for courses? Partly yes. The differences in fingerprint or character do also show that is very difficult to describe a Leica lens in a superficial manner as every lens has its own specific characteristics. 6.6.20 4/35mm PA-Curtagon-R, 1970 Perspective Control (PC) translated into German becomes "Perspektivischer Ausgleich", hence the PA in the name. This version has a movement of 7mm in horizontal and vertical direction. Image quality is good for the intended purpose, but below that of the later PC-28. It is a low contrast lens with limited ability to reproduce fine detail accurately. But as this type of lens needs to be stopped down substantially to use the shift facility, the wide open performance is less interesting. When moving the lens, the ground glass will progressively darken as the exit pupil of the lens and the entrance pupil of the finder are displaced relative to each other.

Figure 152: 6.6.20 PA C It has figured in the catalogue for almost 25 years.

6.7 60 to 80mm

In this range we find two types of lenses: those around 60mm, which are designed for macro and close-up photography and those around 75mm, designated for use in low light situations. The specific focal lengths have been chosen for practical or optical reasons. The 60mm is a bit easier to correct than a 50mm lens. The 75mm lens started life as a 70mm, which fits in more nicely in the focal length table, and the prototypes in the Leica archives all are 70mm and designed in Wetzlar. The production design was reformulated in Midland in the last half of the seventies. These lenses are probably the last ones which have been designed by the analytical or synthetic method. (see chapter 1). The Summilux 1.4/75 and 1.4/80 for M and R are similar designs and represent the new approach of Leitz to try to design the same lenses for both systems, if possible.

6.7.1 6.7.1 3.5/65, Elmar, later Elmar-V, 1960

This is a lens for the Visoflex attachment. It is a low contrast lens with a soft recording of finer details at full aperture. Vignetting is one stop. Stopping down does improve the performance, but it stays a bit fuzzy.

Figure 153: diagram 67

The use of the Elmar design as a macro lens my be questioned. Distortion is visible.

6.7.2 6.7.2 2.8/60,Macro-Elmarit-R, 1972

At full aperture overall contrast is high and very fine detail is crisply rendered over most of the image field, becoming a shade soft in the corners. Vignetting is low with 1.2 stops and distortion is absent. Stopping down to 4 brings in the definition of extremely fine detail and at 5.6 the optimum is reached with a clear rendition of this level of detail recording. Performance from centre to the extreme corners is even and is in this respect better than the current Summicron-R 50mm.

Figure 154: diagram 66

On axis we see the same level of image quality. Close-up performance is as good as that at infinity and if a versatile lens is needed with excellent definition over the whole picture area, this lens might be an interesting alternative to the Summicron-R 50mm.

6.7.3 6.7.3 1.9/73, Hektor, 1931

The Hektor 1:1,9/73mm was the first attempt of Berek to design a high speed lens with a moderate angle of field. The triplet design however could not be stretched too much. The Hektor 2.5/50mm and the Hektor 1.9/73mm allow the same amount of energy flow to pass through the lens. The wider aperture of 1.9 (2/3 of a stop more than the 1:2.5) is offset by a 50% smaller angle of field. (34° versus 45°). clearly was aware of the limits of the generic Hektor design. The 1:1.9/73mm short telephoto lens at the wider apertures has that typical softness at the edges of outlines and the very smooth transition of the sharpness plane into the unsharpness blur of fore-and background, that became the defining characteristic of the portrait lens for generations of photographers. At full aperture the overall contrast is very low and while outlines are recorded with soft edges, the finer details are very soft and becoming blurred in the outer zones. Stopped down to 2.8 the higher contrast improves the clarity of outlines and coarse details. Closing down a few more stops, brings in the fine details, that stay soft however. Given the coarse grained films to be used with this lens, the finer details would become immersed in the grain noise and become invisible. On the other hand, the larger blur circles of this lens would force the grains to clump together more.

Figure 155: diagram 68

Distortion is not visible. Flare sensitivity however is very high. With a price tag of RM 105 (1938) it was 22% more expensive than an Elmar 50mm and about as expensive as the Hektor 28mm.

6.7.4 6.7.4 1.4/75, Summilux-M, 1980 & 1.4/80, Summilux-R, 1980

Comments apply to both lenses and fingerprint differences are noted when appropriate. At full aperture, overall contrast is medium and coarse detail is defined clearly over most of the picture area. Fine detail is recorded with good visibility but softer edges on axis. Performance drops very gradually when going to the corners in the case of the R-version and drops more rapidly with the M-version. Vignetting is 1.5 stops. Flare is well suppressed, but in high contrast light there is a softening of overall contrast. Coma is corrected to a high degree and the typical butterfly images of small light points in the field are relegated to the outer zones. At 1:2 overall contrast markedly improves and very fine detail is recorded with crispness on axis. Again the R-version has the edge in the outer zones, when one looks at the outlines of subjects. We should realize however that these differences, while measurable, will be probably lost in every day picture taking. At 2.8 the on axis quality (till image height 6mm) improves visibly, and extremely fine detail is now recorded with clean edges. In the field we see no improvements when compared to the 1:2 aperture. At 1:4 the circle of excellent quality extends to 9mm image height. From 1:5.6 the image quality in the field is gradually enhanced and till image height of 15mm we see extremely fine detail crisply recorded.

Figure 156: diagram 69 (75)

Figure 157: diagram 70 (80)

Distortion is not visible. Comparison with a Summicron 90mm is not easy as there are several versions. The R-80 comparison with the Summicron R-90 shows that at 2 and 2.8 on axis performance of the R-80 is better (specifically the overall contrast) and the R-90 has the edge in the field. At smaller apertures this behavior does not change, but the differences are less visible of course. The M-75 comparison to the Summicron-M (3)-90 from 1980 shows that at 1:2 the M-75 has a very clear edge in overall contrast and the definition of fine detail in the field has somewhat higher micro-contrast. From 1:4 the M-90 inches ahead with a marginally better quality in the field, similarly the R-lenses. In the outer zonal areas the 90mm lenses render the extremely fine details with crisper edges, which will be visible in bigger enlargements. On the assumption that these lenses will be used at lower speeds in handheld reportage situations, the finer points of difference will vanish for all, but the most critical inspection. The superiority of the 1.4 designs extends to apertures around 1:4. If you use your lenses mostly at middle apertures, the Summicron's are as good a choice and I would suggest that then the latest or current Elmarit1:2.8/90mm would be the obvious choice. The new Apo-Summicron-Asph 2/90mm at 1:2 provides an image quality that the 75/80/90 lenses offer at 1:4 or smaller. This optical progress is hard to believe or accept, but it does show what we can expect from the design team in Solms. There is a time span of 20 years between the 1.4 designs and the new M-90mm, and during this period, there has been progress in many areas, which explains in part the difference noted.

6.7.5 1:2/75mm Leica Summicron-M ASPH

When Leica indicated that they were about to develop a new lens with a focal length of 75mm, I was a bit surprised. The 75mm seems to hold an uneasy place between the 50mm and the 90mm. There is a certain myth around this focal length, based on the excellent qualities of the Elcan 2.4/75mm, designed by the late Dr. Mandler. The physical specifications of this lens have been closely copied by the Voigtlander 1:2.5/75mm. Many photographers dismiss the 75mm as the lens seems to be too close to the 50mm focal length. If you make a few steps forward to your subject with a 50mm lens you can emulate the magnification factor of the 75mm, so the argument goes. And for the 90mm it is the reverse argument: just step back a few steps and you have the magnification of the 75mm lens. This type of reasoning ignores the finer points of the laws of perspective, about which I have to say more in this review.

To answer the basic question why the 75mm came into existence, we have to return to the high speed wars in the sixties and seventies. In those days, every respectful manufacturer tried to outdo the competition with ever-faster lens designs. The aperture 0f 1.2became the norm and the number of lenses with the specifications 1.2/50, 1.2/55, 1.2/58, 1.2/85 grew rapidly. Leica could not stay behind and produced the 1.4/80 for the R-series and the 1.4/75 for the M-series. The choice for these parameters was simply dictated by size and weight considerations. A 1.2/90 for R would be too big and heavy and a 1.2/90mm for M would obscure the rangefinder window too much. And the aperture of 1.2 could not be designed on the basis of the Leica equation for image quality.

So the 1.4/75 was a solution that satisfied the competing demands for size, weight and optical performance.

The rangefinder had to be redesigned with an additional frame for the 75mm and this change was partly responsible for the flare issues that have plagued the rangefinder window after the introduction of the M4P, the first body that could accept the 75mm lens. In fact both were introduced at the same time.

The Summilux 1:1.4/75mm has been designed more than a quarter century ago as a derivation of the classical Double-Gauss design. It offers excellent image quality, even according to current state of the art references. Its wide-open performance is quite good, but lacks the punch of lenses with smaller apertures. The effect of the residual aberrations is too strong at this wide aperture and cannot be countered by the means then available. The wide open performance sits between the more painterly drawing of the Noctilux at 1/50mm and the scientific drawing of the Summicron at 2/50mm, but is improved upon the Summilux 1.4/50mm, due to the smaller cone of light it has to transmit to the film plane.

The Summilux-M 1.4/75mm is a true workhorse: you need the lens and then you use it or you do not need it and then you do not buy it. The lens has no glamour or myth attached to it and is not a collector's item. And when you need it, you use it indefinitely and that may be the reason why so few Summilux 75mm lenses are offered on the second hand market.

The new Apo-Summicron-M 1:2/75mm ASPH is a derivation of the recently introduced Summilux-M 1:1.4/50mm. It has the same design characteristics: floating element, aspherical surface, a copious use of exotic glass types, the variety and cost of which explain in part the price. The design uses seven lens elements as analysis showed that element eight did not contribute to the image quality and had no added value.

The philosophy behind this design can be read in my review of the Summilux-M 1.4/50mm ASPH.

In a recent talk about the design considerations behind this lens, the designer drew attention to the main problems when trying to achieve superior performance with high-speed lenses. We are familiar with the main types of image aberrations, like spherical aberration, coma, astigmatism etc. But once these are sufficiently corrected the designer faces serious trouble in the reduction of the Petzval sum and the secondary spectrum (by means of achromatization). These aberrations can only be reduced by the use of the combination of many different glass types. If we are able to reduce the primary aberrations of spherical, coma and astigmatism, we get a perfectly sharp image point, but on a curved surface. The surface is curved because the lens elements have a curved shape. But we need a plane surface at the film gate. In the past, the designers had to introduce controlled amounts of astigmatism to offset the Petzval curvature. Leica lenses, especially the M lenses, used this technique, partly based on the nature of the Leica photography for reportage and documentary purposes, where good definition from centre to corner was not the prime directive. Most aberrations are corrected by the method of lens bending: changing the radius of curvature. But lens bending cannot influence the Petzval sum and the chromatic aberrations. Only a change in the power of the lens element and the spacing of the lens element can do the trick. Changing the power implies often a different type of glass (different glass index) and the matching of the glass types can hardly be optimized by use of the computer. That may be one of the reasons why in the range from 35 to 90mm, the designs are all based on the Double-Gauss design type.

Leitz did experiment with exotic glass types in the past and even added layers of different glass together in one element to come to terms with these problems. An example of this glass can be found in my book. A theoretical study to break out of the grip of the classical designs was conducted at Leica several years ago and the result was a lens of breathtaking performance (an eight element 50mm design with GRIN lenses), but too expensive to manufacture. The insights gained however, were instrumental in designing the new Summilux 1.4/50mm ASPH. The Summilux is not so fully corrected as the Apo-Summicron-M 1:2/75mm ASPH, which is logical as the field of view and the aperture are both smaller, easing the design problem. But the liberal use of the high index glasses with anomalous dispersion, the use of the floating element (the spacing problem!) and the use of an aspherical element add up to the solution for the reduction of the Petzval sum and the chromatic errors. The aspherics in both the 1.4/50 and the new 2/75 are both the moulded version of the aspherical surfaces, not the grinded versions. One of the arguments to use the aperture of 2 is the size of the aspherical lens, which would be too large if the aperture were to be stretched to 1.4.

The floating element is of a special construction. To get a focusing range from 70cm, wider than the customary 1 meter, the throw of the rangefinder curve had to be widened by 5mm to accommodate the range from 70cm to 100cm, which is mechanically complicated. And the relative movement of both groups is not linear as in most designs.

The Summicron 75mm is a normal long lens construction and not a telephoto version. This supports the performance at close ranges. Still the image quality in the close range is not as good as what is delivered in the range from 1.5m tot infinity. For really critical work one needs to stop down to improve micro contrast and the overall contrast of the image.

On test

At full aperture the lens delivers a very high contrast image with even performance from centre to the extreme corners. The resolution of 80 linepairs/mm from centre to edge is unsurpassed at this time of writing. Of greater importance is the edge contrast that is sharply delineated without the smallest amount of colour fringing. The lens is not perfect wide open as we can see a small band of lower contrast (a dip) in the zone from image height 9 to 15mm. Here the contrast of the horizontal line patterns suffers a bit, but the lines can be seen quite clearly, but with some fuzziness. Coma, often a problem in high-speed lenses is fully corrected, as is astigmatism.

Stopping down to f/2.8 improves contrast and now the dip is gone completely. Resolving power reaches a value of more than 100 to 125 lp/mm over the whole image area. The image is of exceptional clarity and punch and the definition of extremely fine detail is outstandingly good. Stopping down further increases depth of field, and some crispening of the finest recordable detail, but this will be hardly visible outside the lab situation.

In practical terms we may say that the lens can be used wide open with the utmost confidence and the images can be blown up to whatever size one wishes without fear for blurring the details. Pictures made at f/2 at medium distances around 4 to 6 meters deliver excellent imagery and when studying the level of recorded details, one cannot believe that these are made at an aperture f/2.

The colour rendering is quite neutral and on the rich side as far as saturation is concerned. The particular strong point of this lens is its stunning propensity to show the depth of the subject with a three dimensional quality that is seldom encountered.

Veiling glare is totally absent and the lens produces deep black shadows with clean separation of subtle shadow detail. The internal blackening of the mount and the black paint on the rims of the lens elements effectively reduces secondary reflections and halos around specular highlight spots are not detected. On the other hand, we cannot shoot deliberately against the sun without causing some reflections and the lens is not fee of secondary images under all circumstances. It would be quite unrealistic to assume that a lens is totally immune for flare. The Apo-Summicron 75 is quite good in this discipline.

This lens is a primary choice whenever the realistic rendition of solid objects is required. The definition of the unsharpness blur is quite smooth and lacks the harshess of some very high speed lenses.

I made comparison pictures with the 2/50, 2/75 and 2/90mm Summicron lenses and the same distances and at the same magnification and of course wide open and stopped down. The conclusion of this exercise will not please the bo-ke fans. I did not see any visibly significant differences in the reproduction of the background blur. The famous words that beauty is in the eye of the beholder may be transposed to the bo-ke discussion. The subjective qualities of the background are often a major element of the composition, but one should not focus too much on this aspect. The quality of the sharpness area is still the defining property of a picture.

The Summicron 75mm operates with the solid smoothness that is the defining property of the current generation of Leica lenses. The lens is heavy for its size, but the weight of the special glass types asks its toll.

High contrast lenses

There is some confusion about the meaning of high contrast in the context of lens testing. One reads very often about the possibility that a high contrast lens should be matched to a low contrast subject and a low contrast lens should be a good choice for a high contrast subject. The match of a high contrast negative to a low contrast printing paper is well known and presumably one assumes that the same kind of match works for the contrast properties of a lens. A high (low) contrast subject or scene is one where the contrast range from deep shadows to specular highlights is wide (narrow). Or in other words the tone reproduction curve is steep or extended. What works for the tone reproduction cycle in the subject-negative-positive process cannot be migrated to the properties of a lens.

A high contrast lens does reproduce the spatial frequencies with good edge contrast. The low spatial frequencies (around 10 to 20 lp/mm) define the main outlines of the subject. But we need the high spatial frequencies to get good edge sharpness. See the figure below, which shows a bar line with steep edges. To reproduce these edges we need the high frequencies! In the diagram the rounded smoothed curve represents the reproduction of the bar line when the high spatial frequencies have been filtered. The resulting bar line has soft edges and will be seen in the picture as an outline with a fuzzy edge.

A high contrast lens will reproduce the details of the subject with good edge contrast, whereas the low contrast lens will reproduce the details with fuzzy edges and the cut-off level where fine detail is totally blurred is reached quick quickly.

Low contrast lenses are not able to reproduce the high spatial frequencies faithfully and quite often have a high amount of residual aberrations, which will be seen in the picture as an elevated level of flare. This may be the cause for the confusion: the flare in the low contrast lens will redistribute some of the light of the highlight parts of the picture to the shadow areas, which will have more density at the expense of the highlights. It seems that the tonal range is extended in the shadows, but that is not the case. The tonal range is identical, and there is not more shadow detail. The shadows seem to be easier to print.

Comparison with other Leica lenses

The obvious candidates are the Summicron-M 2/50 and the Apo-Summicron-M 2/90 ASPH.

The MTF diagrams below are indicative of the state of the art. The Summicron 50mm is weaker in the corners and the critical frequency of 40 lp/mm is for a large part below a contrast transfer of 40%. In practice this translates in a slightly less punchy imagery. The Summicron 50 at full aperture draws with somewhat wider brushstrokes than the Summicron 75mm. One may reflect on the additional effort that has to be put into the 75 to get a visibly enhanced imagery compared to the relatively modest outlay of the 50mm design.

The Summicron 90mm is in the same class as the 75mm, but note the more pronounced curvature of field of the 90mm. At the most critical inspection of pictures made at aperture f/2 with the 75mm and the 90mm, one can note that the 75mm has a tighter grain structure, an indication that the residual aberrations are reduced to an even lower level.

The four lenses in the focal range from 50mm to 135mm represent the Olympic platform for the Leica M range: the Summilux-M 1:1.4/50mm ASPH, the Apo-Summicron-M 1:2/75mm ASPH, the Apo-Summicron-M 1:2/90mm ASPH and the Apo-Telyt 1:3.4/135mm are able to extract every possible image detail from today's film emulsions and one feels entitled to question the necessity to improve these lenses further as long as one is working with film.

The Leica M camera system is often designated as predestined for wide-angle photography and while undoubtedly true, the qualities of the standard to medium focal length lenses are such that the joy of photography on the performance edge of the medium has to be experienced to become a true Leica master.

The Color-Heliar 2.5/75mm

This Voigtlander design is the obvious candidate for comparison with the new Leica 75mm lens. Overall the C-H has a very good definition of detail in the centre part of the image, but with quite soft rendition of detail in the outer zonal areas of the negative. There is also a visible colour fringing at the edges of the main subject outlines. Stopping down improves the contrast and the performance becomes more evenly distributed over the whole image area.

In numbers: wide open the resolution in the centre is excellent with 125 lp/mm, but this drops to 30 lp/mm at the edges with quite low contrast and fuzzy edges. At f/5.6 the edges are improved to 50 lp/mm with some fuzziness and a faint amount of colour fringing.

The C-H is a very good design with an excellent price-performance relation and one can wonder how it is possible that Cosina can deliver such a performance for the modest price asked for the lens. The image quality of the lens will satisfy many users, it in self a sign that the relentless drive for the ultimate performance has a natural end.

Status of optical design

The Summilux-M 1:1.4/50mm ASPH and its sibling, the Apo-Summicron-M 1:2/75mm ASPH do represent the current state of the art in optical design. The combination of aspherical surfaces, floating elements and in particular the break through in glass manufacture with the new glass types may be the turning point in the history of optical design for film based photography. Looking at the MTF graphs one may see still room for improvement, compared the best designs in the R range (the long focal lenses), but for the M range one is inclined to see the current level as a platform. To extract more performance out of the design would imply more complicated designs at a cost that no one will feel prepared to pay. On the other hand the technique required to use this high performance is so demanding that it makes the concept of a dynamic style of M photography obsolete. Mechanically the new lenses are at the bleeding edge of manufacture and quality assurance. These designs could never be made in large quantities and one may be very happy that Leica is not sitting on its laurels and wishes to exploit its niche properties to deliver outstanding quality for the discerning Leica user and aficionado.

The position of the 75mm in the M lens line.

When I first heard of the introduction of the new 75mm lens, I was a bit sceptical and wondered if the lens, however good, would be squeezed between the popular and classical 50m and 90mm focal lengths. I already own the Summilux 1.4/75mm and I am familiar with the fact that the perspective and field of view of the 75mm are often advantageous, compared to the 50mm and 90mm focal lengths. The 50mm angle of field is in many cases just too wide and you have the inclination to reduce the distance between the camera and the subject, but then some subtle distortion will mar the picture, especially when photographing persons. With the 90mm you need more distance than is required for fine focussing or a psychological rapport to your subject. When you change quickly between the 75mm and 90mm, you will be surprised how fast and accurate the focusing becomes with the 75mm, where the 90mm is slower due to its bigger throw and the reduced (visual) accuracy of the finder. The 75-135 pair could replace, or ideally complement, the classical combo of 50mm and 90mm with a wide latitude in picture opportunities.

The magnificent four (to borrow a title from that classical Western movie, the magnificent seven, deliver the best imagery money can buy in the M line. While there is a certain overlap in possibilities, the fingerprint of these four is sufficiently different to justify the existence of them all.

6.8 6.8 85-90mm

The focal length of 90mm has been one of the first to be added to the Leica lens system. It has been designated as a portrait lens, but it did not originate with such a goal. When films had limited enlargement capacity and quite coarse grain, finer details could not be recorded. The 90mm could be used to magnify details above the threshold of the recording capacity of films and in the original documentation you will find references to this usage. With the 35mm wide angle lens, introduced at the same time, the Leica system comprised of three lenses which have been the classic triumvirate since more than 70 years. The 35, 50 and 90mm focal lengths have been redesigned often, with all kinds of changes in physical dimensions and apertures. The Summicron versions formed the backbone for the best optical quality of the Leica system. For the M-system this still holds. The R-system evolved in a different direction with the high quality zoom lenses. As a historical aside, it may be mentioned that these three focal lengths, developed in the early part of the 20th century, have shaped our view of the world through photographic images. I would not like to label the 90mm (or for that matter the 35mm lens) as the lens for a certain class of objects, nor to state that the 35mm or the 90mm is the prime lens for the Leica M or R system. Lenses are tools, and should be selected based on goal and intention. The 90mm is indeed a fine instrument for portraits, but so is a 180mm or a 50mm and the 90mm may be excellent for reportage and landscapes. The key to successful Leica photography and 35mm photography in general is to fill the small picture area with as much visually attractive content as possible. The old masters were fully right in insisting that the less enlargement, the better. The 90mm is very good for visual concentration, but on the other hand quite demanding on composition. It is easier to find a pleasing composition with a 35mm lens than with a 90mm.

6.8.1 1.5/85, Summarex, 1943/1948 .

The Summarex 1:1.5/85mm is first mentioned in a 1943 catalogue as a black version with the inscription 1:1.5/9cm. The earliest reference is 1940, when 6

lenses have been produced, presumably as a Null-series. In 1943 a batch of 500 has been allocated, but is doubtful if these lenses have been all produced and certainly only a precious few would have been available for sales to the general public, at least in 1943. Closer study of the archives shows that the first 100 lenses of the production were all of 1.5/90 designation and went in a lot to Berlin, to the "Beschaffungsamt"(purchase and distribution department) of the German Army. The other lenses (with addition of a "B"(for the 1.5/85 designation, have been sold to the public, but only after the war. The next series is from 1948 and production stopped around 1954. This might be the appropriate place to mention that actual production period and dates of allocation of serial numbers do not coincide. It is reasonable to assume that a batch will be produced in one production run as the workers at the assembly line can get well trained in the assembly of this lens. In this case the last allocation date is early 1954 with a batch of 1000. The true production period might be anywhere in 1954 and sales might extend well into 1960, when the lens is officially put off the catalogue. To be precise, it would be preferable to state the actual production dates and not the period a lens does figure in a catalogue.

Figure 158: diagram 71

At full aperture the Summarex has very low contrast, but its performance is even across the whole picture area and astigmatism is very well reduced. Outlines and coarse detail is recorded quite visibly, but with fuzzy edges and finer detail is fully blurred. At 1:2 overall contrast improves and now the on axis performance increases visibly. At 1:2.8 we now detect finer detail in the field and on axis performance has a bit more power. From 4 to 8 the definition of fine detail gradually improves over the whole picture area. Stopped down to 1:8, image quality is very good and at 1:11 the lens reaches its optimum with an overall performance equal to the Elmar 4/90 at 11 Flare and secondary images are quite visible, even in the coated version. Vignetting is low with one stop and distortion hardly visible. This lens might be called a limiting case. Stopped down it is as good as any Leica 90mm of contemporary age, and its wide aperture extends the possibilities of the Leica photographer into uncharted areas, but in itself this wide aperture is a bit daring as the image quality shows. The remarkable improvement at 1:2 is an indication of its true potential.

