2009
Industrial Affiliates Day

"High Power Optical Sources for the 21st Century"

CREOL
The College of Optics & Photonics

CREOL, The College of Optics & Photonics

presents

"High Power Light Sources for the 21st Century"

Industrial Affiliates Day
April 17, 2009

Program Guide

CREOL, The College of Optics and Photonics
Industrial Affiliates Day — April 17, 2009
"High Power Optical Sources for the 21st Century"

Morning Session - UCF Student Union

Time	Topic	Speaker	Affiliation
8:30	Continental Breakfast and Walk-in Registrations		
9:00	Welcoming Remarks	Dr. MJ Soileau Dr. Bahaa Saleh	UCF Vice-President for Research Dean & Director, CREOL, The College of Optics and Photonics
9:20	*The Art of Innovation – Laser Technology for new Markets*	Prof. Dr. Reinhart Poprawe, M.A.	Fraunhofer-Institute for Laser Technology and Chair for Laser Technology RWTH-Aachen University
10:00	*HEL Joint Technology Office (JTO) Research & Programs*	Mr. Albert Ogloza	HEL/JTO – Albuquerque, NM
10:40	BREAK		
11:00	*DPAL: a hybrid diode/gas laser approach to high power and brightness*	Dr. Bill Krupke	WFK Lasers – Pleasanton, CA
11:40	*High power fibers lasers and their applications*	Dr. Peter Moulton	Q-Peak – Bedford, MA
12:10	LUNCH Served		Student Center

Afternoon Session - CREOL Building

Time	Topic	Speaker	Affiliation
1:00	Walk to CREOL Bldg. Exhibits Open		
1:15	*Townes Laser Institute – Update on progress to date*	Dr. Martin Richardson	CREOL, The College of Optics and Photonics
1:30	*High Power Beam Combining*	Dr. Leonid Glebov	CREOL, The College of Optics and Photonics
2:10	*CREOL, The College of Optics and Photonics – Research Overview*	Dr. Bahaa Saleh	Dean, CREOL, The College of Optics and Photonics
2:50	Student of the Year – Research Presentation	Oleksandr Savchyn	CREOL, The College of Optics and Photonics
3:20	Poster Sessions ; Lab Tours (contiguous)	CREOL Graduate Students	CREOL Balcony; Tours start from Lobby
5:00 - 6:15	Reception & Award presentations	Dr. Bahaa Saleh	CREOL, The College of Optics and Photonics

Tabletop Exhibits - CREOL Lobby

Exhibitors

Exhibitor tables will either be in the atrium of the Student Union (am) or the CREOL Lobby (pm).

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Stuart, FL 34997
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Vytran
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The Art of Innovation — Laser Technology for New Markets

Prof. Dr. Reinhart Poprawe
Fraunhofer-Institute for Laser Technology and
Chair for Laser Technology RWTH-Aachen University
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Abstract

Innovation did happen, if measurable benefits – usually in the form of financial surplus – can be documented. This strict definition implies that scientific or technical demonstrations are necessary, however too often too soon published, claimed and most importantly seen as success. The true innovation needs partners not only with market know how, but with market presence, i.e. industry. Therefore it is vital to create innovation in networks covering necessary scientific depth for sustainable innovations and – more important – early stage involvement and commitment of market relevant partners.

The Fraunhofer Model is designed to meet the demands of this challenging process. The presentation will focus on the systematics of that model, however in parallel always display actual real world applications and cases, e.g. high quality Diode Lasers, 400W-average power fs-lasers, ablation technology by ps-lasers, EUV-Sources for NG-Lithography, Individual Production by Laser SLM, Metal Deposition for jet engine repair, Laser Polishing, Laser Sorting of scrap metals or material analysis by LIBS. In all cases the entanglement of Fraunhofer-ILT with its partners can be identified as necessary and sufficient condition for success.

