Leica R-Lenses

by Erwin Puts

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Introduction

__The R-System

The first lenses for the Leicaflex have been introduced in 1965 in the then classical focal lengths of 35,50, 90 and 135mm. The Summicron 50mm had a maximum aperture of 1:2, all the others were Elmarit-versions with an aperture of 1:2.8. The quality of the mount was immediately recognized as the best in the world. These characteristics: sufficiently wide apertures and all metal mounts with excellent ergonomics are still true today for all lenses within the R-system. I could myself convince of the longevity and sustained accuracy over many years when I was able to test and check several scores of older lenses, often very heavy used. Every lens, even the most worn out ones, were within the originally specified tolerances and there was not a sign of decentring, one of the earliest signs of degraded performance. The optical performance was as expected from a new lens just out of the box.
The R-system has been developed and evolved over the years from 4 lenses with focal lengths from 35mm to 135mm to 26 lenses with focal lengths from 15mm to 800mm. The average age of all lenses is 11.5 years. Six lenses are less than 5 years old, eleven lenses are less than 10 years old and nine lenses have an average age of about 20 years. This last group of lenses has focal lengths from 24 to 100mm and the optical layout is mostly a Double-Gauss variant. This lens type is based on a very mature design and it is not easy to improve on the performance within acceptable financial and ergonomic constraints. The Summicron-R 1:2/50mm as example is still the best standard lens for reflex cameras. This range of lenses between 24 and 100mm has been complemented in the last decade with a series of high performance zoomlenses.
If we look carefully at the introductions in the last decade we can see where the development efforts will be focused on and what a possible road map could be. Actual and future mainstay of the range will be the zoomlenses and those fixed focal lengths that are eminently suited to manual focusing, like the very wide angle lenses (15mm to 19mm), telelenses with superb performance that can be used handheld (!80mm to 300mm) and specialized lenses with very wide apertures like the Summicron-R 1:2/180mm. The image quality of the R-lenses should enable the photographer to exploit to the full extent the potential of the imaging chain and to implement creative imagery with great clarity of vision.

__The construction

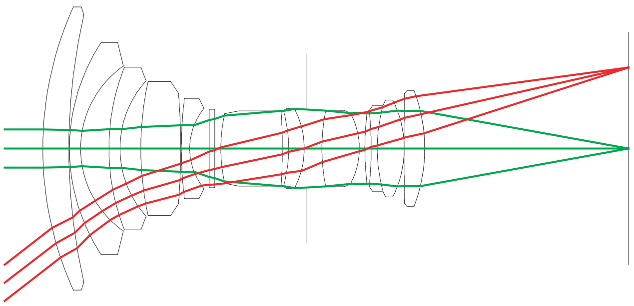
Several limitations are imposed on the design and construction of R-lenses. The most important are the back focal length, that is the distance from bayonet flange to the front of the film plane (in this case also free space for the mirror movement), the manual focusing mechanism and the the mechanical aperture control. You can not create an arbitrary small lens because you need space for the mechanical functions and the mounts. And the aperture and focal length have some influence too. A 180mm lens with a maximum aperture of 1:2 will have a front lens diameter of at least 90mm. Size and weight are important limiting parameters when designing a lens. If you are able to create small lenses, as with the Minox camera, you will encounter less problems with the correction of optical aberrations. That is one of the reasons why the Minox lenses are so good. If you can design a lens without any consideration to weight and size, you can compute a system with many lenses and so reach a very high level of quality. In practical terms, one will have to find a smart middle course and one has to balance the conflicting demands to reach a delicate and individual equilibrium. Every optical designer will set his/her own emphasis and will accentuate certain characteristics.
When designing long focus lenses and high speed retrofocus designs, the back focal length and the bayonet diameter will influence the location of the exit pupil, and this must be chosen carefully. It is really not a simple matter to create a design that will satisfy all demands without some reduction.