6.8.2 4/90 Elmar, 1930

The Elmar 1:4/90 at full aperture has a low to medium overall contrast and renders finer detail with good clarity over an extended area (image height about 12mm). The corners are weak. Stopping down brings somewhat higher contrast and definition of fine detail on axis improves as stray light is reduced and the peripheral rays are cut off from the imaging forming process. Around 1: 8 the centre has crisp definition of quite fine details and the outer zones now record finer detail with soft edges, but quite visible.

Figure 159: diagram 72

The Elmar 90mm lens shows some curvature of field and some focus shift, but can be used with good effect at shorter distances. Compared to the Elmar 1:3.5/50mm we note that overall contrast is on the same level, with the 50mm a shade behind. Finer detail is recorded with cleaner edges by the 90mm version, and when stopping down, the 90mm improves more than does the 50mm.

6.8.3 4/90mm Elmar (rigid and collapsible), 1954.

The general optical and mechanical improvements, including coating of lens surfaces, gave the optical performance of this version of the Elmar 90mm a small boost. Optical layout has not changed, but several new glass types are employed.

Figure 160: diagram 73

As noted at several occasions, the lens drawing does not tell the whole story. At full aperture the lens gives a medium contrast image over most of the picture area. On axis the clear definition of subject outlines and of fine detail brings commendable image quality, if one does not enlarge too much. In the field the performance drops considerably, with the exception of the subject outlines, that soften only slightly. As the eye is most sensitive to the contrast at the edges of large subject shapes, the general impression of pictures taken with this lens, is quite good. At the wider apertures the basis aberrations are still degrading the image quality. Stopped down to 1:11 we find a very even performance of a commendable quality over the whole image field.

6.8.4 4/90mm, Elmar , 3-element lens, 1964.

Figure 161: diagram 74

This lens is a Canadian design and with only three single elements, a case-study of optical simplicity. Its full aperture performance is better than that of the predecessor with the classical 3 group/4 element construction. Overall contrast is a bit higher, the definition of fine detail has improved edge contrast and especially the performance in the field is much better. Vignetting is .7 stops. At 1:4 the contrast gets visibly higher and now very fine detail is recorded over the whole image area with good clarity. The Elmarit 1:2.8/90mm at 1: 4 cannot equal the 3-element Elmar here. Stopping down further brings in finer detail and at 1:11 we find image quality of a thoroughly modern level. This lens has been introduced at the same time as the Tele-Elmarit 1:2.8/90mm, which replaced the Elmarit 1:2.8/90mm. As the Tele-Elmarit could not be used with the bellows attachment and had not the best performance at closer distances, Leitz offered the Elmar as a lens for these applications. Close up performance is quite good. Distortion is negligible. It does show the intriguing strategy of fine tuning the lens performance for a specified set of tasks. It was not possible in those days to create one general purpose lens and so Leitz optimised the designs in different directions. A luxury that could not be extended indefinitely as it was a costly strategy. With modern glasses, this lens would deliver a very interesting performance.

6.8.5 4/90, Elmar-C,1973

The eagerly awaited Leica CL (the "Baby-Leica") was accompanied by its own set of lenses, the Summicron-C 1:2/40mm and the Elmar-C 1:4/90mm . This 90mm lens delivers already at full aperture excellent quality with a high contrast image over most of the picture area. It equals the Elmarit-R 1:2.8/90mm of its day (from 1964), and is better than all Leitz lenses in this focal length and aperture 2.8 and 4, at least the ones available in the early seventies. Very fine detail is clearly recorded, be it with soft edges, which might become visible, at bigger enlargements, as a fuzziness when of small textural details. Stopping down to 1:5.6 and 1:8 enhances contrast and on axis the image quality is quite high now, gradually becoming worse when one wishes to capture really fine detail in the outer zones. Generally the zones do not improve that much with this lens: an indication that the residual errors are still quite active.

Figure 162: diagram 75

Close up performance is excellent too and distortion is non-existent, making the lens suitable for reproduction work. Vignetting is 1 stop. In the lens diagram we note as a remarkable feature, the negative meniscus lens as the fourth element. The Minolta Rokkor-C is identical and has been built in Wetzlar too. The mount and rangefinder coupling of the Elmar-C are different from the regular M-lenses. The Elmar has a very steep curve, as its turns only 120o. A small movement of the focusing ring translates into a substantial movement of the optical cell, which makes it difficult to use for accurate focusing and measurements. C-Lenses couple accurately to the M-body as the bayonet is the same, but focusing errors might occur.

6.8.6 1:4/90mm Macro-Elmar-M

Every advantage has its negative counterpart. We may assume that there is nothing free in the universe. Gain here, loose there. The Leica rangefinder system is a beautiful construction, which adds great clarity to an accuracy that is good enough for a surveying instrument. The system however is built around a complex mechanical-optical design that has some limitations. The principle is quite simple. The rotating movement of the distance ring on the lens is translated into an axial movement of the lens unit. The back of the lens unit, the thread, is shaped like a curve with a certain steepness. This curve acts as a wedge that displaces a roller arm, which in turn moves a rangefinder prism that projects an image of the object on a second prism. This second prism also receives an image of the object through the finder and because of the beamsplitting design of the prism, the eye now sees two superimposed images. Moving the distance ring allows both images to coincide. The maximum distance of movement for the roller cam is about 5 mm and the maximum axial distance for a 50mm lens from infinity to 0.7 meter is 5mm too. This is a 1:1 reduction of the lens movement and the cam movement. But the accuracy is not linearly distributed over the gradient of the cam. If we change the distance setting from 5 meter to 2 meter (a difference of 3 meters) the axial displacement of the lens is 1mm. The cam movement then is also 1 mm. In order to translate this movement to the tiny change in the angular movement of the prism, the steepness of the cam must be considerable. If we If we now change the distance setting from 1 meter to 0.7 meter (a difference from 30 cm), we can observe that the axial movement is 1.5mm and the movement of the roller cam is also 1.5mm. We understand that the relative steepness of the curve, the reduction mechanism and the axial movement of the lens have a limited scope. If we wish to focus more closely to the object, we need a longer curve (the total length of the wedge must increase), which is impossible as the diameter of the bayonet mount is fixed. Or we need to change the shape of the curve and so reduce the accuracy of the measurement. We should not forget that Barnack designed this construction 70 years ago and that it is still the best we have.

The longer the focal length, the more the limitations of this mechanical transfer will be approached and the shortest distance that can be rangefinder coupled is restricted.

The second limitation of the rangefinder mechanism is the parallax, but I do assume the reader is familiar with this one. The upshot is a limit on the range for the near focus distances that can be photographed with the M-camera. This is a pity, because there are many photogenic opportunities in the range between 50cm and 1 meter.

Macro solutions

Leitz knew this too and in the past several solutions have been proposed. These are Leitz-typical jewels of mechanical engineering. In many instances we see an extension tube with an optical attachment to correct the parallax and can be used for a limited distance range. Collectors know the names by heart, like SOOKY and SOMKY and OMIFO. The handling was also Leitz typical and not the most elegant or efficient to use.

Optical evolution

The evolution of the optical design at Leica has been focused, since 1980, when the new focal length of 75mm lens was announced, on the optical improvements of the existing range of lenses. And with great success. Several of the current Leica lenses for the M-system belong to the world’s best lenses and all are part of the top three of the best lens systems of the world. But the photographic opportunities have not been expanded. A 35mm wide angle lens, now and then delivers the same style of pictures, even if the new aspherical version has improved imagery. This changed when the new 24mm was introduced in 1996 and especially with the new Tri-Elmar-M from 1998. Now the M-user could with an easy switch change between three focal lengths from 28 to 50mm. The dynamical style of reportage photography could be enhanced with a new perspective.

The close range however was not the strong point of the M-system. Standard and wide angle lenses could be focused till 70cm, but the low magnification ratio did not allow the subjects to be reproduced large enough on the negative.

Macro-Elmar-M 1:4/90mm and Macro-Adapter-M

Now Leica has filled the gap wit a new lens: the Macro-Elmar-M 1:4/90mm. With the use of the Adapter the lens will focus till 50cm, and reach a magnification ratio of 1:3 and that is quite nice. The lens itself is a four element collapsible design, focusing till 77cm. Collapsed it is a very compact unit and with the Elmar-M 1:2.8/50mm will present a very handy travel set. In combination with the Tri-Elmar you have a range of focal lengths from 28-90 and a distance coverage from infinity to 50cm. This is quite versatile.

The danger is that the new 90mm lens will be seen only as a macro lens. In fact it is a very compact, extremely high performance lens that can be used for reportage style photography, where its high class definition can add a new sense of gritty reality to the pictures. (see below)

Some people will always put a question mark on the longevity of a collapsible construction. I am one of them. But my heavily used Elmar-M 2.8/50 is still impeccable and is being monitored on the optical bench for any loss of performance. There is none! The lens hood is most effective and can be put on the lens as a protection. The lens hood will never win a design price and personally I had hoped for a more pleasing design.

With the Macro-Adapter attached to the body and lens the useable range extends from 77 to 50cm. The lens has two focusing scales for both ranges. The Adapter is in fact a thick extension tube with two M-bayonet mounts and an optical attachment with three eyes to put in front of the three eyes of the camera. This one is crystal clear and does not distort the image in the finder. Previous Leitz constructions were not that good. There is additional parallax compensation and this means that two topics must be addressed. The normal frame lines in the finder of the M-camera are too generous in the near focusing range: there is less on the negative than you see in the masks of the finder. Normally this reduction is about 5%, which is not very important. But in close up photography you may miss important edges. The problem of parallax is the second topic. Both these effects make it difficult to get an accurate framing. You must make test pictures to get a good feeling what is being recorded when you frame with the lines in the finder. I used a page from the Donald Duck and you can see quite clearly what is being captured. You might even tape thin strips on the focus attachment to guide you.

In the macro-position the lens works very efficiently. The rangefinder patch is quite enlarged and the alignment of the images is slow: the distance to cover in order to super impose the finder and rangefinder images is quite large. But is very accurate: the thickness of a Eurocent makes a big difference in the rangefinder images.

Depth of field is very thin: at f/4 and magnification of 1:3 it is 3mm. At f/11 it has been extended to 9mm. You need some are when selecting objects to photograph at this magnification.

Optical performance

A 90mm lens with aperture 1:4 was already available in 1930 and a collapsible version could be bought since 1954. These specifications for a most modern design do not seem ‘sexy’, but the optical designer has a different view. The demand to create a compact and lightweight lens, that performs excellently at all distances, including the macro range, is not an easy one to fulfil. That is why Leitz had in the past always two versions of the 90mm lens, one optimized for the normal (infinity use) and one for the more close-up use. The evolution of the 1:4/90mm lenses is quite interesting. The 1930 version had the classical Elmar/tessar design with three elements, the last being a cemented doublet. The contrast was quite low and the definition of fine detail was just acceptable. The big problem with a 90mm lens with only a few elements is the wish to combine high contrast and high resolution in a lens that inherently has a large secondary spectrum and a high amount of curvature (high Petzval sum). In 1968 Leitz surprised the world with a new 4/90mm lens with only three lenses and two different glass types. It had an astonishingly good performance. It was only a few years on the market and now is a collectible item, a pity. In 1973 The Elmar-C was introduced for the CL body. This lens had four separate elements with four different glass types. The performance was much higher than before and now we have a high contrast image, good resolution from centre to mid zones and only the cornets were lacking in brilliance. A similar design was used in the latest Elmarit-M/R 2.8/90 lenses.

It would have been easy for the design team to adopt this solution. But then the macro quality is lacking. So a new calculation and optimization was done and the result is an outstanding lens. Again with four separate elements, but now the diameter of all lenses is almost the same. This helps to ease the rays through the surfaces with a small deflecction of the ray at the surface.

If you look at the classical triplet design, you see that the middle lens is much smaller in diameter. Here the rays from the bigger front element are steeply deflected and this causes more aberrations.

At full aperture the M-E-M-90 delivers a high contrast image and a very high resolving power (definition) over the whole frame from centre to extreme corner. Curvature and astigmatism are absent and decentring as a measure for quality control during manufacture and assembly is not noticeable. The resolving power in the centre is above 150 lp/mm and even in the extreme corners is still around 100 lp/mm. Many lenses would be happy to have 50 lp/mm in the corner with this contrast.

At 1:5.6 contrast increases a bit due to the reduction of internal reflections. At 1;8 the optimum is reached and this performance holds till 1:16. Only at 1;22 there is a noticeable drop in micro (edge) contrast. This is one of the few lenses that perform equally well at all smaller apertures.

The most interesting resolution can be found between the 10 lp/mm and 20 lp/mm and at these frequencies the edge contrast is very high and we do not detect any colour fringing. In fact one wonders why the lens has not been given the APO designation. The Leica designers are very strict and they did not give the coveted star to the M-E-M In the near range from 50cm to 1 meter the performance is exemplary good. In the range from 50cm to 80cm, the overall contrast is a bit lower and the definition of fine details less crisp, but you will not notice this aspect, as the magnification ratio compensates visually the slight reduction in contrast. Due to the slim depth of field you will most often stop down anyway.

Vignetting is 1,8 stops and can be detected as is the distortion of 1%, that will be noticed at very high magnifications.

To answer this question: no, the macro-adapter cannot be used with other 90mm lenses, as the cam of the M-E-M is specifically designed for the macro adapter.

The other lenses

The R-system has the redoubtable APO-Macro-Elmarit-R 1:2.8/100mm, a most versatile lens. A real comparison is not possible as we have one the one hand a six element design with special macro lens components and a physically large lens. On the other hand a four element design with slender dimensions. Still it is of some academic interest to see what the performance differences are. The M-E-M delivers at full aperture a fraction more of performance at medium distances than the A-M-E-R. The edges of the lower frequencies are somewhat tighter defined and the M-E-M gives a crisper presentation of the facts. Presumably the lower number of lens elements and the careful choice of the glass types are the cause of this behaviour. At 1:5.6 the tables are turned and now the A-M-E-R has a slight advantage, which holds till 1:8. It might be the inherently higher level of correction that is at its optimum at the medium apertures that is responsible.

The Apo-Summicron-M 1:2/90mm ASPH delivers outstanding quality at the wider apertures, but it is logical to assume that at 1:2 the A-S-M-A is not as good as the M-E-M at 1:4. Again it is the higher overall contrast and the very good edge contrast that make the day for the M-E-M. This comparison is not really fair as the Summicron has a two stops advantage at maximum aperture. When we compare both lenses at 1:4 at medium distances , we may note that the Elmar reproduces the fine detail with a crisper edge. The Summicron at 1:4 is somewhat softer. The large front lens of the Summicron collects some non-imaging forming light from the surroundings (especially in back-lit situations), that softens the overall contrast somewhat. I would hesitate to call it veiling glare as this is not the case. In comparison the images of the Apo-Summicron seem a fraction overexposed in relation to the Macro-Elmar.

At smaller apertures, the Apo-Summicron is as good if not better than the Macro-Elmar.

These three lenses deliver high quality imagery of a very high order. Many people will not note any difference at all. Pushed to the limits or using the lenses at their designated optimum role, you will be able to see the subtle and important differences.

With the Apo-Summicron and the Macro-Elmar, Leica has given the user a difficult choice.

As a related remark, I would comment on the often heard statement that an 1:4 lens is not good for reportage work and thus has no place in the M-System. Such an opinion is not based on real insight. Most pictures of Cartier-Bresson were made at aperture 1:8 and no one will deny that his work is reportage style pur sang. It is true that at 1:4 we have a limit when using the lens in situations where the ambient light level is low, but it not the case that the photographic reportage is restricted to the so-called ‘available-light’- photography. And in many cases a slight fill-in flash does the trick when the speed of the lens is too low. We should not forget that in many situations the depth of field will dictate the use of a smaller aperture. The simple yes/no discussion should be replaced with a more mature when/if discussion.

The other contender is the Voigtlander Apo-Lanthar 1:3.5/90mm. This is a Double-Gauss lens with six elements. At aperture 1:4 this lens is a bit behind the M-E-M, specifically in the corner performance where the Lanthar records 70 p/mm against the Leica lens with 100 lp/mm. Edge contrast is also lower, as we see more colour fringing with the Lanthar than with the Elmar.

Conclusion

With the exception of the Elmar-M 1:2.8/50mm, the Macro-Elmar must be the smallest optical package in the M-system. And with the exception of the Apo-Summicron 90mm and the Apo-Telyt 135mm it is one of the best overall performers. Its image quality in the near focusing range is unequalled in the M-range and this brings the added value to the lens. It does not replace one of the existing lenses, but brings new pictorial possibilities into the reach of the M-photographer. To identify this lens as a pure macrolens would be too restrictive. It is a very fine general purpose lens, that will deliver stunning images with today' s black and white and slide material.

6.8.7 2.8/90,Elmarit,1959

In 1959 the Elmarit 1:2.8/90mm closed the gap between the Elmar 1:4/90 and Summicron 1:2/90 designs. It was a triplet derivative with 3 groups of elements, of with the last two were doublets. There are two versions, which differ optically slightly. The first smaller batch has different glass types than the second version, which might be called the normal version. Performance wise it was better at full aperture than the Elmar at 1:4, but at 1:2.8 not as good as the contemporary Summicron 90mm at 2.8.

Figure 163: diagram 76

At full aperture overall contrast is medium, coarse details are clearly rendered with good edge contrast. Only the corners lag a bit behind. On axis, the definition of finer detail is crisp, with a gradual degradation when going to the edges. Stopping down to 4 enhances the overall contrast and the edges of the outlines now are sharply delineated. At 1:5.6 the recording of very fine detail comes within visible range and at 1:8 we find a clear and crisp recording of textural details over the whole image field. For best close-up performance one should stop down a few stops. Vignetting is very low with only half a stop and the picture area can be considered as even illuminated till the very corners. There is some flare at the wider apertures.

6.8.8 2.8/90, Tele-Elmarit-M, 1964

The Tele-Elmarit 1:2.8/90mm, introduced at the same time was of a very short physical length. It is again a Canadian design. In fact it was a modern replacement of the collapsible Elmar 1:4/90mm which could be used with the standard every-ready case. It has slightly higher contrast at full aperture on axis than its ELW predecessor, but also shows some curvature of field where the Elmarit is quite flat. Generally the full aperture performance of the Tele-version is slightly behind the Elmarit.

Figure 164: diagram 77

Stopping down to 4 brings visible improvement and at 5.6 both lenses perform on equal footing. It is more flare prone than the Elmarit-version. The Elmarit-R 1:2.8/90mm (first version), introduced in the same year, offers the best image quality. As noted the R lenses could be built with a larger size and that helped improve the performance. The classical dilemma for M lenses is illustrated here anew: small size and compact designs are more difficult to correct to a very high order.

6.8.9 2.8/90,Elmarit-R,1964

This first Canadian design for a 90mm lens for the R-system is an excellent performer and shares by the way most characteristics with the Colourplan 2.5/90, which is almost identical. A medium to high overall contrast is coupled to a very even edge to edge definition of very fine detail, that is recorded crisply.

Figure 165: diagram 79

Stopping down slowly improves on this quality and at 1:5.6 a very high contrast is reached with a clean recording of very small textural details over a large part of the centre, falling off quite a bit in the outer zones. For best close-up performance one should stop down two stops at least.

6.8.10 2.8/90, Tele-Elmarit-M, 1974

This lens has about the same performance as the Elmar-C and sports a wider aperture of one stop. It is however not as good as the Elmarit-R of 1964 and it is of some interest to find out why this version has been introduced. Leitz wanted to offer the M-user a very compact telelens for use with the ever-ready case. And that demanded a very short optical cell, which was very difficult to create with good performance. This lens is quite remarkable in the Leica evolution. It is evident that in the mid-seventies, the Leitz company had too many lenses in the program. A reduction was necessary and one of the first lenses to go was the 135mm focal length for the M. Still a 135mm lens could not be lacking in the system and so the tiny Tele-Elmarit 2.8/90mm was specifically designed with an 1.5x extender in mind to provide a compact 135mm lens. The idea was very nice, but the performance drop that occurred with the extender, killed the project.

Figure 166: diagram 78

Physically it is more compact than the predecessor and follows the design characteristics of the Elmar-C. The new lens is an optically slightly improved version of the Elmar-C and with 4 elements equals the previous Tele-Elmarit 1:2.8/90mm with 5 elements. Only when high contrast motives are photographed the 4-element version shows a somewhat higher flare level at full aperture. Stopped down some differences are observable, as the Tele-Elmarit has some higher edge contrast of fine detail in the field. Vignetting is with _ of a stop a bit less and distortion a bit more than with the Elmar-C. At full aperture the lens delivers a medium overall contrast and clear definition of quite small details on axis, gradually becoming softer and less distinct in the corners. Stopping down edges up the contrast and the image quality in the corners. At 1:5.6 and 1:8 the overall quality reaches a high level and very fine detail is defined with clean edges and clarity of small textural gradations. Close up performance is excellent too. This high quality has been accomplished with only four elements, still retaining the short length. To improve on this level and sticking to the length would have demanded a new design with one or two more lens elements, making it a complicated and expensive lens for its specifications. Leica wisely choose the Elmarit-R from 1980 as the successor, which is 10 millimetre longer, but still 12 millimetre shorter than the previous Elmarit.

6.8.11 2.8/90, Elmarit-M, 1990 & 2.8/90, Elmarit-R, 1980

In 1980 the Wetzlar designers recomputed the 2.8/90 for the R again and created the best 2.8/90mm ever in the Leica history (R and M). The first series of the R-version have been built in Portugal. The M-version arrived on the market in 1990, and is, even today, one of the best lenses in the Leica M stable. We seem to have reached a temporary platform here and while the new Apo-Summicron-M Asph indicates the future direction as far as design methodology is concerned, an upgrade would not be very cheap.

Figure 167: diagram 80

At full aperture, overall contrast is high and very fine detail is crisply rendered with only a faint trace of colour fringing and astigmatism over the whole picture area. The previous R-version has lower contrast and softer edge definition and needs to be stopped down to 4 to get comparable performance. At 1:4 the contrast improves visibly and at 1:5.6 we reach outstanding image quality with extremely fine detail recorded with high edge sharpness and good clarity over most of the image field. The edges are slightly softer, but this will be visible only when one needs exacting coverage of small details in the corners at bigger enlargements. After this aperture contrast and edge definition drop due to diffraction. Close-up performance is as good as at infinity. Vignetting is low with half a stop, and distortion just visible. Flare suppression is excellent as coma (among others) is well controlled. As the 4 element lens has no cemented surfaces, Absorban can not be used to control colour transmission and it has to be accomplished with several types of coating layers.

6.8.12 2/90, Summicron (1), from 1953 and 1957.

The first 90mm lens with an aperture of 1:2 has been produced around 1953. It was a six-element design that differed from the second version This was the version with the detachable (and large) lens hood. Most seem to have produced from 1957 to 1959. This design was created in Wetzlar and production occurred in Canada and Germany. The series from 1953 belongs to the mysteries of the Leitz company. In the serial-number documentation, these lenses are clearly defined and allocated.

Figure 168: diagram 82

What happened to these lenses, (200 were allocated) is not fully known. The designers allowed the computation to grow to whatever physical dimension was necessary and this lens performed admirably well, when stopped down. At full aperture it has a clear advantage to the Summarex, stopped down to 1:2. Overall contrast is medium now and outlines and coarse detail is recorded with good edge sharpness on axis. Stopping down to 2.8 brings the definition of fine detail in the field above the visibility threshold. At 1:4 the finer details are still a bit fuzzy at the edges and at 1:5.6 very fine detail is captured with clarity on axis and a bit fuzzier in the field. In high contrast situations, this lens shows flare around specular highlights and veiling glare reduces the overall contrast, making the pictures a bit flat, a characteristic that will be often noted with older lenses. Close-up performance at the wider apertures is not so good and stopping down is advisable. This remark is valid for many wide aperture short telelenses. Vignetting is low with one stop and distortion is hardly visible.