Biographical Note

Professor Poprawe holds a M. A. in Physics degree from the California State University in Fresno which he received in 1977. After completion of his diploma and PhD in physics (Darmstadt 1984) he joined the Fraunhofer Institute for Laser Technology in Aachen where he began working as head of the department “Laser oriented process development” in 1985. From 1989 to 1/1996 he has been managing director of Thyssen Laser Technik GmbH in Aachen. Since February 1996 he is managing director of the Fraunhofer Institute for Laser Technology and holds the University Chair for Laser Technology at the RWTH Aachen. He is vice president the AKL Arbeitskreis Lasertechnik e. V. Aachen. Prof. Poprawe has been elected to the grade of Fellow in the Society of Manufacturing Engineers in USA (SME) since 1998 and a Fellow of the Laser Institute of America. Since 2008 he is a member of the board of the Laser Institute of America (LIA) and serves in many national and international boards as advisor, referee or consultant. Relevant R&D-expertise: Diode pumped solid state lasers, diode lasers, pump modules and amplifier modules for multisectorial applications, ps-, fs-lasers, beam forming in space and time, short pulse laser, production process for diode lasers, EUV- and x-ray lasers, drilling, cutting, joining (welding, soldering), surface processing, laser polishing, laser generating, selective laser melting, laser metal deposition, micro technology, nano photonics, system technology, process control, photonics in Life Science.

High Power Lasers Based on Volume Bragg Gratings

Dr. Leonid Glebov
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Abstract

This presentation is a survey of recent achievements in lasers with resonators which include volume Bragg gratings – volume Bragg lasers. The technology of diffractive optical elements (volume Bragg gratings, VBGs) recorded in a photo-thermo-refractive (PTR) glass was developed at CREOL/ The College of Optics and Photonics, University of Central Florida and licensed to OptiGrate Corporation. These elements enable dramatic improvement of parameters of different types of lasers demonstrated by a number of different research groups.

The use of reflecting Bragg gratings as output couplers in external resonators for semiconductor diodes, bars and stacks provided efficient spectral locking with efficiency which usually exceeds 95%. Bragg mirrors enable spectral narrowing of solid state lasers down to couple picometers. Experiments with wide stripe semiconductor lasers have shown that the use of VBGs with angular selectivity comparable with diffraction limited divergence of emitter provides amplification for a single mode only. Effective transverse mode selection in solid state lasers is also demonstrated. Coherent radiation from two and three laser diodes placed at separated stages was observed by phase locking with narrow-band VBG. Chirped Bragg gratings stretch and compress short laser pulses. It was shown that stretching and compression could be performed with efficiency of about 95% for pulse widths down to 200 fs and average power exceeding 100 W. VBGs were used for spectral combining of beams of Yb-doped fiber lasers. Efficiency of five-channel combining of 93% with divergence close to diffraction limit and total power of 750 W were demonstrated.

Biographical Note

Leon Glebov got his Ph.D. in Physics (major in Optics) and Doctor of Sciences from State Optical Institute, Leningrad, Russia (1976 and 1987), where he hold a number of research and administrative positions. His main directions of his research at that institute were color center generation, laser induced breakdown, planar waveguides and photosensitive glasses for amplitude and phase recording. He is a Research Professor at CREOL/The College of Optics and Photonics, University of Central Florida since 1995. He has published a book and more than 280 papers in scientific journals and holds a number of patents. He is a member of Organizing and Program Committees for a number of International Conferences. He is Fellow of Optical Society of America and American Ceramic Society, and a recipient of Denis Gabor award for contribution in holography. The main directions of his research are optical properties of glasses including nonlinear phenomena, photosensitive glasses for hologram recording, holographic optical elements, and lasers with volume Bragg external resonators. Dr. Glebov is a Founder of OptiGrate Corporation, Orlando, FL, where he holds a position of CTO.

A Hybrid Diode-gas Laser Approach to High Power & Brightness

Dr. William F. Krupke
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Abstract

The development of high power semiconductor laser diode pump sources during the past decade enabled a great increase in the efficiency, power, and compactness of solid state lasers (DPSSLs). DPSSL output powers have now been scaled well into the multi-kW regime with excellent beam quality. However, in these lasers waste heat in the static solid state gain must be removed by thermal conduction, resulting in thermo-optical distortions that limit the high brightness power scaling these lasers in a single (spatially) coherent aperture. To overcome this limitation, several years ago the concept of the hybrid diode-pumped-alkali-laser (DPAL) was proposed to retain the attractive efficiency and power scaling properties of high power pump semiconductor laser diodes, while replacing the static solid state gain medium with a gaseous (vapor) gain medium, recovering the feature of convective transport of waste heat out of the laser resonator. In this talk the basic quasi-two level DPAL laser scheme and its physical characteristics will be reviewed, the present state of DPAL R&D will be summarized, and architectures for power scaling will be described.