__Retrofocus lenses

A retrofocus lens is characterized by a back focal length that is longer than the true focal length. The Leica R mirror box asks for some space and the back focal length is 47mm. A lens with a focal length of 15mm will only fit if you can lock the mirror in its upward position. This was indeed the only solution in the past. The designer created so called symmetrical lenses, consisting of two identical groups of lenses, that were mirrored around the aperture stop. A simple and brilliant solution: several optical aberrations generated by the fist group, could be compensated fully by the second group. But the disadvantage of the blocked viewfinder path was too great and so the retrofocus lens was developed. At the beginning the image quality of the retrofocus design was less than what could be expected from the symmetrical design. The first generation of retrofocus designs were simply normal lenses wit a negative lens put in front. In the course of time this type has been evolved to a new type of design with very promising possibilities. Today one can calculate retrofocus designs that are as good or even better than symmetrical lenses (see illustration below). The necessary effort is however much higher and the lenses will not be as small. It is extremely difficult to design a compact retrofocus lens without compromising the image quality. On the other hand the location of the exit pupil can be used to reduce the amount of vignetting.
Without floating elements a good performance in the near focus range at wider apertures is quite a task. Leica will use the method of floating elements whenever needed. But then the opto-mechanical complexity increases and the Leica photographer may find him/her self lucky that the Leica company has this almost fanatical aspiration to reduce the mechanical tolerances to the level that production machinery nowadays can consistently deliver.

__Telelenses

There are some aberrations that become a downright nuisance when the focal length increases. A longer focal length implies a higher magnification of the subject and also an enlargement of chromatic aberrations.You need special glass types to correct these errors. The use of new glass types from among others Schott, Hoya and Ohara, the so called glass with anomalous dispersion, is required to correct the optical errors to a high degree. But these glasses are difficult to manipulate and also very expensive. And it makes no sense to employ this glass if you can not mount and check the manufacture with very narrow tolerances. With the help of these glasses, you can design lenses with excellent performance (if you have understood the optical system) and there are some superb lenses in the Leica program that are a serious challenge for the capabilities of the user. If you have understood the the performance profile of such a lens, you can create astonishingly good pictures.
If you correct the chromatic aberrations to a particular high degree, the lens is called an apochromatic design. Such designation is however not an objective criterion and so the transitions are fleeting. Where an apochromat starts and an achromat ends is not easy to define in practice. The Apo designs from Leica have a vanishingly small amount of residual chromatic errors and can be called apochromats. There are some photographic situations where the subjects will exhibit some small color fringes at the edges, specifically when the dark subject is positioned against a very light background.
The second characteristic of modern telelenses is the use of internal focusing. Here a lens group will be moved over a small distance in order to improve the image quality over a wider focusing range. In addition the focusing movement can be much smoother as smaller masses will have to be moved over a shorter distance.
The small movement must be controlled quite accurately, otherwise the result will be worse than without this method.



An example for a modern retrofocus wideangle lens (19mm f/2.8)

__Zoomlenses

Zoomlenses and Single Lens Reflex cameras form a natural and harmonious unit. The focal length can be changed continuously and you can see the changes in the viewfinder in order to select the appropriate framing of the subject. The Leitz company has for a long time expressed their hesitancy with respect to the optical excellence of zoomlenses compared to the fixed focal lengths. The first zoomlenses (Zoomar 36-82 or Nikkor 43-86) were indeed not revolutionary, but they ofefred an additional added value to practical picture taking that exceeded their limited performances. From the moment that one could improve the quality substantially (with improved understanding of the lens type, new optical design programs, effective coating of the many lens elements) all major lens manufacturers have concentrated on this type of lens.   Even leitz had a special department for the analysis and design of zoomlenses, but limited to the systems for the Leicina, a movie camera that was quite important in those days. The knowledge that was acquired was not transferred to the photo department, even though the famous Dr. Walther Mandler, head of the optical department at Leitz Canada wrote in an article in 1980 hat according to his studies, zoomlenses could deliver   image quality as good as that as that of the corresponding fixed focal lengths.
From 1992 (about ten tears later) new zoomlenses have been designed by Leica. It new start had to be made as the previous experience and knowledge was of limited value. It is the great accomplishment of Lothar Kölsch, then head of the optical department of Leica, to redefine the performance level of zoomlenses to an all time height. The first original Leica zoom is the Vario-APO-Elmarit-R 1:2.8/70-180mm.