6.8.13 2/90, Summicron (2), 1963.

From 1963 the second version (again a six-element lens, but with different glass types) has been produced. Its design is different from the first version, as can been seen from the diagrams. This one is a Midland design. At full aperture the overall contrast is medium too. The clear definition of coarse detail enhances the overall visual performance, compared to the predecessor. The lens is still sensitive, but less so, to flare. Finer detail is rendered with fuzzy edges, and gives the overall image a softer look. Stopping down to 1:2.8 brings some improvements in detail rendition and at 1:4 we have excellent quality over most of the picture area, the corners excepted. This lens can be used with confidence at the wider apertures and at distances from 2 to 3 meters to infinity.

Figure 169: diagram 83

It does exhibit the somewhat turbid recording of finer detail that is the fingerprint the 90mm Summicrons before the Apo-version. Vignetting is low with one stop and distortion is hardly visible. The family trait of the wide aperture 90mm lenses is he relatively large gap between the performance at full aperture and stopped down, mainly attributable to the lower overall contrast, which also lessens the ability to reproduce the very fine and textural details with good clarity or at all. We often do not realize the amount of light energy that flows through a lens with a diameter of almost 50mm. And how forceful the aberrations are acting to degrade the potential image quality. It is relatively easy to note the differences in performance, but much more difficult to appreciate the efforts of the designers to control these aberrations.

6.8.14 2/90, Summicron-R, from 1970

This lens for the R-system arrived in 1970 on the market and has not been changed during its long production life of more than 25 years. It is closely related to, but not identical to the Summicron-M, third version, introduced for the M-line in 1980. It is a 5 element design from Midland origin, and at full aperture not as good as the M-version from 1963. At full aperture contrast is low to medium, with coarser detail recorded with fuzzy edges. Performance is quite even from centre to the outer zones,, dropping in the far corners. Flare is somewhat less well suppressed. Stopped down to 2.8, image quality improves markedly and from aperture 4 there is a gradual improvement till 5.6, where an excellent quality is attained, comparable to that of the M-version. Vignetting is more pronounced with one and a half stop and distortion too is more visible than with the M-design. We see here the careful adjustments and compromises when designing lenses for several camera systems. The R-lens had better performance at the closer distance range, on the assumption that the R-system would be more frequently used in that range.

Figure 170: diagram 86

The slight softness of the Summicron at full aperture would support the romantic portraiture of women, and the lower contrast would help taking reportage style pictures in high contrast lightning situations. These notions are still en vogue today and the full aperture characteristics of the Summicron 90mm lenses is mostly described in this context. I have always felt some hesitance to use these notions. The 1970 version is an excellent lens at apertures from 1:2.8 and even more so around 1:5.6, we should also acknowledge the fact that its full aperture performance is not state of the art.

6.8.15 2/90, Summicron-M (3), from 1980.

This 3rd redesign of the Summicron 90mm, follows the design principles of the R-version, but there are slight differences, as the diagram indicates. Now we have a 5 element lens of less weight. The lens is also shorter (more Tele-type) and more compact. The computation of this version had been completed several years earlier and the long gestation period shows how labourious the process was to bring a lens from blueprint into production. This also is an example of the effort of Leica to ensure that the originally computed image quality will be available in every assembled lens.

Figure 171: diagram 84

The 1980 version shows another type of design compromise. The M line of lenses is a quite demanding one for an optical designer, as the two pillars of M design: optical performance and physical compactness are not easy to accommodate. It is like the squaring of the circle. If you prefer compact lenses, the optical quality must suffer. And if you need superior image quality then the lenses have to be bigger. So the headache for M-lens designers is to do the impossible: get high quality and keep dimensions small. The fingerprint of the M-version shows a higher overall contrast, and due to a better correction of the field curvature, an enhanced performance in the field. Stopped down to 2.8, the contrast improves and so does the definition of fine detail. Still smaller objects are recorded with fuzzy edges. At 1:4 the definition of very fine detail crispens significantly and at 1:5.6 the overall image quality is of a really high order, comparable to the Elmarit 2.8/90mm,) which has more sparkle and points to the new era as its imagery demonstrates. Vignetting is more pronounced with one and a half stop and distortion too is more visible. Two lens surfaces are plane and while this may help to lower production costs, it also derives the designer of additional correctional possibilities. At full aperture the 1980 version is still a shade soft and its overall contrast may be described as medium. Flare in the field gives fine detail fuzzy edges and in extreme cases even will blur the reproduction of detail. This softness at the image plane has the advantage that the transition to the unsharp zones of the image before and after the plane of good sharpness is quite smooth. This behavior has been described as “smooth sharpness” which in fact is a “contradiction in terms”.

6.8.16 2/90, Apo-Summicron-M ASPH (4),1998

To achieve really state of the art imagery at full aperture is not easy and we mostly underestimate the effects on performance when we open up one stop. Aberrations grow nine-fold in magnitude, especially in the field. Optical corrections are possible, but now the demands on tolerances and mounting are sky-high. We may not look at it this way, but when we buy Leica lenses we pay for the wide aperture performance. As the demands on lens accuracy and mounting and quality control become more drastic, production costs rise proportionally. The current Apo-Summicron-M 1:2/90 Asph is a clear example of this trend. Let us first look at the performance.

Figure 172: diagram 85

At full aperture (2.0) we find a high contrast image with extremely fine detail rendered with good clarity and high edge-sharpness over the whole picture area, including the outer corners. A faint trace of colour can be detected. At 1:2,8 the contrast improves a bit and the whole image crispens somewhat, lifting the exceedingly fine details above the threshold of visibility. Stopping down after 2,8 only improves depth of field. This superb behavior holds till 1:11. At 1:4 we find an enhanced capacity for recording very subtle textural details with crystal clear clarity and excellent microcontrast. Perfect centering, only the faintest trace of astigmatism and no curvature of field added by meticulous engineering are further characteristics of this lens. To give you another more intuitive performance measure. At full aperture this lens records more than 100 linepairs/mm from centre to corner with excellent edge contrast.

The apochromatic correction. In practical picture taking you will note that edges of fine detail and also coarse detail (outlines of major subjects) are much cleaner if the adjacent colours are opposed in the colour spectrum. If you see a blue and a red colour next to each other, (or a blue and a white colour patch) the colour fringing and fuzziness of the borderline is quite substantial in the case of the 2/90 and practically non existent with the apo90. That gives outlines and fine details a crispness and clarity that greatly surpasses the 2/90. Also the smaller point-spread function of the apo90 gives it a big advantage in recording fine grey values, which can be seen when doing b&w picturing with 100ISO and smaller. The apo90 is one of the best corrected lens in the M-line at this moment. It employs special glass and uses an aspherical surface, presumably to correct part of the spherical aberration that plagues the predecessor. The apochromatic correction enhances overall and micro-contrast. Leica employs a new type of mechanism to engage the roller cam of the rangefinder. This allows a wider throat diameter at the back and reduces vignetting. These optical and mechanical measures show the amount of study in order to improve a lens nowadays. As the apo90 is on the same price level with much improved performance as the predecessor, we see here a clear example of Leica's future direction in optical design: a blend of optical mastery, mechanical engineering and cost reduction (better maybe cost containment!) will give us, Leica users, optical systems with enhanced imaging capabilities that stretch our own limits of technical mastery and of the films we use.

Vignetting is low with one stop and distortion hardly visible. We do often assume that the optical progress is levelling off and that improvements in performance are evolutionary rather than revolutionary. In some cases, such a view can be supported. This new 2/90mm lens incorporates the latest insights in lens design, in aspherical technology and glass selection for apochromatic correction and in mechanical sophistication. Its full aperture performance is superb. At 1:2 this lens outperforms the previous 2/90 at 1:3.5, the current Elmarit-M 2.8/90 at 1:4, the previous versions of the (Tele)-Elmarit at 1:5.6 and the older 4/90 versions at 8 and 11. The collapsible Elmar 4/90mm, as example needs to be stopped down to at least 1:11 to reach a level that the Apo-Summicron asph delivers at 1:2. A time-span of almost 50 years separates both designs and the performance difference does prove the limited validity of the statement that older lenses are as good as current ones or that all lenses stopped down to 1:5.6 will perform on the same level. Of course, lenses will be closer in image quality when stopped down. But often performance does not improve that much. After analysis of comparison pictures, Still most pictures show a higher level of image quality. What happens is that stopping down increases the depth of field. The eye is more sensitive to sharper details than to blurred ones and tries to avoid looking at them So if the image has more sharp detail. It looks as if the image quality has improved. In fact the same level of quality has been extended over a larger area.

6.8.17 2/90, Apo-Summicron-R ASPH (2)

This lens is optically identical to the M version of this design. The main difference is the shortest distance that can be focused: the R-lens focuses to 50cm.

6.8.18 2.2/90,Thambar,1935

The Thambar 1:2.2/90mm is a so-called soft-focus lens that allowed the photographer to make portraits with the soft effects that were very popular in those days. The extent of softness can be regulated by the iris diaphragm and a special opaque disc, that can be placed in front of the lens and cuts off the central rays. As now only the outer rays will be available for image formation, we see a strong degradation of quality as these outer rays are generally less well corrected than he central rays, that are blocked now. Given the special character of the lens, an evaluation of performance is not relevant.

Figure 173: diagram 81

6.9 6.9 100 to 125mm

6.9.1 4/100, Macro-Elmar,1968, and Macro-Elmar-R, 1978

Optically all versions of this lens are identical and for the report I used the R-version which can be used as a normal interchangeable lens. Aperture and angle of field are modest and with this specification it will be no surprise that vignetting at full aperture and distortion generally are reduced to zero.

Figure 174: diagram 87

At full aperture overall contrast is low to medium, and subject delineations and coarse detail are rendered quite crisp as astigmatism and field curvature are very well corrected. As with many older designs, the small textural details are defined with low contrast, making them difficult to detect. With this lens, they are just visible, partly because of the clean edges, which separates them clearly. Stopping down to 1:8 improves the quality significantly with high overall contrast and a clear definition of extremely fine detail over a larger part of the picture area. Stopping down further just extends the depth of field and improves the corners a bit. Contrast as usual drops as diffraction scatters the concentration of rays from its intended point location.

6.9.2 2.8/100, Apo-Macro-Elmarit-R,1987

The first lens to bring apochromatic correction in a medium tele-lens, that can be used at infinity as well as close-up, it was a revelation at its introduction and quickly became the informal yardstick for image quality. It is still an excellent lens, but is gradually being overtaken by newer designs. Who said, that lens performance has levelled off and has reached a plateau? It is a six element design with an additional group for close up performance. While this group enhances the quality at closer distances, it also limits the feasible optical quality at longer distances. At full aperture a high overall contrast image is being generated, with an even performance of very fine detail from centre to corner. Extremely fine detail is rendered with crisp edges and clarity of colours and subtly graded shades of tones. Vignetting is low with 0.7 stop and at 5.6 the picture area is very even illuminated.

Figure 175: diagram 88

Stopping down brings marginal enhancements in contrast and a crispening of the minute object structures. At 5.6 we not a slight focus shift. In the field exceedingly fine detail is rendered with high contrast and great clarity, becoming of slightly lower contrast on axis. Overall its performance stopped down compares well with newer designs, without however reaches their level. Distortion is zero.

Figure 176 6.9.2 main lens

With the Extender-2, performance at 1:5.6 equals that of the prime lens at 1:2.8, with overall a drop in contrast that is most visible with the rendition of very small details. Stopping down to 1:8 improves performance visibly. 6.9.3 6.3/105,Elmar,1932 The so-called Berg-Elmar 1:6.3/105mm is a compact and very light-weight lens of only 240grams. This lens shows the concern of the Leitz company to produce lenses that are compact and light-weight. These characteristics match the Leica body as the camera for dynamic photography and the camera as travel companion. The lens shares with the first Elmar 4.5/135 the characteristic that the original designs were computed for large format camera's (6x9cm). It started its life as a 1:4.5/105mm.

Figure 177: from HOVE

Often this fact is referred to as an indication of very good image quality. In reality it is not, as lenses for larger format negatives invariably are computed with lesser demands on the recording capacity, due to a smaller enlargement factor. It is a low contrast lens with a modest definition of coarse to fine detail, that crispens visibly after stopping down. 6.9.4 2.5/125, Hektor, 1954 This lens can only be used with the Visoflex attachment and is a bit contradictory in its specifications. It is evidently positioned between the Summarex 1:1.5/85 and the Hektor 1:4.5/135 as a higher speed lens for candid portrait and reportage applications. But the Visoflex, while an admirable piece of equipment, is not very user-friendly for these assignments. There is however an adapter which allows this lens to be used directly at the camera. One may marvel at the ingenuity of Leitz to offer all these flexible options. At full aperture overall contrast is low to very low and coarse detail is rendered with good visibility till image height of 12mm, after which the definition becomes rather soft. Vignetting is a mere 1/3 stop.

Figure 178 diagram 90

At 1:2.5 this lens may be described as a "Weichzeichner" (a soft-focus lens). Stopping down enhances contrast significantly and the on axis performance brings in fine detail with clear edges. Outlines now are crisply rendered over most of the image area, but finer details are soft and becoming very soft when we try to capture small structures. At 1:5.6 the circle of very good quality extends to image height 9, and to 12mm when stopping down to 1:8. Distortion is not visible. Its true focal length is 120mm

6.10 135mm

The 135mm focal length belongs to the classical group of 35, 50, 90 and 135mm lenses, that defined and represented the rangefinder photography since 1930. The importance of this group becomes quite clear if we reflect on the fact that Leica introduced almost 70 versions of these lenses, which is about 50% of all lens-versions in the history of the company till now. For the M-line, the 135mm is the longest focal length that the rangefinder can accommodate, in accuracy and magnification and framing. With the M3, the M6J and M6 .85, the user has an instrument that is very well suited to the employment of this focal length. Leitz was well aware of the limits and designed the 2.8/135mm with viewfinder attachment that used the 90mm frame lines to define the 135mm selection. This lens is heavy and so the advantage of the higher speed is nullified by the weight, which forced the user the select a higher shutter speed. Once very popular, the 135mm lens was taken off the M-lens program, more than once, and has re-emerged recently with the Apo-version, which is one of the best lenses for the M-system ever. Many users assume that the 135mm lens does not identify or support the style of photography with the M-body, but as is the case with most sweeping generalizations, it is hard to substantiate. For all kinds of photography (candid and formal portraits, situational figure studies, landscapes, urban scenes, city and farm animals, etc) the 135mm offers a very seductive perspective. With a relative enlargement of 2.7 (compared to the 50mm standard lens), perspective and selective framing is more important than sheer magnification, which is restricted when the distance is larger than let us say 5 meter. This low magnification power at larger distances may be one of the reasons of the demise of this focal length in the R-system. The 180mm has taken over as the premium focal length for candid and reportage photography and the vario-lens of medium range do incorporate the 135mm position as with the 70-180mm and 105-280mm and 80-200mm.

6.10.1 4.5/135, Elmar, 1931

The Elmar 1:4.5/135mm, as the 6.3/105mm version started life as a larger format lens. At full aperture it is of low contrast and shows strong chromatic errors, blurring the finer details in the field. On stopping down improvements are very gradually and this lens needs to be stopped down to 1:8 and smaller for a acceptable image quality. Leitz replaced this lens with the better Hektor 1:4.5/135mm, which was still not as good as the Sonnar version of Zeiss of those days.

Figure 179 from HOVE

As 135mm lenses were primarily used to magnify objects structures, in order to capture small details on the negatives, that could not stand bigger enlargements, the relatively weak performance would not be noticed too clearly.

6.10.2 4.5/135, Hektor,1933

Of Wetzlar origin, this lens improves upon the predecessor, and shows no vignetting at full aperture and no distortion overall. Overall contrast is low and coarse detail is clearly rendered with soft edges on axis till image height of 9mm, rapidly becoming quite blurred in the outer zones and corners. At 1:5.6 there is a marginal improvement, but we need to stop down to 1:8 to see the area of good definition spread to image height 15mm. Contrast stays low and fine detail is now visibly recorded, but with low micro-contrast. At 1:11, detail definition improves and the outlines of major subject outlines have clean edges that make them stand out from the background. Smaller subject details have fuzzy edges, that make them more difficult to discern in the lower image noise of flare and the film emulsion.

Figure 180; diagram 92

6.10.3 4.0/135, Elmar,1960

We often assume that lenses with modest specifications evolve slowly. In this case the almost 30 years that lay between both versions bring significant advantages. The new Elmar at full aperture is better than the Hektor at aperture 1:11! Wide open the lens has a medium overall contrast, Vignetting is low with 0.7 stops and distortion is barely visible overall.

Figure 181 diagram 93

At full aperture we have a medium contrast image, that brings in the crisp definition of coarse detail and lifts the definition of fine detail above the threshold of good visibility. This lens hardly improves on stopping down. Of course there is some enhancement of overall contrast and better visibility of finer details. But basically this lens at full aperture already is at its optimum. At 1:11 overall contrast drops. Close-up performance of the Elmar is not as good as that of the Hektor.

6.10.4 4.0/135, Tele-Elmar, 1965

With this lens Leitz equalled and in some areas surpassed the Zeiss Sonnar 1:4/135mm , which had set the Olympian record for a lens of this specification. At full aperture overall contrast is improved compared to the Elmar, but vignetting is a bit higher (0.9 stops). Very fine detail is crisply resolved over most of the picture area (till image height 12mm) and becomes gradually softer when approaching the corners. At 1:5.6 the edges of the smaller textural details are cleaned up even more and the overall image has a high level of clarity and fidelity of reproduction of the object structures. Stopping down does not change the performance till 1:11. Close up performance is equal to that at infinity and flare and secondary images are very well suppressed.

Figure 182 diagram 94

Distortion is visible, and as with the vignetting do show the compromises when one changes to a telelens design. This lens is often qualified as to be of apo-quality. It is undoubtedly a front rank design, but for true apochromatic correction we have to look at the next stage.

6.10.5 3.4/135, Apo-Telyt, 1998

This design is very compact to fit into the livery of the M-lenses and here we can see the optical progress in vito. At almost identical physical dimensions, we have a half stop more brightness and an improved imagery, that at 1:3.4 is better than that of the Tele-Elmar at 1:5.6. The apochromatic correction has reduced the secondary spectrum to a very low level, but a faint trace of the tertiary spectrum is visible as very narrow colour bands along black or white borderlines. At full aperture we have a high overall contrast, with extremely fine detail accurately recorded over the whole picture area. Vignetting is low with 0.7 stops. At 1:4, there is a visual improvement in the overall quality, which enhances specifically the definition of the tiny textural details. At 1:5.6 the highest level of high fidelity recording has been reached, but some softness at the edges of tiny details is visible in the outer zones of the field at big enlargements. Overall distortion is just visible in the outer zones.

Figure 183 diagram 95

This design is a masterpiece of the art of optical designer and the mechanical engineer. It delivers imagery of a level that will challenge the technical capabilities of many users. The sparkling luminosity of fine colour patches and specular highlights, the clarity of outlines of fine detail and the reduced level of image noise, compared to the Tele-Elmar, sets a new standard in this focal length and aperture. This lens shares its fingerprint with many recent designs in that the change from the sharpness plane to the unsharpness areas is quite abrupt.

6.10.6 2.8/135, Elmarit(1) 1963, Elmarit(2) and Elmarit-R(1) 1964,

Elmarit-M (3)(1973) and Elmarit-R (2),1968 The first version of this lens appeared in 1963 for the M-system. A year later the version for the R-system was put on the market. This version had almost the same lens prescription as the first version: only the two separate front lenses had less thickness and different glasses were used. Performance–wise there is hardly a difference. This second design has been used for both the M- and the R-systems, but is not exactly clear when the merger took place. The same story does repeat itself with the last redesign, which first was introduced for the R-version and later incorporated into the M-system. Wider aperture versions have been researched for the R-system with good performance, but the days of the 135mm lens were assumed to be history.

Figure 184 diagram 96 M 1

Figure 185 diagram 97 M 2 + R 1

Figure 186 diagram 98 M3+R2

The Elmarit –M (2)/Elmarit-R (1) at full aperture exhibit low contrast, and the definition of fine detail is rendered with softer edges. Performance is very even over the picture area, and vignetting is low with half a stop. The low contrast in the field, due partly to coma, however, does degrade the overall image quality. Stopping down to 1:4 does enhance contrast and brings the image quality almost to the level of the Tele-Elmar 1:4/135mm at 1:4. Stopping down further improves quality very reluctantly and very fine detail is crisply rendered at 1:8, but the outer zones stay a bit soft. Outlines and coarse detail are recorded quite crisp, but slightly below the quality of the Tele-Elmar.

Distortion is very slight. The next version has improved contrast at full aperture, giving the rendition of coarse and fine details an edge in clarity. From 1:4 the newer version is comparable to the older version, with one exception: the newer version is a bit softer in the outer zones. Close-up quality of the newer design is improved and delivers excellent rendition of fine detail. Vignetting and distortion are comparable.

6.11 180 to 280mm

The use of the long focal lenses for the M with its cumbersome but very accurate Visoflex housing had its limits and the quick dominance of the SLR type of body owes much to its easy suitability for longer focal lengths. The R-system expanded quite quickly in this area. There is an interesting shift in use from the 135mm to the 180mm for the reflex system. The more powerful magnification gives this focal length a clear advantage in general use and even for portraits (often the motive of choice for the 135mm) the 180mm delivers imagery with a significantly different view. Artistically the 180mm is a very fine focal length to use, but there is a optical quagmire to deal with. With increased magnification, the residual chromatic aberrations are scaled up too. A lens with a longer focal length has a smaller angle of view, and several of the aberrations that plague wide aperture, wide angled lenses, like coma, astigmatism and field curvature are mostly absent. The image blur, resulting from chromatic errors is magnified and this proves to be more of a problem. The apochromatic correction, in whatever guise, finds its prime application in the longer focal lengths. The evolution of the 180 to 200mm lenses will demonstrate the advantages. The first Telyt 1:4.5/200mm lens for the Leica rangefinder delivers very low image quality, and the recent Apo-Summicron-R 1:2/180mm is more than a light year ahead.

6.11.1 2.8/180,Tele-Elmarit,1965

The short lived Tele-Elmarit 1:2.8/180mm (1965) is a Scheider design. Schneider not only provided the wide angles, but also produced parts of the Elmarit 90mm lenses. What exactly was the intention for this lens is unclear. The design, with its characteristic construction of a cemented group of three elements in the middle, is a close derivative of the Zeiss Sonnar 1:2.8/180mm, of Olympics 1936 fame. This resemblance and the lower quality of this lens (an appraisal based in this case on the constructional details) might be responsible for the vanishing act. In the Leitz archives there is mention of a Midland design of interesting specifications for the M-body: a 1:3.4/180mm with attached goggles like the Elmarit 2.8/135mm, which might be the successor of the Schneider lens. Anyway, this is just a historical footnote of minor importance. Picture 6.11.1 A: lens diagram: NOTE: not in my file, but it is in Rogliatti's Book, so should be on file at Hove.

6.11.2 4/180, Elmar-R, 1976

A 2.8/180mm lens needs at least a front diameter of almost 70mm, which automatically requires a certain physical volume. A lens, more compact, can have a smaller aperture. The 4/180mm is indeed a small and short lens. At full aperture overall contrast is medium, with coarse detail rendered with good clarity over the whole picture area. Vignetting is below half a stop. At 1:5.6 contrast improves marginally, which brings more edge sharpness to the delineation of the medium detail outlines. Very fine detail is now defined with soft edges over most of the field. The fingerprint of this lens is remarkable because of the low contrast of the definition of very fine detail, which is markedly below that of the 2.8/180 at 1:5.6. Stopping down further lowers contrast marginally, and image quality stays on the same level. This typical behavior of many longer focal lenses, that performance does not improve that much at smaller apertures is the result of the residual aberrations and not necessarily, as is often assumed, a signature of optical excellence. Distortion is quite visible in the outer zonal areas when straight lines are reproduced. For best close up performance one should stop down a few stops.

Figure 187 diagram 99

6.11.3 2.8/180, Elmarit-R,1968

This 5-element design delivers medium contrast at full aperture and a very even performance over the whole image area. Vignetting is only a half stop. Delineations of subject outlines have soft edges and fine detail is clearly defined. There is some field curvature, that reduces the contrast of very fine details in the field. At 1:4 overall contrast improves visibly and brings in the crisp definition of fine detail. Very fine detail is recorded with some blur in the field. Stopping down further does not improve the performance, but reduces the contrast in the field and corners, a sure sign that the secondary spectrum is still alive. Distortion is just visible. The previous Telyt version (4/200) is at middle apertures not as good as this one at full aperture.