Biographical Note

Bill received the PhD degree in Physics from the University of California at Los Angeles in 1966. After graduation Bill held technical and management positions at the Hughes Aircraft Company (1958-1961; 1961-1972), Minneapolis Honeywell Company (1962-1963), and the Aerospace Corporation (1963-1966), where he performed research on various gas, chemical, and solid state lasers. In 1972 Bill co-founded the Laser Directorate at the Lawrence Livermore National Laboratory (LLNL), responsible for the development and execution of the Laboratory's Inertial Confinement Fusion (ICF) and Atomic Vapor Laser Isotope Separation (AVLIS) national R&D programs. During his 27 years there, Bill variously served as Program Leader, Chief Scientist, and finally Deputy Associate Director for 20 years. At LLNL, he participated in the design, development, and construction of evermore powerful Nd:glass lasers for fusion research, and the development of lasers for use in an industrial scale, economic uranium enrichment process. Since 1985, he actively engaged in the development of diode-pumped high-average-power solid state lasers, and their use in military, industrial, and commercial applications. In 1999, Bill left LLNL and formed WFK Lasers, LLC to devote full time to develop laser intellectual property and to consult for photonics technology companies. Bill is a Fellow of the Optical Society of America, and has served as an elected member of the OSA Board of Directors. He is also a member the IEEE Laser and Electro-optics Society (LEOS).

Invited Presentations

Power Scaling of Tm: fiber Lasers to the kW Level

Dr. Peter F. Moulton
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Abstract

The power scaling of fiber lasers to the multi-kW level is one of the more notable advances in laser technology in the past 5 years. Nearly all of the scaling work has been concentrated on Yb-doped silica fibers, operating in the wavelength range around 1070 nm. The severe retinal hazard from lasers in this region has motivated the search for power-scalable fiber lasers at "eyesafer" wavelengths beyond 1400 nm. Tm-doped silica fiber lasers, providing output around 2050 nm, are one of the more promising technologies. The energy-level properties of the Tm:silica material allow efficient laser operation with pumping by conventional, 795-nm, high-power diode lasers. In this talk, we described efforts at Q-Peak to better characterize the Tm:silica fiber laser and scale power output to the kW level and beyond. Our work to date includes basic spectroscopy, laboratory demonstrations of efficient lasers at powers nearing 1 kW and technology development of "all-glass" systems. We will discuss these results along with our latest advances.

Biographical Note

Peter Moulton received an A.B. in Physics from Harvard College in 1968 and M.S. and Ph.D. degrees in Electrical Engineering from M.I.T. in 1972 and 1975 respectively. After finishing graduate school he was employed in the Quantum Electronics Group at M.I.T. Lincoln Laboratory, Lexington, Massachusetts. In 1985 he joined a start-up company, Schwartz Electro-Optics, as Vice-President and managed the founding of the company's Research Division in Concord, Massachusetts. He became Senior Vice-President of SEO in 1997 and was involved in spinning out the Research Division as a separate company, Q-Peak, in 1998, and in the sale of Q-Peak to its current parent company, Physical Sciences Inc. in 2001. At present he is the Vice-President and Chief Technology Officer of Q-Peak. Moulton's technical work began in the field of bulk solid state lasers, and in recent years has extended to include nonlinear optics and fiber lasers. Some of his work has been motivated by defense applications, including infrared countermeasures, detection of chemical and biological weapons, advanced ladar and targeting systems, laser communications and directed-energy systems. He has also been involved in scientific applications, including global monitoring of atmospheric water vapor, ozone aerosols and wind, in commercial applications in the semiconductor industry, in laser systems for medical treatment and diagnostics, and in the development of lasers for large-screen color displays. Dr. Moulton is a Fellow of the Optical Society of America (OSA.) He was awarded the R.W. Wood Prize from the OSA and the William Streifer Scientific Achievement Award from IEEE/LEOS, both in 1997, and in 2000 he was elected to the National Academy of Engineering.