__The idea of moving lens elements

A zoomlens is basically an optical system that has a changeable magnification ratio while maintaining the focus position. A zoomlens has two requirements: (1) the focal length must be continuously variable and (2) the distance setting (focus position) must not change so that the object stays focused correctly. Generally one can accomplish this with an optical system with two moving lenses (or lens groups). If you look at the very complicated lens diagrams of current zoomlenses, you may feel surprised that the basic idea is so simple.
Let us start with the basics. Assume we have only two lens elements. One element is needed for the change of focal length and the other one for the distance setting. It does not matter which lens is used for what function. When you move one lens over a small distance, the focal length will change or what is the same the magnification ratio. Now you must move the second lens over a certain distance to compensate the focus position. Both lenses can be coupled mechanically so that a change by one element automatically will move the other element over the required distance. You could imagine the following construction: both lenses are mounted in one tube, that has two grooves with a certain length and angle of inclination. Both elements will move at the same time within these grooves. Now we can start to understand the basic problem of zoomlenses. One of the elements can be moved in a linear fashion, that is a straight line. The other one must move in a nonlinear fashion. The optical explanation is quite daunting and will be skipped here. The resulting shape of the nonlinear curve can be very elaborate and is very laborious to construct with the required accuracy. Even more difficult is a shape where the movement of the lens has to be reversed and one must provide a twist in the curve. As the movement of all elements has to be accomplished with one turning movement of the lens mount, one needs a quite complicated shape of the curve that is very expensive to manufacture. This method of lens coupling is called the mechanical zoom compensation.

The second method of compensation is called the optical compensation. This one has the advantage that all movements are linear. Biggest drawback is the fact that the focusing is only accurately compensated for a few positions of focal length. At all other positions the image is slightly unsharp. The user has to adjust the focus manually. With autofocus systems there is no problem as the AF sensor will detect this unsharpness and can refocus. Systems with optical compensation are quite elaborate as one needs more lens elements and groups (up to 5 moving groups). Then we may expect problems with the accuracy of

mounting, the transparency and flare.
Leica has basically chosen to only employ the method of mechanical compensation. This construction has definite advantages. On which more later.

__From principle to construction

The basic design with two moving elements is just theory. The optical designer wants to create a very good overall level of error correction and to secure this performance over the whole magnification range of the zoomlens. In this case the two elements are hopelessly inadequate. In addition one needs two fixed lens groups, a front group for manual focusing and a master group at the rear part. This master group is known from normal photographic lenses and defines the angle of view and the maximum aperture of the system. Between these two groups you will find the linked moving elements. The overall complexity is dependent on the required level of optical correction.
You can also change the fixed front group (for focusing) to a moving element and it this case there are three moving groups and has the front group a double task. Leica has zoomlenses with different designs in the program. The first design by Leica was the Vario-Apo-Elmarit-R 1:2.8/70-180mm and has 13 elements with a very high performance profile. The Apo-Elmarit-R 1:2.8/180mm has 7 elements and delivers an even higher performance. This comparison is not entirely honest, but it does indicate the higher level of effort that is needed for complex zoomlenses. On the other hand can you use these additional elements to improve the quality if you understand the optical system. There is a rule of thumb in optical design that says that it is better to distribute the total power of the system evenly over the lens elements. With more elements this is somewhat simpler. In addition the designer will pay attention to the fact that the contribution of every lens surface to the total optical error of the system has to be minimized. This is only feasible if you understand the shapes of the curvatures very well in their error contribution. The creative mind is the most important asset in lens design and superior to any computer program when really good solutions are requited.