Figure 188 diagram 102

6.11.4 2.8/180, Elmarit-R,1980

The earlier version of this lens was a heavy-weight with 1300 grams. This redesign is reduced in weight through the use of newer glass of anomalous dispersion and other measures for weight reduction. At full aperture the lens delivers medium contrast and coarse detail is rendered with clean edges over the whole image area, with the corners being even better than the centre. Overall the performance is equal to that of the replacement lens. Vignetting is slightly higher at 1 stop. Stopping down to 1:4 improves the contrast, but brings only marginal better definition of fine detail. From 1:4, image quality does improve very slowly, with an improved definition of very fine detail on axis and a reduction of contrast in the field. Here one sees the effect of the residual chromatic aberrations. Distortion is visible in the outer zones. This lens has also improved performance at closer distances. The improvement in image quality has been made possible by a reduction of lateral chromatic errors and the chromatic version of astigmatism, which points already in the direction of the apochromat. Not well-known is the thermic problem. Bigger glass elements, which are cemented or tightly contained in a mount, will expand substantially when heated. The earlier prototypes had some trouble here, as the glass has a tendency to crack due to different thermal expansion coefficients. A careful selection of glass types is needed to tackle this problem, which has relevance for all large lenses, which are cemented.

Picture 6.11.4 A: lens diagram

Figure 189 diagram 103

6.11.5 3.4/180, APO-Telyt-R, 1975.

This lens has gained a mythical status. It started life as a special purpose lens for reconnaissance purposes, but it soon was incorporated into the normal R-system with 6000 units planned for production. The apochromatic correction with synthetically grown fluorite crystals had the problem of the sensitive surfaces of this material and Leitz preferred the use of glass with specific properties. At full aperture we have high overall contrast with a crisp definition of very fine detail over most of the image area, becoming much softer in the outer zones. Vignetting is one stop. Outlines are reproduced with very clean edges, that really stand out from the background with brittle sharpness, and this is even true when the background is of much higher luminance as in contre-jour picture taking and in high light contrasts. We should be realistic here. This image quality is really first class. But the Elmarit 2.8/180 from 1980 has comparable performance, stopped down to 1:4. Where the Apo-Telyt scores is the image quality when stopping down to 1:5.6. On axis till an image height of 10mm, the definition of extremely fine detail is brought to a new level with very clean edges and excellent clarity of textural details. In the outer zones the performance drops visibly with a much lower contrast. Distortion is visible in the outer zones too. There is some tendency to flare, but internal contrast stays high. Let us have no illusions here. Any lens can and will under adverse conditions generate secondary images or flare patches. This lens, especially around 1:5.6, defined the state of the art of 180mm lenses in the eighties. The next 'apo'- designated lens in the 180mm class is the Apo-Summicron-R 1:2/180mm, which at 1:2 has improved image quality, that surpasses the performance that the Apo-Telyt 3/4/180mm delivers at 1:3.4. This is a stunning leap forwards and indicates the progress made by the Leica designers in the last 20 years.

Pi

Figure 190 diagram 100

6.11.6 2.8/180, Apo-Elmarit-R,1998

At full aperture we see an very high overall contrast with a crisp definition of extremely fine details over most of the picture area. Exceedingly fine detail is defined with crystal clarity and excellent edge contrast. In the outer zones the micro-contrast of tiny image structures drops somewhat. Vignetting is low with 0.7 stop. At 1:4 this level of detail recording softens slightly and at 1:5.6 we see a faint drop in overall contrast. At this aperture, the lens can be compared favourably with the 3.4/180mm, which has the advantage on axis over a small central area, while the 2.8/180 has much improved imagery in the field. There is some distortion visible in the outer zones. The new Apo-Elmarit has a most interesting behavior. At full aperture it is already at its zenith, with a superb performance, that is constant over the aperture range, with only a drop in contrast when stopping down. The previous Apo-Telyt 180mm has excellent performance at full aperture and improves on stopping down, an indication that chromatic errors are not so well corrected as in the case of the Apo-Elmarit. Both lenses meet each other around 5.6, where the Elmarit is already lower in quality and the Apo-Telyt is at its best.

Figure 191 diagram 104

Part of the magic of these lenses is the internal focusing, that improves imagery significantly and also gives very smooth focusing. This lens is handholdable, but best performance will be extracted when the lens is supported. The perspective of the 180mm in combination with the distinctive background blur are excellent for portraiture, full figure and fashion/glamour photography. The rendition of the finest detail in the subject sets a new standard and the overall contrast brings in detail and a new level of penetrating power for long distance shots. Both the Apo-Summicron 2/180 and this 2.8 focus past the infinity mark. The additional distance is more than 5 millimetres. The amount of glass and metal in these lenses is such that thermal expansion becomes an issue. The free space beyond the infinity mark has thoughtfully be provided so that whatever the temperature the true infinity focus can be used. The apochromatic correction delivers true apo quality over the whole image field to the corners (no colour fringes whatsoever). Close up performance (about 2 meters) is absolutely equal to the infinity setting. There is some pincushion distortion, however. The overall imagery is even a fraction better than at infinity. This is a most remarkable behavior and can be explained by the mechanism of internal focusing. Only one lens element inside the lens moves when you focus and the designer has very skilfully used this shift to correct the close up performance. Not a real floating element, but sort-of, so to speak. The 2.8/180 does not exhibit any stray light, blacks are deep dark and light sources are very tightly delineated. Specular highlights show finely graded shades of white and secondary reflections are only observable under very unfavourable and not often encountered circumstances.

This lens delivers optical quality of a very high order indeed and is in an absolute sense better than the Apo-Elmarit 1:2,8/100 (R) and the Apo-Summicron-M 2/90 (M).

6.11.7 2/180,Apo-Summicron-R,1994

At full aperture performance is better than that of the Apo-Telyt 3.4/180mm at its 3.4 aperture, and only slightly below that of the Apo-Elmarit 2.8/180mm, which shows progress indeed. Very high overall contrast, vignetting of 1 stop and a very crisp rendition of extremely fine detail till image height of 10mm and a gradually softening of the fine object structures, characterize the lens. At 2.8 the quality equals that of the Apo-Elmarit, with the exception of the corners, that stay a bit soft. From there is absolute equality in character and performance between both lenses. Stopping down after 1:8 is to be avoided if absolute quality is required. Distortion is very small.

Figure 192 diagram 105

The depth of field of the 180mm at f/2 and 2.5 meter is about 1 cm (10 mm). That's pretty narrow. It is by the way a new experience to use such a lens with DoF even less than that provided by the Noctilux. The Leica documentation mentions that the 2/180 can be used hand held and used on a monopod. This you need to interpret liberally. A slight movement will generate unsharpness at full aperture. So this a lens for stationary use, landscape, portrait, nature, wild life, the fashion cat walk. The extremely high quality of this lens is not degraded by the permanently attached protective filter in front of the lens. Of extremely high contrast, the 2/180 also exhibits a rarely seen definition of fine detail and a very distinctive unsharpness/sharpness gradient. The 70-180 Vario lens has an excellent 180 position. But both the Apo-180mm lenses (2 and 2.8) are better and if you need the ultimate in performance one of both is the choice. The 2/180 has obviously more weight (2.5 Kilo versus less than a kilogram) and a much larger diameter. The full stop advantage may be crucial and so the choice should be made very carefully The Summicron 2/180 at full aperture is almost on the same level as the Elmarit at 2.8. The overall contrast is exceptionally high and over an image height of 5 to 6 mm (image circle of 10 to 12mm) exceedingly fine detail is defined with excellent clarity and exceptionally high edge contrast. In the outer zones the contrast drops visibly, when one looks the definition of the very fine detail. Outlines of subjects are defined very crisply. The far corners are quite soft and fine detail, while clearly visible is soft with fuzzy edges. Stopping down to 2.8 improves micro contrast in the outer zones and now the performance is almost identical to that of the 2.8/180. Further stopping down improves the micro contrast of the outer zones, but now the on axis performance drops a fraction. Close up performance is identical to infinity performance and can be explained by the same mechanism as in the Elmarit 180. The outstanding property of this lens at full aperture is its definition of the smallest possible detail with a very high micro contrast and overall contrast. On location photography in twilight and semi-dark level of exposure (50 ISO at 1/4 to 4 seconds) shows an excellent power of penetration of distance: fine detail at a distance of 50 meter in very low contrast light is defined with outstanding edge contrast and subtle shades of colours are recorded with high fidelity. Colours itself are clean and transparent. Shots of models at about 5 to 10 meters in the twilight record details not visible with the naked eye. Portraits close up produce pictures with a very pleasing perspective and a recording level (even at full aperture) that would be a challenge for any medium format lens to equal.

Figure 193 6.11.7 internal focusing

The 2/180 is obviously a tripod only lens and performs superbly in its intended application: location and studio photography in a stationary situation. The catwalk is an obvious deployment as is model (glamour?) photography, where the low light capabilities of this lens extend the limits of twilight photography. Nature, and animal photography are also suitable areas. The 2.8/180 is a bit more versatile as it can be used handheld. Both lenses have an extremely shallow depth of field (the Summicron at 2 to 3 meters operates at about 1 to 3 cm!). The accuracy of the R8 is fully capable to handle this and you can be assured that the plane you wish to focus on, is indeed recorded with the best image quality. The 2/180 again does not have any stray light and for such a lens it is amazingly well behaved here. Halos are also very well suppressed although a shade less than the 2.8/180. Secondary images can be seen when shooting straight into the sun or another strong light source. When the light source is just outside the image area, and very oblique, then we may see in certain but not all situations, a veiling glare that can be distractive. The excellent suppression of stray light shows in the details that hold contrast and gradation.

These lenses approach the ideal of a lens, that gives optimum performance at full aperture, do not degrade when stopping down and perform as well at close distance and at infinity and give equal image quality over the whole image area (2.8) or a big portion of it (2.0).

6.11.8 4.5/200,Telyt,1935

A Visoflex-only lens, that is free form any distortion and brings at full aperture a low to medium overall contrast with coarse detail rendered clearly on axis and becoming very soft when approaching the corners.

Figure 194 diagram 107

Vignetting is low with .8 stops. Stopping down improves performance only reluctantly, an indication that the residual aberrations are strong. At 1:8 contrast is medium and fine detail is accurately recorded with slightly soft edges. This lens exhibits the typical dullness that is the fingerprint of several older designs, when one looks at the definition of finer details and the overall impression of sharpness. At smaller apertures it has comparable image quality as the Hektor 4.5/135mm. The small angle of view makes life easier for the designer and he did not have to ponder the possibility of an apochromatic correction, as the glass types needed were not available and any way the computational and mechanical complexities ruled out this solution.

6.11.9 4/200,Telyt,1959

This four-element Visoflex-only lens is a visible improvement over the previous version. It has reduced the monochromatic aberrations to a lower level, which gives a more consistent quality in the field. Overall contrast is slightly improved, but the cleaner reproduction of finer detail in the field, gives a higher clarity image. Vignetting is a mere half stop.

Figure 195 diagram 106

Stopping down at first enhances contrast in the centre, and from 1:8 the field also improves. At 1:11 image quality is at the level of the Hektor at the same aperture, but the Telyt draws visibly softer. Distortion can be neglected. Close up performance is very good.

6.11.10 4/250 (1), Telyt-R,1970

This Midland lens expanded the range of the Leicaflex lenses with a new dedicated design and at full aperture it shows medium overall contrast with vignetting of a half stop. Performance is very even over the whole picture area. Coarse detail is crisply rendered, but finer detail is of low contrast, and stopping down to 1:5.6 enhances the definition of fine detail and does capture very fine detail with medium contrast and softer edges, especially in the field. Further stopping does not improve the image quality, but makes the chromatic errors (the curse of longer focal lengths) more visible with a rather soft recording of fine details in the outer zones.

Figure 196 diagram 108

There is some distortion in the outer zones. Close up performance is not so good as with the long focus lenses (Telyt 4/200 and Telyt 4.8/280), because of the telelens construction. .

6.11.11 4/250 (2),Telyt-R,1980

This redesign adds one lens element, and loses a bit of overall contrast at full aperture. Vignetting is slightly above a half stop and coarse detail is rendered on the soft side in the field. Stopping down to 1:5.6 enhances the contrast and now very fine detail is within the visibility range, but with fuzzy edges.

Figure 197 diagram 109

At 1:8 the micro contrast of fine detail increases, but the blurred edges stay. At smaller apertures there is no improvement and here we have a medium contrast image with clearly delineated subject outlines, becoming progressively softer when we approach the corners and the finer object structures. Distortion is on the same level as the previous version. For best performance at closer distances one should use the smaller apertures.

6.11.12 4.8/280,Telyt,1961

This Midland designed Visoflex only lens offers medium overall contrast at full aperture with .3 stops vignetting. Coarse detail and outlines are cleanly recorded with a lower contrast over the whole image area. Finer detail is clearly visible, but is of very low contrast. Stopping down to 1:8 does crispen the definition of fine detail, with a marginal improvement of the overall contrast. Stopping down to smaller apertures does not improve the recording capability of fine detail and in fact softens the edges visibly. Here we see the fact that the natural improvements of stopping down are offset by the residual aberrations.

Figure 198 diagram 112

Given the modest aperture of 4.8, stopping down would be helpful only to a small extent. It has very low distortion and close-up performance is improved too. From # 2340944 a newer design with higher contrast and better definition of fine detail has been produced. Close up performance is very good.

6.11.13 4/280, Apo-Telyt-R,1993

The really spectacular advance made in lens design and image quality is best appreciated when one compares this lens with the Telyt-R 1:4/250 (2) of 1980. This Apo-Telyt-R is one of the really few lenses in the Leica lens family that is truly (almost) diffraction limited. If you need to be convinced that resolution figures can only be interpreted and understood in context, just reflect on the fact that this lens has a resolution limit of a breath-taking 500 lp/mm (1000 lines per mm!) at full aperture. It is impossible to even come close to using this level of resolution, but it does show the diffraction limit. Let us quickly return to photographic reality. At full aperture the Apo-Telyt-R has an even performance from centre to corner and will record outlines and extremely fine detail alike with exceptional clarity and very crisp edges. Overall contrast is very high. Vignetting is low with 0.7 stops.

Figure 199 diagram 110

Exceedingly fine detail of a smallness that will challenge the current film emulsions to the bone, is defined with clean borderlines and a fidelity of reproduction that is almost mirror like. In the field you can notice a faint softening of edge detail. Distortion can be neglected. The construction philosophy of current Leica designers is evident if we consider the following comparison. The Apo-Telyt-R has only seven lens elements for its stunning accomplishment and the Canon EF 1:2.8/300mm IS USM, which is close to but not equal in image quality , needs 17 (!) elements.

6.11.14 2.8/280, Apo-Telyt-R, 1984

Add one kilogram to the weight of the Apo-Telyt-R 4/280 and one lens element and you get the 2.8/280mm. It is still not possible to enlarge the aperture without adding weight. At full aperture overall contrast is high and very fine detail is crisply rendered with very good clarity. There is a slight softening of edge sharpness when going to the corners, at this level of detail capture. Extremely fine detail is clearly recorded with a detectible colour fringe at the edges of tiny structures, that soften the edges and the micro contrast.

Figure 200 diagram 111

Stopping down to 1:5.6 improves the performance on axis, but the residual chromatic errors start to blur the definition of tiny details in the field. With these type of lenses we are in the stratosphere of optical performance and the cutting edge is redefined regularly: the Canon lens referred to in the 4/280 report will have the edge, in the outer zones, but it is a photo-finish. Added advantage for the Leica lens is the mechanical stability and the precision of the mount, as we will see in the Module report.

6.12 350 to 500mm

With these focal lengths, we enter the domain of the specialist. The lenses in this range are often quite exotic and have a narrow field of deployment.

6.12.1 4.8/350,Telyt-R,1980

Closely related to the 4/250 (2), this lens exhibits essentially the same character, but with a generally lower contrast. At full aperture contrast is low to medium, with a vignetting of one stop. Outlines of the larger object structures can be detected clearly, but with softer edges.

Figure 201 diagram 113

Performance gradually decreases in the field. Finer detail is defined with fuzzy edges and really fine detail is blurred when bigger enlargements are made. The residual chromatic errors do soften the edges of fine detail as there is a fair amount of colour fringing at small spots. Distortion is just visible in the field.

6.12.2 5/400,Telyt,1937

The narrow angle of field and moderate aperture allow for a distortionless image with no-vignetting at all. At full aperture overall contrast is low and only coarse detail is defined with clarity and clean edges over most of the picture area, with a slight drop in the corners. Fine detail is defined with very low contrast, adding a kind of image noise over the picture. The lens marginally improves in contrast of the finer details and interestingly has slightly better image quality in the outer zones than on axis.

Figure 202 diagram 115

The static behavior, when stopping down, blows away another time-honored rule: that all lenses improve in quality when stopping down. A fair amount of the lenses, presented in these reports, do not improve optically and only extend the depth of field at smaller apertures, which may be misinterpreted as enhanced image quality.

6.12.3 5/400, Telyt, 1956

This Visoflex-only lens has a slightly higher distortion level than the predecessor. At full aperture it has very low overall contrast and a marginally higher vignetting of one third of a stop.

Figure 203 diagram 112

Overall behavior is close to the earlier Telyt-version.

6.12.4 2.8/400, Apo-Telyt-R, 1992

The 2.8/400mm is a markedly improved design, when compared to the telescope lenses. At its full aperture (1:2.8) it is already better than the 5.6/400 at 1:5.6. Compared to the 1984 version of the Telyt-R 2.8/280 we note a slightly softer rendition of very fine detail in the field. The focal length of 400mm does enlarge the residual chromatic errors a bit more and that is visible. Overall the performance of the 2.8/280 and the 2.8/400 are quite close. And in absolute terms, the 2.8/2400 is an excellent lens. At full aperture overall contrast is high (a necessary condition for a long focus lens), vignetting is about 1 stop. Very fine detail is crisply rendered over the whole picture field , with a faint softening when approaching the outer zones. Extremely fine detail is clearly captured with some fuzziness around the edges, but it is a light year ahead of the older designs.

Figure 204 diagram 118

Figure 205 6.12.4 internal focusing

Stopping down to 1:5.6 brings in exceedingly fine detail that is rendered with good clarity, if a bit soft in the field and becoming really blurred in the edges. Generally we may note that the newer long focus lenses exhibit a level of image quality that is in itself extremely high and surpasses that of the wider angle/wider aperture lenses with ease. We should remember however that these long focus lenses ‘cheat’ a bit as they have a larger magnification that brings in more detail to the unaided eye of the observer, who will assume that the lens does capture more detail, which is not true. Still, the 180 to 400mm lenses for the R-system are a revelation in image fidelity.

6.12.5 8/500, MR-Telyt-R, 1980.

The mirror system or catadioptric system, has some distinct advantages a few very grave problems. As the mirror is a perfect imaging system, an optical system, using mirrors for imaging purposes is free from chromatic aberrations and the monochromatic errors are of much smaller magnitude. It is also possible to build such a lens with smaller physical dimensions and weight.

Figure 206 6.12.5 A diagram

The drawback is the fact that the image is located in the beam of incoming light and has to be beamed out of it with the help of a secondary mirror. (see illustration). This construction lowers the amount of available light and most importantly reduces overall contrast significantly. An image of low contrast and low illumination, is very difficult to focus and its optical performance is weak. A true mirror system has no additional refracting elements (like ordinary lens elements), but to correct some of the problems of the mirror system, you can introduce lens elements into the design. This is called a catadioptric system, and the MR is such a system. The addition of the normal lens elements introduces new aberrations and corrects some other defects. The end does not deliver excellent image quality. Leitz offered in the early seventies a Minolta lens 8/800 with R-bayonet. The principal drawback is the difficulty of focusing and the low contrast of the lower spatial frequencies.

6.13 Telescope lenses: 400 to 800mm

From 1

966 Leitz introduced a series of telescope lenses, also designated as Telyt-lenses, but with a totally different construction and design. The former Telyts were telelens or long focus designs, consisting of four or five elements The new ones are telescope lenses, consisting of a single doublet (two cemented elements) or a three-element cemented group (800mm lens). If we disregard the many versions of the mount of these lenses for the M- and R system (Televit, Visoflex, Novoflex etc) the optical cells can be classified in three groups: 5.6/400 and 560 (1966), 6.8/400 and 560 (1970) and 6.3/800mm (1972). What is the rationale behind these lenses? We noted that chromatic aberrations are destroying the image quality of the longer focal length lenses. Without recourse to true apochromatic correction, one solution is the telescope, which by nature is free from distortion, coma, lateral colour and spherical aberration. Astigmatism however is large and so these designs provide only good quality on axis. Given a smart design, one can correct additionally for the residual chromatic errors, if the glass choice (high index glass) is done very cleverly. With the three-element design, we have extra tools for correction and an even smaller secondary spectrum can be reached.

6.13.1 5.6/400 Telyt 1966, 6.8/400 Telyt 1970, 5.6/560 Telyt 1966, 6.8/560 Telyt 1971

The 6.8 lenses are in fact identical to the 5.6 lenses with a smaller aperture. This report is based on the 6.8 versions.

Figure 207 diagram 120-121

400: At full aperture overall contrast is medium, vignetting is below half a stop and as the theory has it on axis performance is much better than in the field. From image height of 6mm contrast drops rapidly and only quite coarse detail is rendered with good clarity. On axis fine detail is recorded crisply, but only till image height of 3mm. Stopping down from 1:8 to 1:16, improves overall contrast, extends the circle of good definition to 12mm and increases the micro-contrast of fine detail. Generally we have good quality only in the centre part of the picture. The absence of larger colour fringing gives this lens good clarity. 560: with almost identical fingerprint, we note a somewhat lower overall contrast, but the circle of good definition is a bit wider.

6.13.2 6.3/800 Telyt-S, 1972

This lens has higher overall contrast, and at full aperture we have a crisp and clear rendition of fine detail till an image height of 9mm. Beyond that the performance rapidly drops. Stopping down to 5.6 improves contrast and at smaller apertures we see the usual contrast drop.

Figure 208 diagram 122

This lens and the other two Telyts demand much user attention and specific experience is needed to use these lenses. Atmospheric conditions will alter the colour rendition. The cement used for these glasses is very soft and over time performance may be degraded by asymmetry effects. If you intend to take pictures that cover the whole image area, the low image quality in the outer zones asks for a careful selection of objects in space.

6.14 The Apo-Telyt-R module system, 1996

The module system has been specifically designed for the photographer who needs several long lenses for his assignments. And when one is considering focal lengths above around and above 280mm, there is a great chance that flexibility and ease of lens changes are of importance. The system consists of three focus modules with enlargement factors of 1, 1.4 and 2 and two lens heads with can be combined to get 6 different systems.

The several units are very sturdily built, and can be focused very smoothly with an internal focusing mechanism. Being primarily designed as a system, its advantages are found where a system of lenses is needed. There are many smart design elements, like close distance focus, short overall length, rotatable tripod thread, carrying handle, fine thread focusing Optically the lenses perform as a family and can be described as group, noting differences when needed. From module 4/400 overall contrast is very high at full apertures and performance is even over the whole image area. Fine detail is very crisply rendered with a trace of colour fringing at the edges in the field. Stopping down improves overall and micro-contrast and the rendition of extremely fine detail is outstanding. Again a faint trace of chromatic aberrations in the outer zones may be detectible as a slight blurring at the outlines of minute details. The 2.8/280 and 2.8/400 exhibit a high contrast at their maximum aperture, again over the whole image area. Extremely fine detail is recorded with very good fidelity with the 280 version. The 400 version has a somewhat softer look, but you should see this in perspective. Its image quality is equal to that of the previous Apo-Telyt-R 2.8/400, but is does not reach the level of the non-module Apo-Telyt-R 4/280. Stopping down to middle apertures the capture of extremely fine detail is beyond the capabilities of most film-emulsions. Some residual chromatic aberrations are detectible in the field. It is evident that the performance of these lenses can only be exploited with a photographic technique of a very high order. The slightest vibration and defocusing will degrade the inherent quality. These lenses are capable, optically and mechanically, to deliver a very level of imagery. The module system is truly a challenge for the photographer and the material. The quality of the results justifies the efforts.