Townes Laser Institute Update

Martin Richardson
CREOL, The College of Optics and Photonics
University of Central Florida
UCF Trustee Chair: Northrup Grumman Professor of X-ray Photonics
and Director Townes Laser Institute Laser Plasma Laboratory
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Abstract

"The Townes Laser Institute was dedicated May 4, 2007 as a State center of excellence in advanced lasers and laser technologies and recognizing Dr Charles Hard Townes, 1964 Nobel Laureate for Physics, whose ideas lead to the invention of the laser . The primary goal of this institute is to make UCF the premier institution in advanced laser technology in the United States, focusing on applications in medicine, advanced manufacturing tools, and defense. We will provide a brief summary of its mission and progress, with a vision of its future impact on the College, UCF, and academic laser research in the nation."

Biographical Note

Martin Richardson graduated from Imperial College, London, in Physics and gained his Ph.D from London University. He is now a Professor of Optics in the School of Optics at the University of Central Florida, and also holds similar positions in the departments of Physics and Electrical & Computer Engineering. He directs a research program on the development of new high power lasers, and their applications to dense laser plasma studies and x-ray generation in the Laser Plasma Laboratory at the Center for Research & Education in Optics & Lasers (CREOL). Since coming to North America in 1967, his career has been in the development of high power lasers and their application to laser plasma studies.

For 12 years he held positions at the NRC laboratories in Ottawa, Canada, making contributions to high power, ultrashort laser pulsed plasmas and the development of CO_2 lasers and their use in laser fusion studies. In 1980 he joined the University of Rochester where he worked for nine years as group leader for experiments for the then new 24-beam OMEGA system at the Laboratory for Laser Energetics.

Dr Richardson has held visiting scientific positions at the Institute for Laser Engineering (ILE) Osaka University, the Max Planck Institute for Quantum Optics in Germany, and other institutions in Australia, Canada, France and the former Soviet Union. He has published over 300 scientific articles in professional scientific journals, most on them on high power lasers and x-rays and their applications. He holds five patents, with several pending. He has chaired many international conferences including IQEC, ICHSP, and several SPIE meetings. He is a former Associate Editor of JQE, a recipient of the Schardin Medal, and a Fellow of OSA.

Invited Presentations

HEL Joint Technology Office (JTO): Research & Programs

Mr. Albert A. Ogloza
Navy Representative to the
Joint Technology Office for High Energy Lasers
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Abstract

The Joint Technology Office for High Energy Lasers (JTO-HEL) supports the development of laser technology across a broad spectrum research fields and institutions. The research areas include Solid State Lasers, Gas Lasers, Free Electron Laser, Beam Control Systems, Modeling and Simulation, and Laser Effects. This talk will discuss each of these research areas in detail and some of the research institutions performing the work. The main purpose of this talk is to acquaint the audience with the Joint Technology Office and the research that we support.

Biographical Note

Mr. Ogloza received a Masters degree in Physics from Southern Illinois University at Carbondale in 1987. As part of an IMMRRI fellowship his dissertation was on irreversible phase transitions in Solid State materials.

Mr. Ogloza has been a research physicist the Naval Weapons Center at China Lake (NWC) for over 20 years. There he conducted research in High Energy Lasers, including Imaging spectral sensor development, optical metrology, optical fabrication, and optical thin film growth. In 1991 Mr. Ogloza received a NWC Graduate fellowship to attend the University of Arizona at the Optical Sciences Center where he completed his PhD coarse work and conducted research into optical thin film coating development.

In 2002 Mr. Ogloza started working with the Joint Technology Office for High Energy Lasers on the development of Optical Thin Film Coatings and advanced thin film metrology systems. In 2005 Mr. Ogloza received the Michelson Award for scientific achievement, for the development of advanced sensor systems and his work with High Energy Lasers. In 2007 Mr. Ogloza received the position as Navy Representative to the Joint Technology Office for High Energy Lasers. There his duties are to represent the Navy interest in the development of Laser Technology and High Energy Laser Systems. The JTO-HEL coordinates the development of the HEL technology base throughout industry, Government agencies and academia. His primary responsibilities are to represent the Navy interests at the JTO and to select and monitor programs funded by the JTO-HEL.

Sensitizers of Erbium in Silicon-rich SiO2: Nanochrystals or Luminescence Centers?