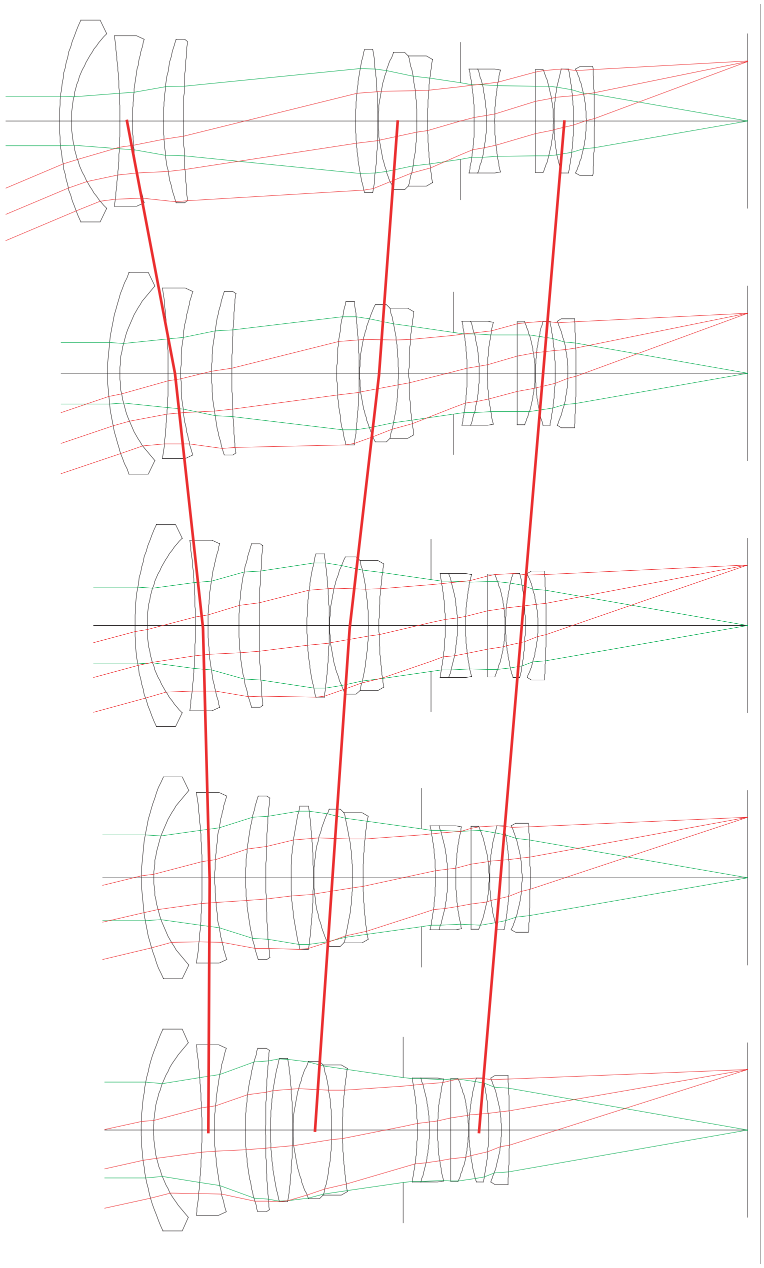
The optical designer has more degrees of freedom when he/she has control over more elements that can be moved within limits and the possible error correction can be of a very high order indeed. But to make a high quality zoomlens that will deliver at all focal lengths within the zoom range the movement of the sliding groups should be as small as possible. The two-group design with mechanical coupling is the preferred solution within the current range of Leica zooms. The Vario-Elmar-R 1:4/35-70 and the Vario-Elmar-R ASPH 1:3,5-4/21-35 have this design. The Vario-Elmarit-R ASPH 2,8/35-70 has two moving groups and in addition a "floating element" to add error correction. Here three groups are moving in concert.
These two-group moving systems are excellent solutions for zoomlenses with a zoom range between 1:2 and 1:3. Examples are : 21-35 makes 1:1.66, 35-70 makes 1:2.0, 70-180 makes 1:2.5.
With this system, one can get outstandingly good results, but the manufacturing process has to work with narrow tolerances.

__Metal mounts

The meal mounts of Leica lenses make it possible to work within these tolerances, that are below 0.01mm in many cases. The Leica mounts are produced nowadays with CNC machines and every part will be carefully and painstakingly finished manually by experienced workers. The mechanical control of the movement of the lens groups functions within minute tolerances and that is indeed required. After having found the correct framing of the motive by changing the magnification of the lens, you do not want to have to refocus, which is a nuisance and will disturb the act of photography. When using AF cameras, the requirements are less precise, as a small unsharpness will be corrected by the AF system. In a general sense, one should know the limitations of the AF system. AF is extremely fast, much faster than what one can accomplish manually with eye-hand coordination. AF systems are not very exact in their focusing. I have noticed this personally when testing systems from several well known manufacturers.

The complex barrel construction of the Vario-Apo-Elmarit-R 70-180 mm f/2.8

Movements of the optical groups when changing the focal lenght (Vario-Elmarit-R 35-70 mm f/2.8 ASPH.)



In many instances I had to refocus after changing the focal length to get a sharp image of the subject. And many photographers switch off the AF function when they need really accurate focus. It is without any doubt that AF is a great help and often necessary when you want to capture fast and unpredictably moving subjects. But there are many motives where accurate focusing is more important than fast focusing. Here one enters the domain of Leica-R photography.