Figure 209: 123 to 128!!

Figure 210: 6.14 A system overview

Figure 211: 6.14.B internal focusing

6.15 Vario lenses

The development of the vario systems and the technique has been detailed in previous parts. Suffice it to note here that the concept of the vario lens has added significantly to the ease of use of 35mm camera's

6.15.1 1:3.5-4/21-35mm Vario-Elmar-R ASPH

General considerations

The zoomlens may be considered as the standard type of lens construction since a decade or two.

Photographers and cinematographers have always wanted to change focal lengths quickly and easily. The step from the thread mount to the bayonet mount was the first method in this direction. The turret with two or three different focal lengths was the next step and this was even offered for the Leica M camera. But a smooth change of focal lengths became only a possibility with the zoomlens. This type of lens is now the norm.

The lens line up of one of the best known names in 35mm camera production consists for over 50% of zoom lens designs. The Leica R lens catalogue shows that about 20% of the current lenses are of zoom lens design.

In cinematography and video cameras the zoomlens with large focal length ratio is ubiquitous. And the current crop of digital cameras is almost invariably equipped with a zoomlens with a ratio above 1:10.

The optical performance of the first zoomlenses in the late fifties and early sixties of the previous century was quite mediocre. For a long time it was widely assumed that this design could never challenge the image quality of the prime lenses with fixed focal length. When you study the current lens designs, you may indeed wonder how it is possible that a single lens with 9 elements can cover the range of focal lengths between 21 and 35mm, where the prime lenses need from 6 to 9 elements to cover one single focal length.

The answer is not so difficult to provide: better knowledge of the design problems, new glasses with special properties and/or with high refractive indices and the insight into the possibilities of aspherical surfaces allow the designer to create zoomlenses with great performance. The major factor for the good quality of the zoomlens is of course the relatively low speed of the lens. Doubling the speed of a lens implies a hefty increase in the impact of the optical aberrations. And any lens designer will tell you that it is not possible to reduce all these aberrations to a level that they are inconsequential in normal photography. You may comment that the new generation of digital cameras have zoomlenses that combine high speed and a large zoomratio. That is true, but to paraphrase a famous remark by Bill Clinton: it is the format, stupid! When the image area is small(16mm movie film, APS format, 6x8mm sensors), a high speed lens is less difficult to create, compared to the relatively large 35mm picture size.

Designing really high quality zoomlenses for the 35mm format is not easy and when you add the requirement for high speed, it becomes quite a daunting challenge. Not only optically, but also mechanically. Increase the speed and the zoom range simultaneously and you are stuck with a very big lens that is not convenient to handle.

When you look at the lens diagrams of modern zoomlenses, you may feel impressed: many lenses have a very high number of lens elements, from 15 to over 20. And if you care to glance into other areas, the zoomlenses for videocameras may have more than 30 elements.

The basic zoomlens however can be designed with only two elements. The focal length is changed by increasing or decreasing the variable air space between the elements. Then you shift the whole system to keep it in focus. That is not convenient and a second moveable element was added. One element moves to provide the shift in magnification (focal length) and the second element moves to hold the focus. The relative movement of both elements is very non-linear and that causes he elaborate mechanical linkage of the moving elements. This is the basic principle of he mechanically compensated zoomlens. In a real lens, you do want not only to change the focal length and hold the focus, but also to correct the aberrations. The basic layout consists of a primary lens group that corrects the aberrations and a zoom group that is responsible for the other actions. The zoomgroup is often designed in the classical plus-minus-plus configuration. The original Cooke triplet is indeed a seminal design. The front lens element is used for focusing, the middle element for changing the focal length and the third element is the mechanically linked compensator for the focus position during the zooming action. This layout can be seen very clearly in the Apo-Elmarit-R 1:2.8/70-180mm. But in the more recent designs the construction is more elaborate and the relative movements of the lens groups are more interlinked. Here we see a natural evolution of knowledge and experience.

It is not too difficult to create a lens with the current optical design programs. The optimization algorithms are very powerful and the manufacture of lenses is often highly automated. But the number of lens elements does increase often beyond necessity. The prime directive of the current generation of Leica designers is simplicity of design, based on a true understanding of the problems involved in a lens design. It is the basic principle of Lothar Kölsch, the former head of the optical department, that it does not make sense to try to optimize a lens, without a very good grasp of the inherent problem areas of a design. Pencil and paper are still the starting tools of the Leica designers as is creative understanding of the optical configurations.

The quest for a design with minimal elements also supports that other goal of the Solms designs: every lens element must be mounted without any deviation from the intended location. The drive to assemble a lens without the slightest amount of decentring may be seen sometimes as obsessive, but it is this seamless integration of optical perfection and mechanical excellence that provide the fingerprint of current Leica lenses.

The other side of the coin is a lens, which offers less features than can be found with the competition.

These considerations may be read as background information when discussing in general the philosophy of the Leica R zoomlenses. Compared to other well-known manufacturers and certainly when compared to the independent makers of zoomlenses, the specifications of the Leica zoomlenses seem quite modest. A lens however is the result of a series of conflicting demands: specifically a small size is very difficult to combine with excellent optical performance. And a compromise is then unavoidable. Leica will never soften their focus on optical excellence, even if this implies that a lens may have specifications that are not up to what the competition does offer. And the Leica users will have to accept this fact. One of the very charming consequences of this approach is the fact that every lens will perform in identical fashion (with the exception of course of the notorious Monday morning lens, that is always possible, even with the very quality conscious environment of the Leica manufacture)

Optical considerations

The Leica Vario-Elmar-R 1:3.4-4/21-35mm ASPH is a good example of this philosophy. The lens has nine elements in eight groups and has two aspherical surfaces, both located before the aperture stop. The Leica Elmarit-R 1:2.8/24mm has nine elements too, but is much less versatile and does not offer more image quality. The design goal of the Vario-Elmar-R 21-35 was to provide a very compact lens with excellent performance over the whole focal range. One of the most pressing problems in a zoomlens is the distortion, which cannot be eliminated, but only distributed over the whole system. Here we have a part of the argument why Leica did not extend the zoomrange to 17 or 18mm on the wide angle side. If we look at the distortion figures, we see that at 21mm the distortion is –3.5%, which is quite visible in architectural work and when there are straight lines at the outer zones and the horizontal edges of the picture. The distortion diminishes when changing the focal length to 35mm, where it is –1% (at 28mm it is –2%).

Vignetting varies from two stops at 21mm to about one stop at the 35mm position. Many persons are a bit amazed that the values for vignetting should be so high. In fact they are not. We may study current and older lens designs form Leica and note that in most cases the wide angle lenses have vignetting form around one to two stops at the wider apertures. This is not a typical defect in Leica lenses, but is the consequence of the cosine-to-the-fourth law. Total vignetting is the sum of artificial (mechanical) vignetting and natural (physical) vignetting. The mechanical vignetting can be reduced by using large lens diameters, but the natural vignetting is based on a physical law. It can be explained as follows. When we have a pocket torch and point it directly (with a straight angle) to a wall, we see a circular patch of light that uniformly illuminates that part of the wall. When we point at the wall from the same position, but with an oblique angle, the illuminated area is much bigger, but the illumination itself is less, because the distance has increased. Vignetting with wide angle lenses is a fact of life. It is at times very annoying and can spoil your picture, but you cannot eliminate the effect, only take care of the consequences.

The relatively low number of nine glass elements is one of the reasons for the excellent clarity of the pictures at full aperture. Careful treatment of the glass surfaces and very effective coating techniques are other reasons for a picture quality that surpasses the comparable fixed focal length lenses. Of course you cannot compare directly a 4/35mm lens with a 1.4/35mm. The design parameters are too different. But at comparable apertures the zoomlens has definitely the edge, especially in the outer zones of the picture. This is a general characteristic of the Vario-Elmar-R 21-35mm in comparison with the fixed focal lengths: the improved quality in the outer zones of the image. When you study the MTF graphs, you may notice two characteristics of the newer zoomlens: the tangential and sagittal curves are close together and the drop in quality at the edges is quite limited. Astigmatism and curvature of field are very well controlled and this should please most users, as they can use the full picture area without expecting a loss of quality. The Leica users who like smooth unsharpness gradients and picturesque background shapes (the bo-ke effects) may be slightly disappointed: the new Vario-Elmar-R 21-35mm does not produce harsh and brittle shapes in the unsharpness zones, but is does produce somewhat rough shapes.

Colour fidelity is very good and colours are reproduced with natural hues. Even when using slide films with a warm balance, the colours are very pleasing.

Flare and secondary reflections are hardly visible, as is coma. With this lens, you can stop worrying about unpleasant surprises when shooting in demanding conditions and the choice of aperture and focal length is purely a matter of artistic consideration.

The high level of optical correction has pushed the residual errors to the margin as can be seen from the behaviour of the MTF graphs. There is a tendency in the internet user groups to diminish the information value of the MTF curves as being irrelevant to real picture taking, drawing a parallel to the resolution figures as a yardstick for image quality.

It would be a pity if this approach to MTF graphs would become wide spread. Studying these curves is very informative: it will tell you at once that at all focal lengths, stopping down the lens has hardly any effect on the quality of the image. As example one may care to analyse the graphs of the 31mm position.

There is a high contrast image at full aperture, as can be seen in the closeness of the graphs for the 5, 10 and 20 lp/mm and the fact that all three graphs are above 9% contrast transfer. Micro contrast is excellent too as can be seen from the shape and location of the graph for the 40 lp/mm. At 5.6 very fine detail in the outer zones becomes quite crisp and edge contrast is very good too. There is no colour fringing at the edge of black-white borders. At 8.0 we note a slight reduction in overall contrast and some residual colour errors.

The best performance can be found at the focal positions from 28 to 31mm. The 21mm focal length is slightly softer overall and should be stopped down to 5.6 for best quality. This is especially true when making pictures in the near focus range.

A comparison of the MTF graphs at the various focal lengths and at full aperture indicate the evenness of image quality. The Leica brochure has a value of 1:3.5 attached to the full aperture at every focal length: in reality there is a progression from 21mm (1:3.5) to 28mm (1:3.7) and to 31 and 35mm (1:4). The half stop difference is however not a problem in normal situations.

Resolution figures, for whom it may concern, do vary from 70 lp/mm to 150 lp/mm, with the exception of the far corners, where we find values around 20 to 40 lp/mm.

Handling considerations

A compact lens with very smooth handling characteristics and relatively low weight, can not be constructed without the use of thin aluminium tubes for the focusing mount. A thick metal wall would increase the lens diameter and make the focusing less smooth. Compare the ease of handling of this 21-35mm with the 70-180mm vario lens. Sometimes you may hear a complaint that the focusing mount can be distorted when putting a strong pressure on it, as when you lift the lens out of the camera bag with a strong grip on the front part of the lens. The mount cannot be distorted, it is too strong for that, but you can change the smooth movement by pressing hard on the mount and so increasing the friction. Some see this behaviour as a lowering of the manufacturing quality of the Solms products when compared with the rock solid mounts of the older Leica lenses with fixed focal length. This conclusion would be wrong: it is not a question of manufacturing quality, but of ergonomics and a more complicated combination of demands. The focusing movement of a zoomlens is very different from that of a fixed focal length lens. And the handling requirements of a zoomlens must be taken into consideration.

This said, we might notice that the Vario-Elmar-R 1:3.5-4/21-35mm ASPH is a delightful lens to use, with the solid smoothness of movement and positive clickstops we expect from Leica, but do not always get.

When using the lens at the 21mm position during street photography and group photography, you should try to avoid having persons at the edge of the filed, as they will be stretched horizontally to inelegant proportions. This is not the effect of the distortion mentioned above, but the result of the wide angle characteristics as explained in the chapters on the 15mm and 19m lenses.

The comments made in the earlier chapters from 19 to 35mm about the artistic considerations (perspective, relative size, and depth of field) apply for this lens too and should not be rehearsed here.

Conclusion

The Vario-Elmar-R 1:3.5/-421-35mm ASPH has an optical performance that equals and in many cases surpasses the comparable fixed focal lengths and delivers very punchy images.

The 19mm and the 28mm fixed focal lengths have an aperture of 2.8 and somewhat better performance and indicate that there is room for dedicated lenses. The Summilux-R 1:1.4/35mm is obviously the champion in low ambient light, but in other areas shows its age, as does the Summicron-R 1:2/35mm. The older 21 design is of significantly lower contrast and the 24mm design can only compete on axis with the performance of the 21 position of the Vario-Elmar-rR

The range of 1:1.7 seems a bit on the low side and looks more limited than it is in daily use. The range from 21mm to 35mm covers a very interesting range and should be able to help you create very potent pictures in the wider angle range from 90 degrees to 63 degrees. Especially if you are looking for close contact pictures with a sense of tightness and immediacy, this lens is very versatile and useful. You need to adjust to the lens characteristics in real photography and do not judge solely from first experiences or from paper specs.

The maximum aperture of 1:3.5 does seem to limit the deployment possibilities a bit, especially when using slow speed slide film. I am not so impressed with this type of argumentation. If you choose a film and a lens carefully, you do so with a specific goal in mind. And then the speed limitations are obvious, but can be countered by flash and/or a tripod. Only when scrolling around on the search for a suitable subject, you may find yourself in a position where the speed of the lens and the speed of the film are at a mismatch. But then the human quality of improvising may be honed.

My only problem with the aperture of 1:3.5 is the brightness of the focusing screen, tat makes accurate focusing sometimes difficult. In this respect Leica has to reconsider their technique of the focusing screens.

It is customary to designate this lens for landscape or reportage photography as the preferred areas, but this is too limited a view. Situational portraits, human interest scenes in close and tight quarters and everything that can be imagined by the photographer to benefit from a wider perspective at close distances can be captured with this lens. It is the photographer not the lens that defines the subject.

The Vario-Elmar-R 1:3.5-4/21-35m ASPH is very pleasant to use, compares favourably to companion lenses of fixed focal length, has excellent to outstanding overall performance and gives the user a new range of creative possibilities. It is one the few lenses that has no weak points in performance or handling.

6.15.2 3.5-4.5/28-70,Vario-Elmar-R,1990 & 1997

This is a Sigma design. Both of these lenses can be described together. The first version has a weaker performance at the 28mm position. In the second version this has been improved. At all other settings the image quality is the same. At the 28 position overall contrast is high at full aperture (3.5), outlines are crisply rendered over most of the picture area., excepting the corners and finer detail is recorded with slight fuzziness in the field. Vignetting is 1.5 stops. Stopping down improves contrast and improves the rendition in the corners. Barrel distortion is very high and would make this setting not really useable for exacting work.

Figure 212 diagram 133-134

At the 50 position overall contrast is high at full aperture (4), with vignetting that can be neglected. Fine detail is rendered clearly over most of the picture area and very fine detail is defined with good visibility on axis, with a gradual drop in quality to the corners. Stopping down brings in a somewhat higher micro-contrast in the field and with the definition of very fine detail. Pincushion distortion is clearly visible. At the 70 position we see at full aperture (4.5) a high contrast image with crisp rendition of fine detail with good coverage over the picture area. Vignetting can be neglected.

Stopping down does not bring improvements. Pincushion distortion is high. The lens is a definite improvement on the earlier Minolta design, but no match for the current Vario-Elmar-R 4/35-70. Stretching the focal length to 28mm may be a bridge too far for this type of design. With 11 elements, compared to 8 for the Solms designed lens we can grasp the significance of the remark that less is more.

6.15.3 2.8-4.5/28-90mm Vario-Elmarit-R ASPH

Introduction

This is a new zoomlens, designed and manufactured by Leica, Solms, that has a remarkably long list of innovations. First: this is the first zoomlens with a range of more than 1:3, to be exact: 1:3.214, close to the magical number pi (3.14....). Second there is a new method of mechanical movement to ensure an almost frictionless smoothness of focal range selection and distance setting. Thirdly there is a new method of assembly that minimizes tolerances to a narrow range. The zoomrange covers 90% of the most frequently used focal lenths,as a study by Canon, some years ago indicated. The analysis of thousands of pictures indicated that the statistical mean was a shutter speed of 1/125 and an aperture of 1:8 at a focal length range from 28 to 90mm, with the 135mm as a quite often used lens, but now almost extinct. The aperture starts at 1:2.8 and ends with 1:4.5, which is very good, considering that one of the closest competitors, the Zeiss Vario-Sonnar-T* f/3,5-4,5/24-85mm starts at 1:3.5 (and 24mm). The Leica literature now uses the Zeiss designation with f/2.8 and not the classical Leica designation with 1:2.8. What is in a name, mused Shakesperare.

The Leica designers have to wrestle with the following problem. If you study a modern handbook about production technology, you will find that for small production batches (typically 500 to 1000 pieces) CNC machines have to be used. It is not cost effective to do dedicated machine tooling to produce the required parts. Economy of scale is not possible. CNC tools are very flexible, but quite expensive and there are technical limits to the designs that you can manufacture with this technology.

Given the small batches of production, one can only use the time honored method of hand assembly. There is no use employing robots ar other automatic methods of assembly. One of the arguments to use as low a number of lens elements (besides the optical ones) is the additional effort during hand assembly: every additional element implies an additional cause of errors and an additional step in the quality assurance chain.

These facts of life can be seen as advantages too: Lens design and assembly methods can be integrated already at the initial stages of the optical design. The normal way of operating is to divide the total task in two unrelated subtasks: the best possible optical design and the best possible method of assembly. The connection between the two is a statistical analysis of the error distribution of the manufacturing tolerances and the assembly process. The idea is to find the widest range of tolerances before the required image quality drops below a precisely defined limit. Assume that you specify an MTF value of 60% at a certain location in the image field. Your tolerance range is ± 10% (assumed average) : you will accept every lens that will perform within a 54 to 66% range. If the tolerance analysis indicates that a certain lens element can be decentred by x%, before it will effect the final result to a level below 54%, this decentring may be accepted and the quality assurance can be adapted to this knowledge.

The Leica designers nowadays approach the problem from the other perspective. They know the possible accuracy of the CNC tools and they know the precision with which human beings can assemble parts and they know the precision of the equipment to adjust the assembled parts. They can design a lens in such a way (calculating an aspherical surface as example) that they know for sure that this shape can be manufactured within a very narrow tolerance in order to avoid adjustments and compensations during assembly. The optical design is already taking into account the limits of manufacture and assembly and the construction can already be prepared for tolerance compensation to stay within narrow limits.

The optical specs and the mechanical construction

The designer of a zoomlens has in fact a luxury problem: he has a larger number of lens elements to correct lens aberrations than are available with a fixed focal length. That is the reason why the best zoomlenses can deliver quality above that of fixed focal lengths. With the exception of the maximum aperture: here the fixed focal lengths are still unsurpassed. Fixed focal length lenses are totally stationary: the lens elements are fixed and there is only a helicoil movement to change the total lens group (with the exception of 'floating elements'). In a zoomlens we have several lens groups that move in raltion to each other in a complicated way and they have to move with a very high precision. One needs a different mount: one in which the cylindrical mount has a number of slots (curved lines) in which the guiding rollers slide to govern the movements of the separate lens groups. When you have a two group zoom (as is usual with the Leica lenses) this mount can be made with the required structural stability. The new lens has a three group zoom design and in this case the number of slots in the mount would be destabilizing the cylindrical mount. Leica has employed a new method (as far as I know unique in this area) and has designed a mount where the slots are milled into the inner surface of the aluminium mount with the help of CNC machinery, designed by Weller, a previous Leitz Wetzlar subsidiary. There are numerouys chisels that work at the same time to cut into the inner walls of the mount to get the rquired shape and precision. The challenge here is not only to operate at an accuracy of 0.01 to 0.005mm, but also to ensure that the surface roughness is also below these tolerances to ensure a smooth movement.

The usual requirement at Leica is a mechanical tolerance of 0.01mm. But in this case there are additional requirements. The surfaces of the lens elements are manufactured to a tolerance in the nanometer range. (aspherical shapea and surface treatment to allow the new methods of coating). These lenses must be fitted into the mounts and assembled without the slighest stress or strain. This could deform the shape of the surface and generate a drop in performance. This is not easy with normal mechanical methods and hand assembly. Leica now uses a method of integrated mechanical compensators. This is a mechanical device that is already integrated in the original lens design and mechanism to make very small adjustments during assembly to minimize the tolerance bandwidth.

During the subassembly and testing of the lens with high magnifcation MTF equipment, any deviation from the norm can be adjusted without re-assembly or adding shims or negative/positive lens elements.

The lens consists of 40 main parts (without lens elements and electronics and aperture mechanism) and it takes an average of two hours to assemble the parts.

The lens consists of 11 elements in 8 groups and has two aspherical surfaces, one in front and one at the back (like the old Noctilux).

The minimum focus ovr the whole range is 0.6 meter. A macro facility is not available, but at 90mm one still has that 0.6 meter near focus and that is acceptably close in many situations.

Performance

The Vario-Elmarit-R f/2.8-4.5/28-90 mm ASPH is an excellent performer at all apertures and focal lengths/ A fixed focal length can be optimized for one distance (or magnification) and this is usually the infinity position. A zoomlens can be corected for one focal length, usually the one in the middle and both extremes suffer. With this lens, we see a gradual improvement form the 28 position to the 90mm. Generally we may note that the performance over the whole image area is very high, where the fixed focal lengths often have a very high quaility in the center portiona nd a gradual dropping towards the corners.

and full aperture (2.8) we have a high contrast image that can record above 150 Lp/mm in the centre of the image and more than 80 lp/mm in the outer zones. Only the corners are weak with a soft recording of fine detail. Stopping down to 5.6 the performance of the centre now extends over an image circle of 12mm diameter. There is no trace of astigmatism and a slight field curvature. Some colour fringing is visible at very high magnifications. Distortion is visible with -3% (barrel distortion) and so is vignetting at 2.5 stops. Compared to the Elmarit-R 1:2.8/28mm, the overal contrast is a bit lower and so is performance at the corners.

At 35mm and full aperture (2.8) there is a small improvement in the outer zones where the lens now records 100 lp/mm with good micro-contrast. Distortion now is about -1%. At 5.6 we have optimum performance with a crisp rendition of very fine detail over most of the image area. Vignetting is practically gone. Compared to the Summicron-R 1:2/35mm the vario version has an improved definition in the outer zones and a crisper rendition of small details.

<p>At 50mm and full aperture (3.4) we see a very high contrast and an exceptionally high resolving power of more than 150 lp/mm over a large section of the negative. There is still some faint colour fringing, but in practice one would be very hard pressed to note it. At 5.6 we have impeccable performance that easily surpasses the quality of the Summicron 50mm lens, especially in the outer zones of the field. At this aperture

the Summicron has less definition of the very fine details. Most people have never noticed this drop of performance in the Summicron, and this is an indication of the evry high quaility of teh new zoomlens

At 70mm and full aperture (4) the image quality becomes superb and we have an extremely high contrast and a very crisp definition of the finest details. Stopping down to 5.6 does improve edge contrast and now the corners are quite good too. Distortion is 1% (pincushion) and vignetting is negligible.

At 90mm and full aperture (4.5) the best performance is reached and compared to the 70mm position the outer zones and corners are now as good as the centre of the image. Vignetting is gone and distortion is very low with 1%. The low distortion at the tele side of the zoomrange is quite remarkable. A comparison with the Apo-Summicron-R 1:2/90mm ASPH shows that this lens has the same performance at 1:2 as the Vario lens at 1:4.5. Still the vario lens has a slightly higher impact, because of lower internal reflections and a smoother unsharpness gradient.

Flare properties

I made a special study of the flare properties of the lens, as this is the one area where lenses have to go ‘a bout de souffle’;. Veiling glare is hardly visible at all focal lengths, implying there is no loss of contrast when the background is much brighter than the subject itself. When the sun is obliquely shining into the lens, and is behind the subject, one can see some secondary reflections of small extent in the picture, but the well-known diaphragm blade reflections are not visible. With the sun flooding the image, there is of course a bleaching out of the picture details, but in such a situation one would change the position slightly to evade this direct confrontation with the sun.

In general I would say that for veiling glare the lens is better than the average Leica lens, and for secondary reflections it is slightly better.

Conclusion

This is a lens with amazing characteristics. It offers outstanding quality and can be compared very favourably to the fixed focal lengths. A detailed comparison with the equivalent fixed focal lengths is now possible based on the published graphs in earlier chapters and in the lens data sheets, available separately on the leica website.The reader can do this him/herself. In general the fixed focal lengths will be more compact and offer a higher speed per focal length. Stopped down there is no longer a big difference and compared to older lens generations, the zoomlens often has better imagery in the outer zones of the image.