Oleksandr Savchyn
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Abstract

The implementation of silicon photonics requires the development of a compact silicon-compatible light source. One of the possible routes for its realization is to use the emission from optical centers incorporated into silicon-based matrices and sensitized with dopants. It has long been thought that silicon nanocrystals can be used as efficient and dominant sensitizers of erbium in silicon-doped SiO2. In the current presentation it will be shown that the indirect excitation of erbium in this material does not require the presence of silicon nanocrystals. This conclusion clarifies a number of previously unexplained results and opens new opportunities in the field of silicon photonics.

Biographical Note

Oleksandr Savchyn received his M.S. in Optics from CREOL in 2007 and his Specialist degree (B.S. & M.S.) in Physics from the Lviv 'Ivan Franko' National University (Lviv, Ukraine) in 2002. During 2002-2004 he worked as a research assistant at the Department of Physics of Lviv 'Ivan Franko' National University. In 2004 he joined the Nanophotonics and Near-field Optics group at CREOL led by Dr. Peter Kik where he currently pursues his Ph.D. studies. His scientific interests include semiconductor photonics, indirect excitation of erbium in glass matrices, optical properties of silicon nanocrystals. He is a student member of OSA, SPIE, IEEE/LEOS, MRS.

CREOL Building 2nd Floor — 3:20 - 5pm

Abstracts are numbered in the order Posters are displayed: Student Presenter is listed first and underlined. Faculty Supervisor is underlined. All listed contributors are affiliated with The College of Optics & Photonics, *unless otherwise noted.*

POSTER I

Symmetry Breaking and Carrier Dynamics in Lead Salt Quantum Dots

Gero Nootz,[1,2] Lazaro A. Padilha,[1] Scott Webster[1], David J. Hagan,[1,2] Eric W. Van Stryland,[1,2] and Edward H. Sargent[3]
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Abstract

Semiconductor quantum dots (QDs), semiconductor particles with sizes small enough for effects due to quantum confinement of the electronic wave functions to be observed, have been investigated for several decades, but only recently have high-quality lead-salt QDs with narrow size distribution successfully been synthesized. Understanding the electronic structure and carrier dynamics is of fundamental importance for future applications of these mane made and highly customizable materials.

In this work we investigate the carrier dynamics in PbS and PbSe QD's, measured by femtosecond white-light-continuum transient-absorption, and two-photon absorption (2PA) spectra, measured by two-photon fluorescence and Z-scan. We identify different relaxation processes and measure their time constants. The buildup time of the 1S state population when electrons are excited to the 1P level in PbS QDs is measured and found to increase with increasing QD size. For the interband transition from the 1S level into the ground state Auger recombination is determined to be the dominant relaxation process in QDs when more than one exciton is generated.

We show that symmetry breaking in QDs relaxes the selection rules for one and two-photon transitions. This is evident from linear absorption measurement where features in the one photon spectra appear where theoretical calculations predict two-photon allowed transitions. Similarly, features in the 2PA spectra are seen where one-photon transitions are measured and predicted.

POSTER II

Photosensitive Polymeric Materials for Two-Photon 3D WORM Optical Data Storage Systems

Ciceron O. Yanez,† Carolina D. Andrade,† Sheng Yao,† Gheorge Luchita,† Kevin D. Belfield†‡*

† Department of Chemistry University of Central Florida, Orlando, FL 32816 and
‡CREOL, The College of Optics and Photonics, University of Central Florida, Orlando, FL 32816
***Kevin D. Belfield, Belfield@mail.ucf.edu, 407-823-1028**

Abstract

A fluorescence readout, WORM optical data storage system has been previously reported by this group where protonation of a 2PA fluorene dyes in solution with 2PA photoacid generator (PAGs) were performed by both one and two-photon excitation of photosensitive polymer films. Commercially available photoacid generators (PAGs) were used in this work. We evaluate the versatility of this data storage system by modifying all of its three components. PAG photoacid efficiency, fluorescent dye versatility and polymer substrates were the elements that were modified. One of the 2PA WORM ODS systems proved to be resilient to overexposure. Furthermore, the inherent nonlinearity of 2PA components enabled a crosstalk free system in which the 3D character of the ODS was demonstrated. The advantages of two-photon writing and readout were clearly evidenced, affording a substantial storage density capacity (up to ca. 1011 bytes/cm3).