Metal mounts are an important characteristic of Leica lenses. But one should keep a sensible eye on the matter. There are opinions that claim that synthetic materials are inferior to metal parts. This is not true. Synthetic materials has many characteristics that are quite valuable in precision engineering mechanics. A negative attitude is a thing of the past. But synthetic materials are best suited in mass production situations, because the individual parts can be made by dedicated machinery that are custom made and must be depreciated in a short period. Metal mounts are always slightly larger than comparable synthetic components, but the size should be kept in reasonable dimensions. If one could built without restrictions, the optical designer can create aberration free lenses. One can then use as many lenses as needed and can create many degrees of freedom, including lens diameters. This can be seen in the field of micro-lithography where lenses are used for the chip manufacture and were 30 lens elements for one system are not an exception.

__Ergonomics and size

A lens needs a very good ergonomic shape, especially if it is used manually. The size of a lens depends on a few parameters. The most important are the focal length, and the front and rear lens opening (the maximum aperture and the bayonet diameter). R-lenses are also constrained by the back focal length (mirror box and space for moving mirror). Not only the focusing is manual, but the diaphragm mechanism is mechanically actuated too. This fact is important as you need room for the mechanical linkages. Actually this linkage is a challenge for the engineers, as there is force involved. And the transmission of forces by mechanical means is not that simple. The time parallax between the moment the shutter is tripped and the closing of the diaphragm should be small and work without resistances. The position of the diagram is not really free with telelenses as it cannot be placed to far in the front part of the lens. Mechanical constraints, optical demands and ergonomic criteria together define the construction, shape, handling and weight of a lens.

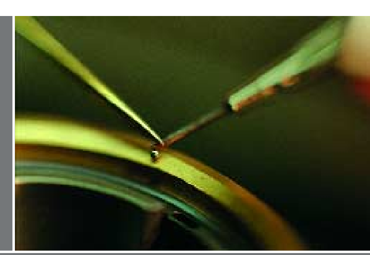
__Focusing

The focusing movement is accomplished with parallel threads and the movement must be very precise, tight and smooth at the same time. And backlash may not be detectable after decades of use. The choice and tooling of the materials is very critical. To enhance the smoothness of operation it now customary to employ internal focusing groups. While smoothness is improved, the demands on accuracy increase. But leica often uses constructions that are not mentioned in the literature. The Apo-Elmarit-R :2.8 / 180mm not only offers a superb performance profile, but also a patented focusing construction and a new form of the aperture blades. The customary discretion of the Leica engineers not to disclose their accomplishments, has its virtues, but many fascinating details are kept in the dark.

__Performance profile and lens personality

Leica R-lenses are characterized by a very homogeneous performance profile: the optical quality is very high, but the performance peak is not an isolated value. You could design a lens with excellent values at a certain distance and aperture, but and lower values at all other positions. With Leica lenses one can expect the same high quality at all apertures and object distances, and for zoomlenses over all focal lengths. This optical performance is accompanied by a very good ergonomic design. These goals can be attained because the metal mounts allow for the accuracy and precision that is needed.

Mechanical precision down to the finest details



And we need this accuracy as there is no AF system that can smooth out small errors in mechanical accuracy. Here the circle is closed: because there is no AF, a higher level of precision is required and that can be delivered only when using metal parts that are individually and manually finished. And the current requirements can only be met when the zoomranges are not too extended.

Every lens for a photographic purpose is a compromise between many often conflicting demands. Size and weight and correction of optical errors are interlinked parameters. The word 'compromise' is probably not the right designation as it could give the impression that we are talking about a less desirable solution. It would be better to talk about an equilibrium condition. The optical designer searches for an optimum solution within the allowable space conditions and will balance third order aberrations with fifth order aberrations. This balance will be different for a standardlens, a wide aperture wide angle retrofocus lens or a zoomlens. You can not characterize the profile of a lens along a unidimensional scale. A wide angle lens has requirements that are different from a tlelens and what is acceptable for a wide angle lens, may be anathema for a telelens. In this area individual and personal views play some role and the definition of the image quality is a bit personal. Optical designers are very creative people who will select one specific design out of many possible solutions, that they accept as the best possible design, but there are no objective standards.

That is why every Leica lens has an individual personality within a family likeness. A Summicron-R 1:2/50mm is a classical six element Double-Gauss design, of which hundreds of variants exist. There are bigger and finer differences between the many design forms and the individual aberration correction. Precisely these smaller differences do define the final image quality and the fingerprint of the Leica lenses. One needs a bit of time and discipline to discover these finer characteristics and use them to good effect during picture making.

The lens reports that follow, will expand on these issues.

See you soon!
Erwin Puts