The images made with the Vario-Elmarit-R f/2.8-4.5/28-90mm ASPH have a very good colour fidelity, a very fine pictorial depth and documentary realism. This is a lens for slide film and if you have not yet tried slide film, the acquisition of this lens might be a good incentive to try these films.

The wide zoomrange from 28 to 90mm highlights another property of the reflex system: the normal finder screen of the R8/9 is a bit too dark at the 90mm position and it is difficult to focus accurately at the 28mm position. Focusing at the wide angle range is often not very critical as depth of field will cover slight errors. If accurate focus is required, it is best to focus at 70mm and zoom to 28mm (or 90mm and zoom to 35mm).In this range, focus constancy is abolutely spot on.

6.15.4 3.5/35-70,Vario,Vario-Elmar-R, from #3171001, 1983, and from # 3418891, 1986/88

The optical cell of this lens has not been changed from version 1 to 2, only the mechanics have been re-engineered to align them with the production standards of Leica, Solms. It is a Minolta design and the lens has been manufactured in several locations. There is a still a tendency within the Leica community to want to know specifically where a certain lens has been manufactured. From an optical perspective and for evaluation purposes the origin of a lens is of less importance than its image quality. The Minolta design was not the best on the market and in its original Minolta version showed some manufacturing defects. The Leitz quality control ensured that only the lenses within Leitz tolerances were accepted. At the 35mm position at full aperture we have a high overall contrast and light fall off of 1.3 stops. Performance is quite even over the picture area, with a strong drop in the corners. Fine to very fine detail is defined with soft edges, becoming blurred in the outer zones. Stopping down to 5.6 and 1:8 brings slight improvements, as the definition of very fine detail crispens on axis, but in the field there is a visible blurring of this detail level.

Figure 213 diagram 131

Barrel distortion is quite pronounced. At the 70 position at full aperture the image quality is slightly below that of the 35 position, due to somewhat lower contrast. Vignetting is a half stop lower. Stopping down to 5.6, there is a marked improvement in the field and the centre now lags a bit behind. At 1:8 there is no more improvement. Distortion is less pronounced and as usual of pincushion shape.

Figure 214 6.15.2 movements

6.15.5 0/35-70,Vario-Elmar-R,1997

The step from a f/4 lens to a f/2,8 is a major design problem and the step from f/2,8 to f/2 even more so. The argument for this state of the art view is explained in chapter 1.2. The luminous energy flowing through a lens of aperture f/2,8 is twice the amount of a lens with an aperture of f/4 and the effort to control and manage this energy flow is very demanding. It is not well recognized how difficult it is for a designer to control aberrations when stepping up one stop. The Vario-Elmar-R 1:4/35-70, introduced in 1997, is designed in Solms and built in Japan, has 8 lenses, of which one surface is aspherical. The newer 2.8/35-70 has 11 lenses, many of which are of exotic specification, proving the effort to go up just one stop. With this lens Leica introduces an interesting strategy and that is building a low aperture lens to very high optical standards of performance. With a weight of 500 grams it is half the weight of the 2.8/35-70 and equal the weight of the new Apo-Summicron-M 2/90 ASPH.

Figure 215 diagram 129 A B C The performance at 35mm.

At full aperture (4) a high contrast image is produced, slight pincushion distortion is visible and a trace of vignetting in the far corner. On axis (till image height 6mm) outlines of objects are very crisply rendered. Very fine detail can be clearly detected with a trace of softness caused by a very narrow band of colour fringing at the edges. Extremely fine details are recorded with softer edges and exceedingly fine detail is just perceivable. In the field this performance holds with a slight softening of the details at various levels of detail rendition. The reproduction of extremely fine detail shows a certain softness. In the far corners the very fine detail is still visible, but very soft by now, producing fuzzy details. This level of performance holds till 1 meter and in the macro position, where the distortion is a bit more pronounced. At f/5.6 the overall image gets a visibly higher sparkle and in the field the rendition of extremely fine detail becomes quite crisp, showing that high contrast and very high resolution go hand in hand. Corners stay behind. At f/8 the optimum is reached in the field, where the outlines in the centre already show a slight setback. This performance is identical in the f/11 position, and the f/16 shows the usual fallback of quality. The performance at 50mm. At full aperture the overall contrast is a bit lower than in the 35 position, no vignetting or distortion. In the centre (on axis) the outlines of objects are quite crisp as are the fine and very fine details. Extremely fine detail has fuzzy edges, but still a high contrast. In the field fine detail is crisply rendered and very fine detail has slightly soft edges, becoming quite fuzzy when the extremely fine details are recorded. In the far corners very fine details are just visible. At f/5,6 the image markedly crispens up and at f/8 the extremely fine details possess the sparkle and clarity of the best modern Leica lenses. This performance holds till f/16 and in the close-up range. The performance at 70mm. At full aperture the overall contrast is a bit less than with the 50 position. In the centre the outlines have tightly drawn contours, necessary for the sharpness impression. Very fine detail is clearly rendered with a bit soft edges and extremely fine details are a bit fuzzy and start to overlap each other. In the field fine detail is quite crisply rendered and extremely fine detail is just detectable. The corners show a drop in micro contrast and produce fuzzy detail. Slight distortion and a bit vignetting can be noted. At f/5.6 the usual crispening over the whole image field is noticeable with a faint improvement of the rendition of very fine details. At f/8 again more contrast and ever finer detail is recorded, now extending into the far corners. At f/16 the performance drops a bit. Performance holds up to and including the macro position, but when flat objects are recorded it is advisable to stop down a few stops. . Centering is perfect. Veiling glare and secondary ghost images are in most picture taking situations non-existent and hardly to just detectible in adverse conditions Compared to the Summicron-R 2/35 and the Summilux 1,4/80 (the 90 would be too long) at their f/4 aperture we see a lower overall performance. A wide aperture lens has an inherently much higher aberration content than a f/4 design and since the current crop of designers masters the intricacies of zoom lenses quite well, we might expect that the fixed focal length lenses are challenged. As they are indeed. Side by side comparison shows that the Summicron and Summilux have a bit less clarity and sparkle of very fine detail than the Vario-Elmar-R , especially in the field. Some study clarifies this behavior. Looking at the rendition of extremely fine detail we note that this level of detail recording is beyond the capabilities of the Summicron-R and Summilux-R and just within recording level of the Vario-Elmar-R. The Vario-Elmar-R has a lower amount of residual aberrations and a better balance of them. This will show especially in the overall sharpness impression. It is also understandable that the better performance in the field of the Vario-Elmar-R will show in the centre too and the somewhat lesser performance in the field of the 'cron and 'lux will also have its effects on the centre and overall performance. While it is convenient for a test to divide a lens in zones to describe its performance, in practical photography all zones and residual aberrations contribute to the overall imagery of that lens. You have to sum all optical performance aspects to get one overall quality impression. That is what counts for the viewer and the user. Optical analysis can try to explain why a certain lens has this behavior or this image character, but the eye is holistic. It captures the image as a whole.

6.15.6 2.8/35-70,Vario-Elmarit-R Asph,1998

This lens has about twice the volume of the Vario-Elmar-R 4/35-70, which makes sense. It is double the aperture. The 35 mm position at full aperture produces a high contrast image with extremely fine detail already crisply rendered. The edges of the larger outlines are a shade of soft and there is a faint trace of astigmatism and miniscule colour fringes along edges. Outlines and very fine texture details are recorded with great fidelity over the whole image field. Only the far edges are soft and here the finest details are lost in fuzziness. There is some slight barrel distortion, some light fall off and absolutely no decentring and curvature of field. The 2.8 performance is better than the 2.8/35 and the 2/35 at 2.8. Not so much in the centre but especially in the field. At 4 the trace of softness disappears, and the corners improve. Now exceedingly fine detail starts to be recorded. At 5.6 the overall image is a bit below the f/4 performance and from now it well useable till f/22, but at these apertures the highest image quality can not be expected.

Figure 216 diagram 132 A B C

Close-up performance at full aperture is excellent, but slightly below the infinity setting. One should stop down one stop to get the best performance. The 50 position at full aperture is as good as the 35 position at 4. Extremely fine detail is recorded with clearly defined edges over the whole image field, including the edges. No distortion or decentring or astigmatism. Stopping down to 4 brings in a shade more crispness and clarity and now the optimum is reached. This lens is better in the field than the Summicron-R 2/50 at 2.8. The performance gain is not very large, but quite visible. Close-up performance has the same pattern as the 35 position. Stopping down a bit for max performance is advised. At 70mm we reach the overall best position of this lens. At 2.8 it approaches very closely the wide open performance of the Apo 2.8/100 . The finest possible details, just at or even over the border of the recording capacity of the best current films, are defined with high clarity and edge contrast. Overall outlines are edged into the grain with a razor-sharp line and this performance extends over the whole image field. Close-up performance is identical. No need to stop down here. Stopping down to 4 improves contrast a bit and the minuscule details are rendered with slightly better edge contrast. After 5.6 the image softens a faintly and a bit more so after f8. The macro position gives a 1:2.8 reduction which is quite useful, but the shallow depth of field necessitates a small aperture, even if the full aperture performance is very good. The sharpness/unsharpness gradient is intriguing. Leica lenses are supposed to have mythical qualities in this respect. This V-E has a quite steep gradient from sharp to unsharp. The first zone of unsharpness exhibits shape preservation, that is the larger objects keep their geometrically correct form, but loose detail information and in the second zone shapes loose their characteristic form and become amorphous colour blotches of various patterns. The very large object forms have somewhat harsh outlines. On the borderline of sharp/unsharp the outlines of details are a bit rough and have the character of a Van Gogh brush. Atmospheric perspective is enhanced and the sharpness plane is pressed into view quite forcefully. The etchingly sharp outlines of the grosser details are preserved over a large zone in the sharpness/unsharpness border. This effect is most visible in the 70 position. The 35 position naturally has these effects to a smaller degree and with a smoother gradient. Modern Leica lenses have these characteristics as a family trait: quick change from sharp to unsharpness with shape preservation and a progressive loss of fine detail information. Night pictures are quite demanding as specular highlights, deep shadows and large bright light sources generate secondary reflections and veiling glare and halo effects . The Vario-Elmarit-R is outstanding here. No coma at all: in the critical zone in the negative (2/3 from the axis that is the zone of 12 to 18mm from centre), light sources are cleanly delineated, hold their shape and are without any halo rings. Light sources very close together at far distances are separated clearly and without fuzzy rings and have a brilliantly clear luminance. Dark shadows are clean black and the darker colours have fine colour hues. Often you see here a bit sooty blacks and colours and light sources look as it photographed in a misty atmosphere. Veiling glare and back-lit pictures. It is always possible to take photographs with secondary reflections and veiling glare. No lens I know of is immune to forced glaring effects. More important is the performance in more 'natural' circumstances. When taking pictures with the object against a strong light source (sun or whatever) the Vario-Elmarit-R holds clear edges, dark areas and very fine detail in the non-lit areas. The highlights are very clean, with subtle shades of white light illuminance. the shadow colours are clean and well saturated. Microcontrast is very high and no loss of overall contrast. When strong veiling glare illuminates parts of the picture you will notice a haze of lightness, but within these areas and just outside the veiled areas, fine subject detail is preserved with good contrast, but the colours are of course more pastel-like. The Vario-Elmarit-R can be used without any reservation in strong backlit situations and in oblique lighting when the sources are just outside the lens elements. When forced you will notice an occasional strongly coloured secondary reflection in the image. Efficient coating on the almost twenty free lens surfaces is evident. Optically this lens brings the vario performance a few steps higher. The 70 position is the best and has Apo qualities.

6.15.7 2.8/70-180, Vario-Apo-Elmarit-R, 1995.

At full aperture this lens has very high overall contrast and outstanding edge contrast of subject outlines. In the past (and sometimes even today) excessive attention has been given to resolution figures, but in fact it is the crispness of subject contours that define the sharpness impression. Leica is one of the very few manufacturers to use the 5 lp/mm criterion in their MTF graphs. This value is very important for image quality. Not well known is the fact that good edge contrast implies high micro contrast. The Apo-Elmarit at full aperture renders exceedingly fine detail with good clarity over the whole image field from 70 to 120mm focal length.

Figure 217 diagram 138 A B C

Optimum performance will be found at the focal range from 80 till 110 mm where high edge contrast and exceedingly fine detail will be rendered from centre to the far corners. In this span of focal length the performance of the Vario-Apo-Macro-Elmarit-R 1:2,8/100 is equalled if not surpassed. At 70mm the on axis performance is on the same level, but now the far out area loses a bit in the crisp rendition of extremely fine detail. The 135mm position has excellent on axis imagery, but now the outer zones will render very fine detail with good contrast. The 180 position renders very fine detail on axis with excellent clarity. The outer zones and the far corners will show fine detail with good contrast. In comparison the new Apo-Telyt-M 3.4/135 and the new Apo-Elmarit-R 1:2,8/180 are better than Apo-Elmarit-R 1:2,8/70-180 at the corresponding focal. The older generations of the 135 (2,8) and the 180 however are not on the same level as the Vario-Apo-Elmarit-R 1:2,8/70-180, as are the 1.4/80 and the 2.8/90. Vignetting is practically absent at all positions, but distortion at the outer positions (70 and >150) is not. It depends on your deployment if it is acceptable. It is visible though. Stopping down of course improves the imagery a bit, especially at the extreme positions. To preserve optimum quality you should not stop down after 1:5,6 or 1:8.0.

The handling of this lens demands strong shoulders. At almost 2 kg this lens is weighty evidence that optical performance does not come easy. The superb image quality is easily confirmed on the bench or on a tripod (make it heavy and secure!!). Practical tests in the field with 100 ISO material (and lower) show that many pictures taken at a speed below 1/500 exhibit a slight fuzziness due to movement. At 1/250 or below you are in the chance area. At 1/1000 or above the true image potential may be reaped. Colour rendition is of the modern Leica signature: accurate colours, just on the verge of full saturation, with great clarity and transparency . Flare is suppressed very effectively as can be seen in shots where specular highlights are part of the scene. The Leica hallmark of very smooth and subtle gradation of highlights is fully proven. Images get a sparkle and a high light tonality that must be projected on a large screen to be believed. Mechanical construction and smoothness of all parts is beyond reproach. The distance ring however has a long throw to go from 1,7 m to infinity. A bit prefocussing will help. Turning the ring the whole distance will not improve the much needed stability when handholding and focusing at the same time.

This lens provides outstanding performance in all picture taking circumstances when used expertly. This will be discussed in the next part.

The Vario-Apo-Elmarit-R 1:2,8/70-180 is a very good example of the optical progress of the last ten years and living proof of the capabilities of the optical team in Solms. Some time ago Leica stated with some bravado that zoom lenses would never reach the high level of their prime lenses. At the same time Zeiss was producing zoom lenses with excellent imagery. In the photographic world men dominate as well as in the industrial companies, It is fine twist in history that the VAE is indeed better than most prime lenses which focal length it covers and has been designed by a female optical designer. (the Summicron-ASPH 2/35 is also designed by her). At 70mm, 90m and 110mm the lens reaches its optimum at f/4,0, while at f/8.0 the performance already starts to drop a bit. At 135 and 180 the pattern of improvement of performance must be looked at from two angles. At these focal lengths the performance in the field (outer areas) at full aperture was lower than on axis and in comparison to the wider field angles (70 to 110). Stopping down to f/4,0 improves the image to its on axis optimum. That is over a circular image area with a radius of 15mm. If there is a need to get impeccable quality till the far out corners one should stop down to 5,6 and 8.0. The overall performance (crispness of outline delineations and very fine textural details) will drop slightly. Vignetting at full aperture is very slight and only visible in the extreme corners. (Quite often when masking a transparency it might be covered by the mask). There is some flare at the longer focal lengths in the outer zones when strong light sources are present in the vicinity of the edge of the picture area. Presumably the built-in filter is partly responsible for this phenomenon. When shooting directly into the sun or into the sun partially covered behind a tree or roof of a building the internal reflections are very well suppressed and the black parts just adjacent to the sun spilling over the border are still black and the details are preserved with good contrast.

6.15.8 4/70-210, Vario-Elmar-R,1984

This lens is a Minolta design and generally has the same character as the 3.5/35-70mm lens. At position 70 overall contrast is medium with a clear definition of fine detail over most of the picture frame, softening slightly and dropping in contrast when we reach the outer zones. Very fine detail is resolved with good visibility on axis (till image height 6mm). Vignetting is 1.5 stop. Stopping down to 5.6 brings a high overall contrast and a crisp rendition of very fine detail with some fuzziness at the edges. Barrel distortion is quite strong. At 1:8 performance does not change.

Figure 218 diagram 135

At position 150 overall contrast is high and very fine detail is crisply and evenly rendered over the whole picture area, with a slight drop in the corners. Vignetting is 1.5 stops. Stopping down to 5.6 and 1:8 brings a very high quality image with excellent edge sharpness and a crisp and clear definition of very fine detail. Distortion is visible and of pincushion shape. At position 210 the performance is very close to the one found at 150. Distortion is more pronounced and when stopping down the fine details are defined more soft and with lower contrast in the field than in the 150 position. . The overall performance of the lens does not justify the well-known statements from contemporary Leica students that the variable focal lens will never surpass the well designed fixed focal length lens. Its philosophy of correction is clearly a high performance at the longer focal lengths, as good as if not better than the lenses of focal length above 135mm. This is a sensible strategy. The Vario-Apo-Elmarit-R 1:2.8/70-180, a decade later, not only is a vastly better lens than this one, but also does surpass many of the fixed focal length lenses.

6.15.9 4/80-200,Vario-Elmar-R,1996

This lens is close relative of the Vario-Apo-Elmarit 1:2.8/70-180mm as the lens diagrams do indicate. And it has the same relation to this lens as has the Vario-Elmar 4/35-70 to the Vario-Elmarit asph 1:2.8/35-70mm. Overall it delivers improved imagery when compared to the predecessor (3.5/70-210) and is a bit below the 2.8/80-170. Specifically the clarity of definition of the extremely fine detail is duller and more soft. But is has not the apo-designation to be sure. Stopped down is a as good a performer as the apo-relative.

Figure 219 diagram 139

In the 80 position at full aperture we have a high overall contrast with crisp definition of fine detail over most of the picture area. Outlines have very clean edges, enhancing the sharpness impression. Very fine detail is clearly visible with some softness in the field of the image. Vignetting is about one stop. Barrel distortion is visible. At 5.6 and 1:8 image quality is visibly enhanced and now is on a par with the 2.8/70-180. In the 140 position overall contrast is higher and on axis (image height 9mm) the rendition of extremely fine detail is very crisp and clean. In the corners there is a drop. Vignetting is again 1 stop. At smaller apertures we see the same level of performance with a faint improvement in the field. Distortion is low and pincushion in shape. In the 200 position there is a general drop in performance, especially over most of the field. At full aperture there is a high overall contrast, but the definition of fine details is a bit fuzzy and very fine detail is blurred in the outer zones. Vignetting is about one stop. At smaller apertures there is no visually detectible gain in image quality. Distortion is more pronounced (and pincushion). As with the 70-180, the longer end of the zoom range is a bit below the quality at shorter end and middle range.

6.15.10 4.2/105-280,Vario-Elmar-R,1996

This lens is also closely related to the 4/80-200. In this case the performance balance is shifted to the medium and longer end of the zoom-range.

Figure 220 diagram 140

At the 105 position we have medium contrast with clearly defined outlines of subject shapes and a clean rendition of fine detail, progressively softening when reaching the corners. Very fine detail is detectible, but a bit fuzzy. Vignetting is hardly visible. Stopping down improves the overall contrast visibly. Overall performance stays the same. Distortion is of barrel type and visible. At the 200 position image quality is clearly better, with high overall contrast and a crisp definition of extremely fine detail over the whole picture area. Vignetting and distortion can be neglected. Stopping down deliver the same image quality. At the 280 position overall contrast is medium to high and very fine detail is clearly defined on axis (image height 8mm), gradually becoming softer in the field. Vignetting is very low. Stopping down to 1:5.6 brings a marked improvement on axis and a slight improvement in the field. Pincushion distortion is just visible.

6.16 Early zoom lenses.

There are a number of very early zoom lenses, provided by Angenieux, Schneider and Minolta, like the 2.8/45-90, Angenieux-Zoom,1969 and Minolta's 4.5/80-200, Vario-Elmar-R, 1974 and 4.5/75-200, Vario-Elmar-R,1978 and 2.8/45-100, Schneider Variogon and Tele-Variogon 4/80-240.

Figure 221 6.16 several pictures

I have no direct or hands-on experience with these lenses. They are listed just for completeness. The product literature of Leitz from these days uses quite evasive descriptions to characterize the performance, which may be a clue. It is interesting to reflect on the fact that most vario-lenses from the beginning had good contrast and a clean rendition of subject outlines. The many lens elements used in the designs needed a very effective reduction of unwanted reflections and the application of efficient coating did enhance the general impression of sharpness at the subject outlines.

7 Appendices

7.1 Appendix A: Serial numbers and production dates.

The study of the Leitz archives is a fascinating experience, but also a most humbling one. You should not expect, that you will find a neat and clear-cut listing of all products and their serial numbers. In fact the records are not as systematic as you would hope for. The general idea is simple. At first a new lens is designed and gets an internal identification. Then a few hand made prototypes are machined. Sometimes these prototypes get a real serial number, but often they get their own numbers, like 000123. When the prototype has passed all tests, there are two possibilities: the lens goes straight into the production cycle or a small batch is produced to simulate the manufacturing stage in order to study the feasibility of the production. Sometimes the lens needs some more fine tuning optically and this small batch is used for taking photographs by the testing department or selected outside photographers. Whatever the case, somewhere during this stage a range of serial numbers is reserved. The first batch might already be given these numbers, but that is not necessarily the case. The date, assigned to the serial number range is the reservation date, not the real production date. The lists of Leica lens numbers (and bodies) you see in several Leica books and in this book too are based on a big tome in folio format, that is used since 1933 and updated till today, which does register a date, a batch of serial numbers and a lens name. As example: September, 10, 1957, from 1535001 to 1537000, Summarit (+ a code). The date is the date that the serial numbers have been reserved, that is put in the big book. It does not tell you when actual production started and it does not even give information if this batch of 2000 Summarit lenses has been manufactured in one or more runs. It might be the case that the last numbers of this series have been assembled somewhere in early 1958. You cannot be sure if all the allocated numbers have been produced. It is likely, but it cannot be found in this list. This document is updated by the manufacturing department, specifically that part where the serial numbers are engraved as they are responsible that numbers are not engraved twice or not at all. A second series of books have been kept by Leitz, at least till about serial number 2.100.000, which are the so-called “Verkaufsbücher” (sales records). In these books you will find a listing of all serial numbers, consecutively numbered one per line and every line shows the serial number, the designation of the lens, the date it has been sold and the name of the person, or company where it went to. There are a number of gaps however in these listings where the serial numbers are empty. The question then is, what happened here. Did Leitz not produce these specific lenses, or have they been produced but not sold, that is used internally. Sometimes such empty numbers have been used to designate a special prototype as is the case with the Summaron 3.5/35mm. Most historians set the production date of this lens in 1946, but the engraving department notes that the first allocation is recorded in late 1948. What happened is this: Leitz stopped making lenses in 1944 with serial number 594852, incidentally an exotic lens, the Summar 1:0.85/150mm. When the war was over and Leitz resumed production in the summer of 1945, they started with a clean number, at # 595000. The first batch of serial numbers for the Summaron is allocated in 1949 In the sales records you see three numbers: 594853, 594859 and 594860, with designation Summaron and dates between 11-07-1946 and 11-05-1948. If you look carefully at the names of the recipients, the puzzle is solved. The three names are heads of the optical and mechanical departments and Mr Leitz himself. These three lenses are prototypes and have been duly registered as being handed out to Leitz personnel. The true production date of the Summaron then is 1949 and not 1946. The early batch of Summarex lenses can illustrate the problems with identifying lenses and fixing dates. The first batch of these lenses starts with #593001, early 1943 and the first 100 (with designation 8,5cm)have been sold to the German Army. The next 400 lenses (the “B’” type with designation 9cm), starting with 595101, have been sold to the public, but after the war. These 400 are not exclusively reserved for the ‘B’type however and sometimes you find a non-B type. The sales records have dates till 1950 for this first batch of 400 lenses. This does indicate that the person in Havana, who has ordered a Summarex in 1949, gets a lens produced in 1943. Or it might also be the case, that Leitz did not manufacture all these Summarex lenses in 1943, but had spare numbers, which were filled with a production run in 1948. Both example are in themselves trivialities, but it indicates that the true history of the Leica products has yet to be written. And it specifically cautions you to be careful when studying published figures and dates too closely. The serial number list you find here give the numbers as reserved and dated by the engraving department. But it is clear that numbers allocated in the last week of a year, will have been manufactured early in the next year. The figures for 1943 and 1944 must be seen as indications as a cross check of documents do reveal differences, being even more problematic as they are handwritten and overwritten and stricken out and new numbers written in.