POSTER III

Broadband Wide-angle Reflective Polarization Converter Using Liquid Crystal Films

Yan Li and Thomas X. Wu, Shin-Tson Wu
***For information, contact: yanli@creol.ucf.edu, 407-823-6800; swu@creol.ucf.edu, 407-823-4763**

Abstract

We propose a broadband wide-incident-angle reflective polarization converter for light recycling inside a liquid crystal display (LCD) panel. The polarization converter consists of a twisted nematic (TN) liquid crystal film, a uniaxial A-film and a reflector. The device configuration is optimized using genetic algorithm. As a result, our design can convert light from TM to TE polarization (or TE to TM) at a maximum 99.7%, minimum 91.3%, and average 96.7% conversion efficiency for the whole visible spectrum and incident angle from 0 to 60 degrees. Such a broadband reflective polarization converter is particularly useful in enhancing the light efficiency of LCD and reducing power consumption.

Poster Presentation Abstracts

POSTER IV

Optimization of Long-wave IR Surface Plasmon Grating Couplers

J. W. Cleary,[1] R. E. Peale,[1] W. Buchwald,[2] and R. Soref[2]*
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[2]Air Force Research Labs / RYHC, 80 Scott Dr, Hanscom AFB, MA 01731
Point of contact: Justin Cleary, jcleary@physics.ucf.edu, 407-823-3076

Abstract

Experimental investigation of the coupling of free space radiation to surface plasmons by silver or Pd_2Si gratings was performed for different grating profiles at CO_2 laser wavelengths. Comparison of the results with the theory of Hessel and Oliner 1965 and of Wheeler, Arakawa, and Ritchie 1976 suggests that the former gives the more accurate description in the long-wave IR. For that theory, the comparison gives an empirical non-linear relation between the physical depth of the grating grooves and the surface-impedance modulation amplitude. The Hessel-Oliner theory predicts stronger photon-plasmon coupling for the higher impedance silicide, suggesting that these conductors may be preferable for silicon-based IR plasmonic devices. Shifts and broadening of the surface Plasmon resonances with increasing grating height are also reported and found to be weaker than similar effects observed previously at visible wavelengths.

POSTER V

Cubic Oxide Alloys for Deep-UV Applications

J. W. Mares, R. C. Boutwell, A. Schuerer, M. Falanga, and W. V. Schoenfeld*
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Abstract

In this work, the epitaxial growth and characterization of lattice-matched NinMg1-nO thin films on MgO bulk crystal is presented. Radio frequency oxygen plasma assisted molecular beam epitaxy was exploited to produce films of varying nickel concentrations as measured by Rutherford Back-scattering. Optical characterization was carried out using standard transmission spectrophotometry and indicates well behaved shifts in film bandgaps over the range Eg = 3.45eV to 4.75eV with decreasing Nickel. Atomic force microscopy revealed good surface morphological quality with root-mean square roughness ranging from 0.7 Å to approximately 25 Å. These results will be used in device development for deep-UV applications.

POSTER VI

Femtosecond Laser Direct Written Volumetric Diffractive Optical Elements and Their Applications

Jiyeon Choi, Mark Ramme, Troy Anderson and Martin Richardson
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Abstract

Femtosecond laser direct writing has become a powerful tool to create 3D volumetric structures in transparent materials. It relies on the nonlinear absorption process that occurs when a laser beam is tightly focused into the material and the intensity of the focused beam exeeds the threshold intensity of photo-structural modification. This method has been widely employed to various areas of photonic device fabrication such as active and passive wave-guides, couplers, gratings, and diffractive optical elements (DOEs). DOEs are very attractive elements to replace bulky refractive optics to reduce device size for compactness. However, conventional fabrication methods such as lithography and holography cannot produce volumetric 3D structures because most glasses and polymers are opaque to the VUV illumination light source. Fabrication of volumetric 3D diffractive optical elements using femtosecond laser direct writing is attractive not only to enable 3D processes but also to bring many more advantages such as its simple production scheme, ease of changing patterns, clean production process etc. LPL has been heavily working on the fabrication of volumetric DOEs via femtosecond laser direct writing. We present DOE fabrication technique using laser direct writing as well as the characterization of laser-written DOEs by various techniques such as refractive index change measurement and diffraction efficiency measurement. We also propose new integration schemes of DOEs with other photonic devices that would impact on the fabrication of integrated photonic devices.