1933 156001 195000 39000 1934 195001 236000 41000 1935 236001 284600 48600 1936 284601 345000 60400 1937 345001 416500 71500 1938 416501 490000 73500 1939 490001 540000 50000 1940 540001 566000 26000 1941 566001 582250 16250

1942 582283 593000 10718 1943 593001 594750 1749 1944 594751 594852 101 1945 595000 601000 6001 1946 601001 633000 32000 1947 633001 647000 14000 1948 647001 679000 32000 1949 679001 756000 77000 1950 756001 840000 84000 1951 840001 950000 110000 1952 950001 1051000 101000 1953 1051001 1124000 73000 1954 1124001 1236000 112000 1955 1236001 1333000 97000 1956 1333001 1459000 126000 1957 1459001 1549000 90000 1958 1549001 1645300 96300 1959 1645301 1717000 71700 1960 1717001 1827000 110000 1961 1827001 1913000 86000 1962 1913001 1967100 54100 1963 1967001 2015700 48700 1964 2015701 2077500 61800 1965 2077501 2156300 78800 1966 2156301 2217200 60900 1967 2217201 2254400 37200 1968 2254401 2312750 58350 1969 2312751 2385700 72950 1970 2385701 2468500 82800 1971 2468501 2503100 34600 1972 2503101 2556550 53450 1973 2556551 2663450 106900 1974 2663451 2731921 68471 1975 2731922 2761150 29229 1976 2761151 2809400 48250 1977 2809401 2880600 71200 1978 2880601 2967550 86950 1979 2967251 3007150 39900 1980 3007151 3087000 79850 1981 3087001 3160500 73500 1982 3160501 3249100 88600 1983 3249101 3294900 45800 1984 3294901 3346200 51300 1985 3346201 3383200 37000 1986 3383201 3422890 39690 1987 3422891 3455870 32980 1988 3455871 3481900 26030 1989 3481901 3503150 21250 1990 3503151 3540467 37317 1991 3540468 3583830 43363

1992 3583831 3610679 26849 1993 3610680 3644475 33796 1994 3644476 3677030 32555 1995 3677031 3730290 53260 1996 3730291 3770929 40639 1997 3770930 3818624 47695 1998 1999 2000 2001

7.2 Appendix B: all Leica lens designs

Design Specs Name Year of announcement Serialnumber Zeiss 8.0/15 Hologon 1972 5.474.xxx Zeiss 3.5/15 Super-Elmar-R 1980 3.004.101 Minolta 2.8/16 Fish-Eye-Elmarit-R 1975 2.682.801 ELC 2.8/19 Elmarit-R(1) 1975 2.735.951 Solms 2.8/19 Elmarit-R(2) 1990 3.503.151 Schneider 4.0/21 Super Angulon(1) 1958 1.583.001 Schneider 3.4/21 Super Angulon(2) 1963 1.967.101 Schneider 3.4/21 Super-Angulon-R(1) 1964 2.056.001 Schneider 4.0/21 Super-Angulon-R(2) 1968 2.283.351 ELW 2.8/21 Elmarit 1980 2.993.701 Solms 2.8/21 Elmarit ASPH 1997 3.796.510 Minolta/ELW 2.8/24 Elmarit-R 1974 2.718.151 Solms 2.8/24 Elmarit ASPH 1998 3.737.201 ELW 6.3/28 Hektor 1935 250.001 ELW 5.6/28 Summaron 1955 1.231.001 ELW 2.8/28 Elmarit(1) 1965 2.061.501 ELC 2.8/28 Elmarit(2) 1972 2.314.801 ELC 2.8/28 Elmarit(3) 1979 2.977.551 Solms 2.8/28 Elmarit(4) 1992 3.585.865 Solms 2.0/28 Summicron-M ASPH 2000 n.a. ELW 2.8/28 Elmarit-R(1) 1970 2.440.001 Solms 2.8/28 Elmarit-R(2) 1994 3.664.831 Schneider 2.8/28 PC Super-Angulon-R 1988 3.470.571 Schneider 4.0/35 PA-Curtagon-R 1969 2.426.201 ELW 4.5/35 Elmar 1935 n.a. ELW 3.5/35 Elmar 1930 n.a ELW 3.5/35 Summaron 1948 706.001 ELW 2.8/35 Summaron 1958 1.615.001 ELW 2.8/35 Elmarit-R(1) 1964 1.972.001 ELW 2.8/35 Elmarit-R(2) 1979 2.928.901 ELC 2.0/35 Summicron-M(1) 1958 1.630.501 ELC 2.0/35 Summicron-M(2) 1969 2.307.451 ELC 2.0/35 Summicron-M(3) 1969 2.312.751 ELC 2.0/35 Summicron(4) 1980 2.974.251 Solms 2.0/35 Summicron ASPH 1996 3.767.100 ELW 2.0/35 Summicron-R(1) 1972 2.402.001

ELC 2.0/35 Summicron-R(2) 1976 2.819.351 ELC 1.4/35 Summilux 1961 1.730.001 Solms 1.4/35 Summilux aspherical 1988 3.459.071 Solms 1.4/35 Summilux ASPH 1994 3.636.101 ELW 1.4/35 Summilux-R 1984 3.271.401 ELW 2.8/40 Elmarit-C 1973 2.512.601 ELW 2.0/40 Summicron-C 1973 2.507.601 ELW 3.5/50 Anastigmat/Elmax 1924 n.a ELW 3.5/50 Elmar (1) 1925 104.xxx ELW 3.5/50 Elmar (2) 1930 125.xxx ELW 3.5/50 Elmar (3) 1954 1.140.016 Solms 3.5/50 Anastigmat 200?? n.a. ELW 2.8/50 Elmar 1957 1.402.001 Solms 2.8/50 Elmar-M 1994 3.668.031 ELW 2,5/50 Hektor 1931 92.xxx ELW 2.0/50 Summar 1933 167.001 ELW 2.0/50 Summitar 1939 487.001 ELW 2.0/50 Summicron collaps. 1953 920 ELW 2.0/50 Summicron (2) 1957 1.400.001 ELC 2.0/50 Summicron (3) 1969 2.269.251 ELC 2.0/50 Summicron (4) 1979 2.909.101 ELC 1:2/50 Summicron-R (1) 1964 1.940.501 ELC 1:2/50 Summicron-R (2) 1976 2.777.651 Schneider 1.5/50 Xenon 1936 270.001 ELW 1.5/50 Summarit 1949 820.001 ELW 1.4/50 Summilux (1) 1959 1.640.601 ELC 1.4/50 Summilux (2) 1961 1.844.001 ELW 1.4/50 Summilux-R (1) 1969 2.411.021 Solms 1.4/50 Summilux-R (2) 1998 3.797.910 Solms 1.4/50 Summilux-M ASPH 2004 n.a. ELW 1.2/50 Noctilux 1966 2.176.701 ELC 1.0/50 Noctilux 1976 2.749.631 ELW 2.8/60 Macro-Elmarit-R 1972 2.497.101 ELW 3.5/65 Elmar 1960 1.697.001 ELW 1.9/73 Hektor 1931 96.xxx Solms 2.0/75 Apo-

Summicron ASPH 2005 n.a. ELC 1.4/75 Summilux 1980 3.063.301 ELC 1.4/80 Summilux-R 1980 3.054.601 ELW 1.5/85 Summarex 1942 541.053 ELW 4.0/90 Elmar 1931 n.a ELW 4.0/90 Elmar collaps. (nullseries) 1954 633.001 ELW 4.0/90 ELmar collaps. 1954 1.010.001 ELC 4.0/90 Elmar, 3element 1964 1.913.001 ELW 4.0/90 Elmar-C 1973 2.505.101 Solms 4.0/90 Macro-Elmar-M collaps. 200? n.a. ELW 2.8/90 Elmarit 1959 1.585.001 ELC 2.8/90 Tele-Elmarit 1964 2.001.001 ELC 2.8/90 Tele-Elmarit-M 1974 2.585.501 ELC 2.8/90 Elmarit-R (1) 1964 1.965.001 ELW 2.8/90 Elmarit-R (2) 1984 3260001 ELW 2.8/90 Elmarit-M 1990 3.462.071 ELW 2.2/90 Thambar 1935 226.001 ELW 2.0/90 Summicron (1) 1957 1.119.001 ELC 2.0/90 Summicron (2) 1959 1.651.001 ELC 2.0/90 Summicron-M (3) 1980 3.163.007 Solms 2.0/90 Apo-Summicron- ASPH 1998 3.815.625

Solms 2.0/90 Apo-Summicron-R ASPH 200? n.a. ELC 2.0/90 Summicron-R 1969 2.400.001 ELW 4.0/100 Macro-Elmar-R 1968 2.279.851 ELW 2.8/100 Apo-Macro-Elmarit-R 1988 3.412.891 ELW 6.3/105 Elmar 1932 n.a ELW 2.5/125 Hektor 1954 1.051.001 ELW 4.5/135 Elmar 1931 n.a ELW 4.5/135 Hektor 1933 172.001 ELC 4.0/135 Elmar 1960 1.733.001 ELW 4.0/135 Tele-Elmar 1965 2.046.001 Solms 3.4/135 Apo-Telyt-M 1998 3.838.125 ELW 2.8/135 Elmarit-M (1) 1963 1.957.001 ELW 2.8/135 Elmarit-M (2) 1964 2.151.551 ELW 2.8/135 Elmarit R(1) 1964 1.967.001 ELC 2.8/135 Elmarit-M (3) 1968 2.404.001 ELC 2.8/135 Elmarit R(2) 1973 2.655.901 ELW 4.0/180 Elmar-R 1976 2.785.651 ELC 3.4/180 Apo-Telyt-R 1975 2.748.631 Schneider 2.8/180 Tele-Elmarit for M 1965 2.082.501 ELW 2.8/180 Elmarit-R 1968 2.161.001 ELW 2.8/180 Elmarit-R 1980 2.939.701 Solms 2.8/180 Apo-Elmarit-R 1998 3.798.410 Solms 2.8/180 Apo-Elmarit-R (2) 200? n.a. Solms 2.0/180 Apo-Summicron-R 1994 3.652.221 ELW 4.0/200 Telyt-V 1959 1.710.001 ELW 4.5/200 Telyt 1935 230.001 ELC 4.0/250 Telyt-R 1971 2.406.001 ELC 4.0/250 Telyt-R 1980 3.050.601 Solms 4.0/280 Apo-Telyt-R 1993 3.621.833 ELW 2.8/280 Apo-Telyt-R 1984 3.280.401 ELC 4.8/280 Telyt-V 1961 1.850.001 ELC 4.8/350 Telyt-R 1980 2.991.151 ELW 5.0/400 Telyt 1955 1.366.001 ELW 5.0/400 Telyt 1936 332.001 ELW 5.6/400 Telyt 1966 2.212.101 ELW 6.8/400 Telyt-R 1971 2.370.001 Solms 2.8/400 Apo-Telyt-R 1992 3.569.973 Minolta 8.0/500 MR-Telyt-R 1980 3.067.301 ELW 5.6/560 Telyt-(R) 1966 2.212.301 ELW 6.8/560 Telyt-(R) 1972 2.411.041 ELW 6.3/800 Telyt-S 1972 2.500.651 Solms 2.8/280 Apo-Telyt-R module 1996 3.754.626 Solms 2.8/400 Apo-Telyt-R module 1996 3.754.626 Solms 4.0/400 Apo-Telyt-R module 1996 3.754.626 Solms 4.0/560 Apo-Telyt-R module 1996 3.754.626 Solms 5.6/560 Apo-Telyt-R module 1996 3.754.626 Solms 5.6/800 Apo-Telyt-R module 1996 3.754.626 Solms 4.0/35-70 Vario-Elmar-R 1997 3.773.930 Solms 4.0/28- 35-50 Tri-Elmar 1998 3.753.126 Solms 4.0/28- 35-50 Tri-Elmar (2) 200? n.a. Minolta 3.5/35-70 Vario-Elmar-R 1983/8 3.171.001 Solms 2.8/35-70 Vario-Elmarit-R Asph 1998 3.812.110 Sigma 3.5- 4.5/28-70 Vario-Elmar-R (1) 1990 3.525.796 Sigma 3.5- 4.5/28-70 Vario-Elmar-R (2) 1997 3.787.860 Minolta 4.0/70-210 Vario-Elmar-R 1984 3.273.401

Minolta 4.5/75- 200 Vario-Elmar-R 1978 2.895.401 Minolta 4.5/80- 200 Vario-Elmar-R 1974 2.703.601 Solms 2.8/70- 180 Vario-Apo-Elmarit-R 1995 3.697.501 Solms 4.0/80- 200 Vario-Elmar-R 1996 3.698.001 Solms 4.2/105- 280 Vario-Elmar-R 1997 3.790.510

7.3 Appendix C: best image quality

Leica lenses are capable of very high image quality, but only if all the elements of the picture taking process are controlled and tuned to maximise the image clarity. In an ideal world a photograph would be a faithful and accurate reproduction of the subject. The topic of image degradation could be expanded easily to a full book, and it may seem rash to treat the subject in a few pages. A few very important guidelines may be helpful. It is an almost perverse fact of life that a better lens will demonstrate our technical shortcomings most clearly. A slight defocusing error, some camera vibration, a shade of overexposure will be magnified more when the lens performance is higher, This is quite logical as defects are recorded with greater precision too. The clean and crisp drawing of the main subject outlines and the precise recording of the very fine subject details (textures and minute details) are trademarks of the current Leica lenses. The reduction of flare and the containment of halo rims around specular highlights add to the impression of sparkling clarity. Leica lenses are capable of recording fine image structures up to 100 lp/mm, that is details that on the film area occupy 5 micron of space. Any defocus blurs, scattering of light (halation) due to over exposure and movement during exposure will degrade these fine structures significantly. But also the high edge sharpness of the subject outlines will be degraded by these effects.

7.3.1 Film selection.

This is one of the most intensely discussed topics in Leica circles. The choice of film is closely related to the size of the final image carrier. The performance of the Leica lenses is most evident when big enlargements are made from a negative or projected from a slide. The small details of 5 micron are invisible to the eye when a negative is enlarged only 5 times (that is 13x 18cm). Under ideal circumstances the eye can discern details that are equivalent to 6 lp/mm. The finest details that the Leica lens can record, are visible to the unaided eye only when we enlarge at least 15 times. Or use slides. I am convinced that the perennial discussion among Leica users whether lenses of the older generation are as good as or better than the current ones, is as yet not over, because the evidence used to support the statement is not able to exploit and show the best features of the current lenses.

7.3.1.1 Slide film.

7.3.1.2 After many years of testing lenses and films, I can testify that the current slide films of ISO25 to ISO100/200 are the best medium to enjoy Leica pictures and their optical performance. A large scale projection at a screen of 3 meters wide however will show every defect and technical shortcoming of the photographer and may be a humbling experience at first. I personally see it as a challenge to improve my expertise in this area and a strong visual exposure to the effects of image degradation are very helpful if improvements are to strived after. Generally speaking, films from all reputable manufacturers can be

used, as long as the ISO value is up to or below 100. For purposes of optimalization of the recording capacity and disregarding the colour characteristics, I find emulsions with a tight but small grain pattern and high MTF values from 1 to 20 lp/mm to be the best to use. I am using always Kodak films, Kodachrome and Ektachrome, depending on the circumstances, because these films suite me well. I have also extensively used all Fuji and Agfa films for comparison purposes, and can also recommend the Agfa RSX II with ISO50, and the Fuji Velvia ISO50 and Provia ISO100 series. In my practical shooting I use the Kodak E200, Kodachrome 200, Kodachrome 64 en 25, Ektachrome 100 SW and Ektachrome 100VS. This is not a film test, but the choice of films gives me the opportunity to look at the parameters with which film type the qualities if current Leica lenses can be exploited. The E200 ISO film has remarkably fine grain for its speed and certainly when compared to the K200. Still the K200 pictures bring out more of the image potential of the VAE than the E200 films. Why? The finer grain (or more precise: the very small and closely packed clouds of dye) and the lower character curve of the E200 make it difficult or impossible to see the very fine details. The K200 on the other hand while preserving the edge contrast and the crispness of the Leica imagery, has large grain, which reduces the richness of the texture and colour hues of fine detail. The 100SW and 100VS have a higher inherent contrast and are better suited to preserve the VAE performance. The dye clouds are indeed very fine and closely packed, but as with the E200 series this characteristic still reduces the ability for a crisp rendering of fine details somewhat. The K25 and K64 establish again their reputation as the sharpest slide film. These films, coupled with Leica lenses produce imagery of the highest order, that is as yet still unbeatable. The colour rendition of the Kodachrome series is completely different from that of the 100 SW and 100VS. The excellent preservation of high light gradation and microcontrast in the white (that is overexposed) areas, effectively enhance the subject brightness range that can be recorded. The inherently higher contrast of the 100SW/VS can be exploited without washed out white or whitish areas. The Kodachrome films would be my first choice when I need to explore image quality "a bout de souffle". The long process cycle in many countries might put off some users. The E100 family then would be alternative choice to sample the quality of the Leica lenses. The E100 images at 30 times enlargement show crisply rendered extremely fine detail with that famous Leica clarity. Apo correction of course helps the clarity and textural gradation of very small colour patches.

7.3.1.3 Black and white films

7.3.1.4 For best image quality films in the category of ISO 100 and below are the first choice. My approach here is to go for the film first and then choose a developer. The quest of finding the best match between any film and developer will generate hundreds of suitable combinations. I tested many of these combinations and I must say that the influence of the developer on the final result is less important than the other variables, like accurate focus, good exposure and so on. Only when all variables are tightly controlled, the role of the developer might become crucial. Films I use are the Kodak Technical Pan, Agfa APX 25 and Ilford 100Delta. For these films I use Paterson FX-39, but you will be very happy with Technidol for the Techpan and Agfa Rodinal or Ilford DD-X for the other films. My strategy is to use only a few well chosen-developers as I then know what their character is when using different films. Leica photography should be performed under all circumstances and often an ISO 400 or even ISO3200 (to be exposed as 1600 at most for good shadow detail) is needed. In the ISO400 range I use the Ilford 400Delta if I can carefully expose. Otherwise the Ilford HP5 and Kodak Tri-X are excellent choices. The personality of these films is different and here a wide choice is a must. Never stick to one film, use every film and learn about its character. Stick to one developer to keep things manageable. A secret favourite of mine is the classical Kodak Plus-X (ISO125), with a tight grain pattern and a beautiful

7.3.1.5 tonal scale. If you would have a start I recommend as developer for all films (exception Techpan) the classical Kodak D76 or newer Xtol or the Ilford DD-X. These developers can handle almost every film on the market,

with a very good balance of speed, granularity and acutance. Always use the nominal ISO value and never push your films more than half a stop. If film speed is an issue, use the 3200 films or go to colour negative films.

7.3.1.6 Colour negative films

7.3.1.7 I am not happy with colour negative films in general. The extremely fine dye clouds and the bad processing kill all inherent image quality. If you can find a good lab that does manual enlargements for a reasonable price, you might try any one of the current ISO160 films (Fuji, Konica and Kodak). The only area where colour neg is a viable and interesting alternative is the high speed film. The new Kodak Supra and Portra 800 films can be exposed without bad side effects at EI 1600 and deliver excellent image quality. These films have more exposure latitude than their monochrome comrades and will let you use your Leica in challenging situations where photography is exciting and Leica lenses are at an advantage.

7.3.2 Shutter speed and tripod use.

It is a truism that any movement of camera and subject will degrade image quality. For really outstanding picture quality a tripod is a must, even when using a 50mm lens. The classical rule that the lowest possible shutter speed for handheld picture taking is the reciprocal of the focal length. is nonsense. I shot thousands of pictures at a range of shutterspeeds from 1/4 to 1/8000 with all types of lenses. Statistically it is not possible to get fine imagery below 1/250 (big chance factor is involved when shooting that slow). At 1/250 to 1/500 the chances of a good quality picture are higher but it is not fully secure. Above 1/1000 (M-system) and certainly at speeds of 1/2000 and 1/4000 (R-system) the true image potential can be enjoyed. There is a tendency among many Leica users that a tripod is anathema for true Leica photography. This is a bad proposition. A tripod has to be used when it is needed: slow film, slow shutter speeds, small apertures and/or maximum resolution and sharpness. If you take pictures with the camera only supported by your own body, the highest shutter speed that is useable should be selected. There is no need to set the aperture to 5.6 or higher and often it is better to use a wider aperture as image quality is higher at these apertures. The only rule of the game is this: when you select shutter speeds below 1/60 and often you have to) make a rapid series of pictures. The chance factor will work to your advantage: the chance that one picture is degraded because of camera motion is reduced by a large factor if you have more pictures to choose from.

7.3.3 Accurate focusing.

This is a most important topic. (For accuracy calculations, see appendix 7.5). There is only one sharpness plane and that should be located exactly in the solid space of the subject where you want it. Zone focusing, or the hyperfocal distance or the depth of field scales are all approximations, based on the circle of least confusion. With bigger enlargements, the depth of field is automatically reduced. Always focus with the rangefinder or ground glass on the subject plane you want to be critically sharp. If you need the horizon to be sharp, set the lens at infinity and do not use the depth of field scales to artificially extend your range. At closer distances (1 to 2 meters and sometimes even more) another phenomenon will be visible sometimes. That is the effect of the focus shift. When a lens is stopped down the rays from the outer zones are cut off and we get a narrower bundle of rays. As the bundle is narrow, the blur circle is also of smaller diameter and we get more depth of field. But at the same time, the plane of best focus also shifts a little. This can be seen with all high speed lenses of longer focal length, that is from 50mm. The Noctilux is an example: when you take a picture at 1.5 meter at full aperture and then another one, stopped down to 1:5.6 the original focus plane might be closer to the camera. It looks as if you have focused on the wrong plane. The rangefinder cam coupling is calibrated for the wider apertures. When you focus on the eyes of a model and stop down to 5.6 to get enough DoF, and look at the picture, you might be under the impression that you missed the correct plane of sharpness or that your rangefinder is inaccurate. If fact neither happened, but you see the effect of the focus shift. This phenomenon is hardly visible, but under critical circumstances it might.

7.4 Appendix D: groups of focal lengths

The computed focal length is the theoretical focal length that will have a certain variation in the production process as some tolerances must be accepted. Leica acknowledges this fact and use a coding system to give the actual focal length. In the past this procedure was valid for M and R lenses, but after some period, the adjustment of focal length for the R-lenses could be abandoned. On many M-lenses you will see a number inscribed after the infinity mark. The meaning of this number is as follows.

Nominal focal length Code number Actual focal length Elmar 50mm 2 50.1 3 50.4 4 50.7 5 51.0 6 51.3 7 51.6 8 51.9 Other 50mm 00 50.0 10 51.0 11 51.1 13 51.3 15 51.5 17 51.7 19 51.9 22 52.2 75mm 47 74.7 50 75.0 53 75.3 56 75.6 90mm 95 89.5 00 90.0 05 90.5 10 91.0 135mm 45 134.5 50 135.0 55 135.5 60 136.0

7.5 Appendix E: the rangefinder accuracy

The accuracy of the distance measurement is a very important parameter in the quality of the image. The M and R systems are very different here. The M-range finding is based on a separate range finding mechanism, that is mechanically coupled to the lens movement. This coupling must be of high accuracy and precision as the two main movements (focusing ring on the lens and movement of the rangefinder patch) are invisibly and mechanically linked. The focusing method of the SLR is completely different. Here we focus through the lens on a ground glass screen and there is a direct visual check if we have focused correctly

7.5.1 Rangefinder focus accuracy.

Obviously any measuring instrument has some tolerances, mechanical and optical/visual. The rangefinder of the Leica measures the distance of an object by superimposing two images of that object and noting the degree of coincidence of both images. If both images fully align, the distance measured is correct. As our eye is the critical factor here, the limit of accuracy is dictated by the eye' s visual resolution. Every equation that tries to compute the rangefinder accuracy has this limit of visual resolution incorporated. The blur circle that relates to the depth also defines necessary accuracy of field. The eye has a maximum limit of resolution of 0.06 mm at a viewing distance of 25cm, translating to 8 line pairs/mm. Often a more practical limit of 0.1mm is used, which translates to 5lp/mm. Even this value is too high for most uses and so the industry settled to a more convenient 2 lp/mm as the norm for optical formulae. These 2 lp/mm refer to a distance between two adjacent objects (points or lines) of 0.25mm (1 mm divided by 4). As we are talking here about the print or transparency , we need to translate this figure to another one on the negative. Assuming an 8 times enlargement factor we divide the 0.25 mm by 8 and we get 0.03mm: the famous diameter of the blur circle. We know that in reality we only have an infinitely small sharpness plane that is 'artificially' extended into three dimensional space by this DoF mechanism, combined with the resolution limit of the eye. The rangefinder in theory measures a point in space at one exact distance. There is always a certain latitude in measuring inaccuracy: the focusing error. Slightly before and slightly behind the real distance the instrument will give identical readings. As a bottom line for rangefinder accuracy we must state that the distance of the focusing error is at least equal or less than the DOF distance. That is the most minimum demand. As the rangefinder is based on triangulation, we do not use in our equations lp/mm but the equivalent angular resolution. For the limit of 0.06mm the angular resolution is 1 minute of arc. For the often used 2 lp/mm the angular resolution is 3.4 minutes of arc. The former figure relates to optimum viewing conditions and the latter one to normal conditions. We are almost there! The triangulation method obviously is more accurate when the base length is larger. The Leica M rangefinder has an effective base length of 49.86mm for the M2/4/5/6 and 58.863 mm for the HM series. Contrary to the opinion of many authors I must state that the physical base of ALL Leica bodies from M1 over the M3 to the latest M6 is identical (69.25mm). The only difference is the magnification (0.58, 0.72, 0.85 or 0.92). The CL has a physical base of 31.5mm.

Model Frames for Focal lengths Magnification Effective base length M1 35, 50 0.72 No rangefinder M2 35, 50, 90 0.72 49.86 M3, MP 50, 90, 135 0.92 63.71 M4,M4-2, M4P, M5, 35, 50, 90, 135 0.72 49.86

M6J 35, 50, 90, 135 0.85 58.56 M6, M6TTL, M7, MP .72, 28, 35, 50, 75, 90, 135 0.72 49.86 M6TTL, M7. MP .85 35, 50, 75, 90, 135 0.85 58.56 M6TTL, M7,MP .58 28, 35, 50, 75, 90 0.58 40.17 CL 40,50,90 0.60 18.9

Any equation that computes the RF accuracy will use at least three variables: effective base-length, visual resolution in angles and blur circle diameter. These are intimately related. There are several different equations to be found in the literature and unfortunately the results differ greatly. The factors that enter into the equation are the diameter of the blur circle which is normally taken as 0.03mm, which in my view is too large, the resolving power of the eye, which has different values, based on point discrimination and vernier acuity and the measuring circumstances like contrast level and fatigue of the eye. If we assume for all these factors reasonable values, we can calculate the following table, on the basis of a blur circle of 0.03mm and 0.01mm and a realistic power of discrimination of the eye. The table gives you the limiting values for normal accuracy based on point discrimination and critical accuracy based on vernier acuity. Column three lists the values when you are relying on superposition and contrast and column four lists the values when you need the highest accuracy based on vernier acuity. If you are planning to make really big enlargements or project your slides on very wide screens, these numbers are indicative of the care required when focusing at the wider apertures.

Focal length Aperture Effective base needed 0.03 Effective base needed 0.02 Leica 0.58 Leica 0.72 Leica 0.85 Leica 0.92 21 2.8 1.6 2.1 40.17 49.86 58.86 63.71 24 2.8 2.1 2.7 40.17 49.86 58.86 63.71 28 2.8 2.8 3.6 40.17 49.86 58.86 63.71 28 2.0 3.9 5.1 40.17 49.86 58.86 63.71 35 2.0 6.13 7.96 40.17 49.86 58.86 63.71 35 1.4 8.8 11.4 40.17 49.86 58.86 63.71 50 2.8 8.9 11.6 40.17 49.86 58.86 63.71 50 2.0 12.5 16.3 40.17 49.86 58.86 63.71 50 1.4 17.9 23.3 40.17 49.86 58.86 63.71 50 1.0 25.0 32.5 40.17 49.86 58.86 63.71 75 1.4 40.2 52.3 40.17 49.86 58.86 63.71 75 2.8 20.1 26.1 40.17 49.86 58.86 63.71

90 2.8 28.9 37.6 40.17 49.86 58.86 63.71 90 2.0 48.5 63.1 40.17 49.86 58.86 63.71 135 3.4 53.6 69.7 40.17 49.86 58.86 63.71 135 2.8 65.1 84.6 40.17 49.86 58.86 63.71

7.5.2 SLR focusing accuracy.

The most often used focusing aid is the split optical wedge, which is also based on the property of our vision, known as vernier acuity. The eye can judge very fast and accurate if two lines are broken or aligned. The physical base length of the “rangefinder” depends on the slope angle of the wedges used and the focal length of its ocular. But the magnification of the image on the ground glass by the lens has to be added into the equation. The equation for the base length of the Leica SLR is Focal length / aperture times focal length /61.53 (focal length of ocular). The 50mm lens has an effective base of 9.82mm. Compare these values to the ones from the RF-system and you will see that the RF has higher accuracy. On the other hand we should note that we can focus quite well with an SLR and a 50mm lens. So there is some margin in accuracy needed. With a 135mm lens , the SLR base length becomes 42mm and from there the RF method is less accurate. In fact the real advantages in accuracy are lost around the 90mm focal length as small mechanical inaccuracies are enlarged disproportional in the RF-system. The SLR-system does not need such elaborate mechanical linkages. As long as the film plane and the ground glass are accurately aligned, sharp focus is ensured when the user sees a high contrast image on the screen or uses the split wedge to align vertical lines.

7.6 Appendix F: Lens manufacture in detail.

From an evolutionary viewpoint, we can observe that the inherent image quality of Leica lenses shows improvements that increase steadily, if not exponentially at least in the period from 1988. Creating and computing a new lens design to a higher degree of accuracy and to a higher level of aberration correction is only one part of the equation. The precision of the manufacture of the lens elements and the mechanical components, the care of assembly and the small tolerances in the testing equipment all have to be synchronized to the same level of quality. I would ask the readers attention to what I would refer to as the quiet revolution in lens manufacture in Solms. The result of any lens design looks disappointingly simple. A lens element is fully described when we know the radius of curvature of both surfaces, the diameter, the thickness, the glass type and the distance to the next element. For a triplet lens the following list would completely define the design.

Lens element Radius A Radius B Thickness Glass type Distance to next surface 1 25.500 1100.000 4.800 SK7 3.550 2 -81.40 26.400 1.240 F15 8.810 3 206.000 -55.700 3.380 SK7 86.17

Lens element Radius A Radius B Thickness Glass type Distance to next surface125.5001100.0004.800SK73.5502-81.4026.4001.240F158.8103206.000-55.7003.380SK786.17 The distance of the last element is of course the back focal length, that is the distance from the last surface to the film plane. For a lens as the new

Apo-Summicron-M ASPH 1:2/90mm, that has 5 lens elements, the list is longer, but has the same type of information. These data are the result of a lengthy creative design process that may take many months, if not years to finalize. If you look at the numbers, you see there are three figures behind the decimal point, so the theoretical accuracy is in the realm of a thousands of a millimetre. This unit is often referred to as a micron or 1/1000 of a mm or 1/1.000.000 of a meter. To put the smallness of these numbers into context, remember that the average wavelength of the visible light is 0.5 micron. A triplet lens cannot be corrected to a very high degree and small tolerances will hardly impair the performance. The image degrading by the residual aberrations as larger than by small deviances from the manufacturing accuracy. In practice you see a production tolerance that amounts to tenths of an mm, or a hundred micron. One tenth of an mm (100 micron) may seem large in the perspective of optical calculation and tolerance, but in the shop and even in large scale manufacture, this distance is not easy to hold consistently. If we now look at the design specifications of the original Summicron 1:2/50mm, we see figures like a thickness of 1.42 and a radius of 101.78 (as the actual data may not be published of course, the numbers are just for illustration purposes). It is clear, that a lens that has a higher potential optical quality, should be manufactured with a level of accuracy and precision, that matches the increased performance. Theoretically the precision would be in the range of a hundredth of a millimetre (10 micron), but with the equipment available in that period, one would be very happy if the accuracy would be in the region of a few hundredths of a millimetre or 20 to 30 micron. Again, we should reflect for a moment on the fact that a reduction of the tolerance margin from 3/100 of a millimetre to 1/100 of a millimetre (or a reduction from 30 micron to 10 micron) is a factor three in higher accuracy. This is not so easy to accomplish. We should also remember that no machine does function within the theoretical zero-tolerance of specifications. Equipment has its own tolerance and any piece that is machined will be some % off the specified figure. It would be very nice, if the statistical variation of the production would be within 5% of the specified value. But even this requirement is not feasible, as the mechanical nature of every machine will generate a systematic drift in the specified values. So over a longer period of time adjustments have to be made to bring the machine into line again. Here the human operator is the key player, as he has to sense and check for drifts and out-of-tolerance variations. Any lens element then will depart for a small value from the zero-tolerance value and this has to be accounted for in the stage of mounting the elements and the assembly. One option is to pair components that show the same deviation in value but with opposite signs. In would be statistically unlikely to assume that such pairs exist in all cases, so additional measures are needed. Another option is to use a technique, called adjustment of compensators. One can study the design of a lens and the sensitivity of an element to tolerancing and its effect on image quality. As example for a Summicron-type lens (a double-Gauss design), we can establish that a certain surface radius can depart from the specification by ~0.16mm and another by a mere ~0.01mm before image quality will be degraded. Now a tolerance of 0.01mm is very tight. Additional study showed that the tilt and decenter values had a higher impact on the image quality. Greater care at the mounting stage could compensate for a slightly higher level of tolerancing at the radius and irregularity tolerances. Another way of approaching the problem of the unavoidable manufacturing errors is the study of the statistical distribution of errors than can normally be expected to occur. We first have to specify the required limit of the finished product. Let us say we specify that a lens is considered as accepted at the final check if the measured MTF value at image height of 9mm is no less than 90% of the calculated value. The value may be higher of course, but the minimum is 90%. Assume that 85% of all manufactured lenses will meet this requirement. Then we have 16% of all lenses that will show errors greater than specified. If we study the production quality results, we see that most elements are already at their minimum tolerance values. But a further study shows that a tightening of the tolerances for decentering will ensure that 98% of the lenses will meet the goal of defined image quality. The lesson to draw from all of this that one should look at a lens as a tightly coupled set of components, where the original design, the selection of materials, the manufacturing of the components, the machining of surfaces, the care of mounting and assembly and the care of testing all contribute to the final result. It does not make sense to single out one aspect (glass type or accuracy of radius or the availability of multi layer coating) as the important characteristic of a lens. As noted, decentering and accurate spacing of lens elements are very important variables with a significant influence on the final image quality. The quiet revolution. If we look at lens manufacture, we see at the surface the same procedures as were established during 's times. The main stages: lens grinding and polishing, centering and edging, mounting of lens elements, and assembly of lens elements into the lens barrel and addition of aperture mechanism and focusing mechanism. Between 1988 and 1993 the designers at Solms ran into the limits of the production technology when designing lenses like the Apo-Telyt-R 1:2.8/400mm and the Apo-Summicron-R 1:2/180mm. This last lens has a resolution that is almost diffraction limited, which means that far more than 250 lp/mm can be resolved with high contrast. This lens can resolve details with a diameter of 0.002mm or 2 micron! Compare this figure to the Summicron lens I referred to above, which can resolve details as small as 0.02mm or 20 micron and we see a 10 fold increase in detail rendition, which has to be accompanied by a corresponding increase in manufacturing accuracy. Recall that the average wavelength is 0.5 micron and the smallest detail that can be recorded is 2 micron, pretty close to wavelength dimensions. The rays that are reflected from a tiny detail in the object, will converge to a point on the film plane, and this convergence we can represent as the tip of a very sharply pointed pencil. If we lightly touch the pencil on the paper (read film plane) we will draw a very tiny spot. If we press the pencil-tip with force through the paper surface, we will create a much larger spot. The same happens with the lens. If the distance from the last lens surface to the film plane is not accurately held, the rays will not focus with the sharpest point on the film plane, but before or after this plane. Instead of a sharp spot of dimension of 2 micron we get a spot of maybe 10 micron and most imaging quality will be lost, at least as calculated by the designer. A difference of a hundredth of a millimetre is critical already. Especially the contrast of a lens will suffer over proportionally if the spot diameter is enlarged and thus diffused. Lenses of previous generations had a much higher margin here as they are sensitive to tolerances in the region of 0.1 millimetre or somewhat smaller. The effective image quality depends as much on the manufacturing precision as on the design. If fact, they are mutually dependent. The high quality that the Apo or aspherical lenses deliver cannot be delivered if glasses with very specific properties are not available. This glass is in the standard catalogues of current glass manufacturers. The story that Leica uses glass that is specifically formulated by or for them and is only available to them is not true. What is true, is that the special glass types need to be treated in a very special way, and here lies the secret of Leica. Thy have the technology and expertise to employ these glass types. As example on may mention the sensitivity of some glass to changes in temperature: heating and cooling will imbalance the molecular structure of the glass and if these changes have to be avoided, special coating techniques have to be employed, as example. Surface finish is another example. Sometimes the glass is so sensitive to humidity or oxidation that a glass surface needs to be coated within hours after treatment. Aspherical surfaces have a shape that departs from the pure sphere and in the past these surfaces could only be produced by a specially constructed device and by extensive manual adjustments. This procedure was not only expensive and error prone, but restricted the designer to a few aspherical shapes, which in turn limited the design possibilities. One needed machinery with a higher level of flexibility and that was found in the new generation of CNC (computer numerical controlled) machines. So the causal chain to ensure high imaging quality is as strong as the weakest link. Better imagery asks for specific glass types, specific shapes of the glass surfaces, accurately held tolerances and high quality testing equipment. Current manufacturing technology in Solms is a mix of high tech computer controlled equipment, that has been bought off the shelf or has been designed specifically for Leica in cooperation with the manufacturer. Special training and a long period of experience is needed before one can operate these machines. As the specifications now are increased a tenfold in accuracy (as compared with the previous periods) and dimensions are measured in one thousand of a millimetre, the operation of the machines has to be controlled on that level too and now the anticipation of the behavior of the machine is part of the game: if the tolerance now drifts for a few microns you can throw away the lens. Many machines are computer controlled and almost every workplace has its own testing equipment. Every one is responsible for its own part of the process. It is fascinating to observe that in one room a one-million Dmark machine is quietly and slowly polishing a aspherical surface into the required shape, in another a laser driven machine is grinding the rim of a lens to the accurate mechanical axis and that in a third one a woman is busy with blacking the rim of the lens with black paint by hand as the lens is rotated on a small electromotor. This time honored process, the same as for forty years, cannot be improved and there is still no mechanical substitute for it. A finished lens then is the cooperation of the creativity of the designer, the most accurate production process in the mechanical industry and the careful attention of a female member of the construction team. It is remarkable that this part of the process resists all attempts to mechanization. The causal chain then shows the interdependency of all stages, but also of the impact of improvements in one stage on all others. If you can polish a lens surface to a higher level of accuracy, the coating technique has to follow as does the precision of centering and mounting. Otherwise the gain in one department is lost in the rest of the process. Current tolerances are 2 microns for radius of curvature of lens surfaces, 2 microns for thickness and 5 microns for distance between lens elements. Grinding and polishing. Now that the designer has specified the surface curvatures in thousands of millimetres, that is three digits after the decimal point, with tolerances of less than 2 microns, it is imperative that every glass surface is individually machined into shape. In the past one would fasten 20 to 70 lens elements (blanks or pressings as they are called) to a common support and grind/polish them in one batch. This was economical of course, but it restricted the designer to those curvatures that could be processed in this way. And tolerances had to be larger. In theory one can polish the surface to a very high degree of accuracy, but in practice this cannot be accomplished. As this process requires the glass to be heated, it is unsuitable for some of the glass Leica wishes to use. Therefore individual grinding and polishing is now the rule. Not all glass elements are processed in the Solms factory. Some glass is outsourced as the cost of production would be too high to bear on the glass. The new CNC-machines have specially designed digital motors to position the grinding tool to an accuracy of 4 million positions in a 360o movement. As no machine works with a zero tolerance, the true values wander slightly around the ideal position and these deviations are constantly monitored and adjusted. Very important is the fact that the operator has to understand what the numbers mean, how the machine will react to every adjustment he makes. Grinding is a painful process for the glass. In fact glass parts are chipped away and the surface looks like a moon crater. The polishing has to be done to a depth below the damaged surface and now a precision of 1 micron is required. One person controls 4 of these polishing machines, that will smooth and close the glass surface. An interferometer is used to check the accuracy. In the past one used so called test plates to check the surface. A test plate has a shape that is identical to the one that has to be checked but in the ‘negative’ form. A positive surface will be checked with a negative plate. The principle behind this test is the same as that used with the interferometer. We all know the phenomenon of Newton rings, that is the irregular rings we see when a negative dos not fit exactly to the glass carrier. These rings are irregular and differ in thickness and shape. In the shop one wavelength is specified (often sodium lamp or HeNe laser) and by an interferometric comparison one can study the regularity of the rings. Are all rings concentric and regular, a perfect fit is found. With this device one interference ring refers to one half of the wavelength. If an accuracy of 2 micron is required, one may accept at most irregularities in the first 4 rings from the centre. (4 rings is 4 times a half wavelength equals two wavelengths equals 2 micron). Some newer machines can grind and polish in one step, which fosters the accuracy. Polishing takes on average 20 minutes per surface or close to an hour per lens. As soon as one surface is finished it will be protected by a cover before the next process starts. A surface polished to a few microns of accuracy needs to be centred with the same precision. The rim of the lens has to be grinded so that the mechanical axis (defined by the edge of the lens) coincides with the optical axis that is the line between the centres of curvature of the two surfaces. The rim is machined to a precision of 0.01mm with a computer based laser device and it takes about 15 minutes to centre one lens element. If automatic mechanical centering cannot be done, Leica uses a specifically designed procedure to centre the lens optically. A simple calculation can tell us that a lens with let us say 9 elements already takes more than a day just to manufacture the glass elements. Aspherical surfaces are more complicated to manufacture. The basic shape is spherical but the asphericity has its own optical axis (or more with a complicated shape) and all techniques of grinding and polishing are based on the idea of random movements of the grinding and polishing tool. A sphere has everywhere the same shape so it does not matter where the tool is moving as long as the curvature shape is obeyed. Here a new computer based process has been devised. Now the mechanical axis is the base to work from. The designer has computed the specific shape and this surface contour is fed into the CNC machine that will follow the shape contour as specified and will polish the required form. This is a very elaborate process and a simple check with an interferometer is not possible as there are more curvature shapes on the surface. Leica uses special holograms that precisely represent the aspherical shape and with the help of these holograms an interferometer check can be done. The precision now is less than a _ wavelength. One aspherical surface takes more than one hour to finish. When I visited the factory the lenses that happened to be processed were the asphericals for the Vario-Elmar-R 4/35-70mm. The coating process has been discussed in previous chapters. Before the glass can be coated it has to be cleaned. In 30% of the cases the glass is cleaned by ultra sonic techniques, but not always as some glass is still to sensitive and has to be cleaned differently. I do mention this to indicate that Leica s very attentive that every component gets the treatment it deserves or needs. I can add here that Leica uses the new Advanced Plasma Source technique that does not require heating and cooling. The glass is less strained and its original properties stay intact. The APS technique deposits a smoother and more stable surface coating and so more sensitive glass can be used. The circle of the causal chain is closed again. Generally 4 to 6 layers are used per surface, but is it possible to deposit 36 layers per coating. Every batch is checked as a deviation per layer of less than 10 micron impairs the spectral transmission properties. Then the glass is put in stock in gas filled cabinets or dry cabinets, whatever is best. Ultrasonic cleaning is now used when the glass is prepared for mounting. Again there is additional manual cleaning and inspection by female workers several stages during the mounting and assembly. Lens elements are mounted in a close-fitting sleeve and there are several methods to retain the glass in the mount. One can use a threaded lock ring with or without spacers or the lens can be cemented in place by a plastic cement, that has also a slightly centering effect, care has to be taken that the cement does not overflow and here Leica uses computer-controlled machines that adjust the cement flow very accurately. The individual lens mounts are now aligned so that the mechanical and optical axes coincide. The diameter and distance are very important parameters for the performance of the lens and here tolerances of 1/100 to 5/1000 of a millimetre are specified. The aperture mechanism is installed and is checked with a torque meter to ensure the click stops are within ergonomical specifications. The aperture mechanism of the R-lenses has a specially designed braking mechanism to reduce the bouncing of the blades when the aperture closes to its preselected position. Would the blades be allowed to bounce, this will reduce the aperture opening momentarily and cause underexposure. The mounting of the several lenses or (in the case of cemented lenses) lens groups into the lens barrel is a labourious and exacting procedure, and the machining of the barrel itself has to be done to very small tolerances. Depending on the complexity of the lens , several tests are done to ensure that every stage will deliver a sub product within tolerance. After assembly of the lens, there is a check (with MTF equipment) to see if the lens performs as specified. As additive tolerances can combine in assembly, there is always a possibility that the performance is just outside the tolerance band. By using a compensator mechanism it is possible to fine tune the lens into the tolerance space. Not every lens does get this check as Leica knows by experience which lens types have to be checked individually or by sample. After this step the lens is ready for its final inspection. Every lens that leaves the factory has been individually checked. (see chapter 2.4.2 foe additional information) 8 Additions for reprint 2

Mandler noted that he had to use the same curvature for several lenses, because of costcutting, as the method of grinding many lenses at once encourages the designer to use curvatures that already exist or can be produced economically.

Lipinski, Precision and miniature cameras. 1955 to be precise 24.5 x 36,5 mm???????? Most historians assume that the design of the Elmax (5 lens elements in three groups) was the result of the patents held by Zeiss on the Tessartype-design (4 lens elements in three groups). The patent on the Tessar however expired in 1923 and Leitz and would certainly be aware of that date, if they were bothered by it. The Elmax design is from 1922 and the Elmar has been designed by in 1925. It seems illogical that would design a lens to circumvent the Zeiss patents just one year before the patent would expire and the date for the introduction of the Leica was not yet fixed. The design of the Elmar was finished three years later. As it so happens in the same year as the Leica appeared on the market. In those days there is quite a time lag between the date that a computation is finished and the retooling of the machinery has been completed to start the production. It could be the case that Leitz had planned to introduce the Leica in 1923 and would not have this introduction spoiled by patent issues. Then the Elmax lenses were already in production and when the introduction was postponed, the factory had a number of these lenses on stock and they were used before the new Elmar could be produced. Leica & Leicaflex lenses, Hove, 1980 BIOS, BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE : 1946., page 5 The ease with which Zeiss progressed from the Contax RF lenses to the Contarex is most remarkable M. : Grundlagen der praktischen Optik, Analyse und Synthese optischer Systeme, 1930, de Gruyter and Co. Generally multi coating is more effective in the reduction of secondary images than single coating. But there are of course exceptions on both sides. A multi coating layer with more than 15 layers can exhibit polarising effects when oblique rays meet the surface and can produce mysterious effects on film, which might explain the recording of UFO-like phenomena. Single layer coating is very effective when applied to glass with high refractive index and in this case a multiple layer does not help. Leitz has been involved in the techniques of multiple layer coating experimentally since 1945 and have applied these techniques with some restraint in photographic lenses since then. Current Leica lenses have multi coated surfaces, but some lenses are fitted with single layer surfaces. I am indebted to Mikiro Mori for the translation and the interpretation. I am indebted to Derek Keeling I am indebted to Derek Keeling (BJP, 8-2-1990) for this information This glass has been replaced around 1990 by standard glass from a regular supplier.

Leica lens compendium