POSTER VII

E-beam Assisted Fabrication of an Aluminium Sub-wavelength Mesh for High Efficiency UV Photodetectors

Clarisse Mazuir and Winston V. Schoenfeld*
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Abstract

Using e-beam lithography on a single layer of polymethylmethacrylate (PMMA) we designed a relatively thick subwavelength aluminum mesh on top of sapphire. The 100 nm thick mesh consisted of two perpendicularly oriented sets of 100 nm wide parallel metal lines with a center to center distance as low as 260 nm. This metallic structures were predicted to enhance transmission of light into UV sensitive GaN based photodetectors for both transverse electric (TE) and transverse magnetic (TM) polarizations. Due to the large proximity effect during e-beam exposure and the small spacing between metallic lines the use of an adhesion promoting layer appeared necessary to avoid premature peeling of the photoresist. Using a monoatomic layer of hexamethyldisilazane (HMDS) as an adhesion promoter between the sapphire and the PMMA, a 500 nm thick photoresist layer could be exposed and developed with excellent control over the features sizes. Line spacing distances from 500 nm down to 160 nm were achieved. An oxide plasma etch was found to be necessary for a better metal lines adhesion during the lift-off process. Thermal evaporation of aluminum was performed and compared with e-beam evaporation. An additional ultrasonic bath in the resist stripper was found necessary to ease the lift-off process.

Poster Presentation Abstracts

POSTER VIII

Principal Component Analysis (PCA) of Femtosecond and Nanosecond Laser Induced Breakdown Spectroscopy (LIBS) for Organic Thin Film Discrimination

Christopher G. Brown[1], Candice Bridge[1], Matthew Fisher[1], Matthieu Baudelet[1], Michael Sigman[2], Martin C. Richardson[1], Paul Dagdigian[3]
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Abstract

While not specifically suited for molecular spectroscopy, Laser Induced Breakdown Spectroscopy (LIBS) can utilize molecular emission along with the atomic emission in order to enhance discrimination. Previous studies have shown that atmosphere can be ionized along with plasma constituents resulting in a skewed interpretation of the data. This study makes a comparison of single shot LIBS emission of the molecular species from plasmas produced from organic thin film residues on a silicon substrate. It is important to understand the influence of the surrounding atmosphere on the spectrum of material that is largely comprised of carbon, nitrogen, and oxygen, and identify how the entrainment with air skews the results of the discrimination. The spectra were produced by either a 5 ns duration, 1064 nm/ 266 nm Nd:YAG laser, or a 40 fs, 800 nm Ti:Sapphire laser in both air and aragon atmospheres. Principle component analysis (PCA), considered to be an exploratory technique, was used in order to gain a better understanding of the selected variables. The variables of interest were based on the atomic carbon and oxygen peaks as well as the diatomic species CN violet bands $(B^2\Sigma - X^2\Sigma)$ and the C_2 Swan bands $(d^3\Pi_g - a^3\Pi_u)$. PCA was used to identify similarities between the organic analytes via the emission spectra, and Receiver Operating Characteristics (ROC) curves were then generated to measure the performance of the analysis and the influence of the atmosphere on the spectral signatures for the different laser regimes.

POSTER IX

Preparation of Functional Three-Dimensional Nanophotonic Materials and Devices by Multi-Photon Direct-Laser Writing in SU-8 on Silicon

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Abstract

Multi-photon direct laser writing (DLW) is a powerful and versatile method for creating truly three-dimensional micro and nano-scale structures and devices. SU-8 is a negative tone photoresist designed for patterning at 365 nm, but exhibits sufficient multi-photon absorption at 800 nm which can be used for DLW. Being able to fabricate photonic structures into materials such as silicon is of particular interest for future applications in integrated photonics and optoelectronics, but complicates the DLW process further because the material is opaque near 800 nm. Here we demonstrate how DLW can be used to prepare photonic structures directly onto silicon substrates, and how sample preparation and exposure conditions, such as resin bake time and focus depth, affects feature size and structure fidelity.

POSTER X

Femtosecond Laser Direct Written Volumetric Diffractive Optical Elements and Their Applications

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Abstract

Femtosecond laser direct writing has become a powerful tool to create 3D volumetric structures in transparent materials. It relies on the nonlinear absorption process that occurs when a laser beam is tightly focused into the material and the intensity of the focused beam exeeds the threshold intensity of photo-structural modification. This method has been widely employed to various areas of photonic device fabrication such as active and passive waveguides, couplers, gratings, and diffractive optical elements (DOEs). DOEs are very attractive elements to replace bulky refractive optics to reduce device size for compactness. However, conventional fabrication methods such as lithography and holography cannot produce volumetric 3D structures because most glasses and polymers are opaque to the VUV illumination light source. Fabrication of volumetric 3D diffractive optical elements using femtosecond laser direct writing is attractive not only to enable 3D processes but also to bring many more advantages such as its simple production scheme, ease of changing patterns, clean production process etc. LPL has been heavily working on the fabrication of volumetric DOEs via femtosecond laser direct writing. We present DOE fabrication technique using laser direct writing as well as the characterization of laser-written DOEs by various techniques such as refractive index change measurement and diffraction efficiency measurement. We also propose new integration schemes of DOEs with other photonic devices that would impact on the fabrication of integrated photonic devices.

POSTER XI

Gate Voltage Tunable Plasmon Resonances in Two Dimensional Electron Gas in InGaAs/InP HEMT

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Abstract

We report voltage-tunable plasmon resonances in the two dimensional electron gas (2-deg) of a high electron mobility transistor (HEMT) fabricated from the InGaAs/InP materials system. The device was fabricated from a commercial HEMT wafer by depositing source and drain contacts using standard photolithography process and a semi-transparent gate contact that consisted of a 0.5 µm period transmission grating formed by electron-beam lithography. Narrow-band resonant absorption of THz radiation was observed in transmission in the frequency range 10 – 50 cm^{-1}. The resonance frequency depends on the gate voltage-tuned sheet-charge density of the 2deg. The observed separation of resonance fundamental from its harmonics and their shift with gate bias follows theory, although the absolute frequencies are lower by about a factor of 2-3.

Poster Presentation Abstracts

POSTER XII

Surface Plasmon Excitation Using Compact Nanoparticle Enhanced Grating Couplers

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Abstract

Surface plasmon excitation using a periodic array of metal nanoparticles near a metal film is studied via full-field simulations and experiments. Illumination of a nanoparticle array induces resonant electron oscillations in the nanoparticles. The resulting local electromagnetic field oscillations excite propagating surface plasmons in the nearby metal film. Simulations (using Finite Integration Technique) of an infinite array show the separate contributions of the particle resonances and the grating resonances towards excitation of surface plasmons. Tuning of the two resonances to match reveals strong inter-coupling and resulting anticrossing of the two resonances, and a reduced surface plasmon excitation strength at the predicted crossing of resonances.Electron-beam lithography was used to fabricate finite metal nanoparticle arrays above a metal film. Geometry dependent reflection measurements reveal the existence of several optical resonances. Strong coupling of the in-plane nanoparticle plasmon resonance and propagating plasmons is evident from clear anticrossing behavior. Reflection measurements at high numerical aperture demonstrate the excitation of surface plasmons via out-of plane particle polarization. The thus excited plasmons do not exhibit anticrossing in the considered frequency range. The results are explained in terms of the known surface plasmon dispersion relation and the anisotropic frequency dependent nanoparticle polarizability. These findings are important for applications utilizing surface-coupled nanoparticle plasmon resonances.

POSTER XIII

Guided Mode Resonance Filters as Stable Line-narrowing Feedback Elements for Thulium Fiber Lasers

Robert A. Sims[1*], *Zachary Roth[2], Timothy McComb[1], Lawrence Shah[1], Christina Willis[1], Pankaj Kadwani[1], Vikas Sudesh[1], Poutous Menelaos[2], Eric Johnson[2],* *Martin C. Richardson*[1]
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Abstract

Guided Mode Resonance Filters (GMRF) were used as external feedback elements for thulium fiber lasers in order to spectrally narrow and stabilize their output. GMRFs were fabricated with a diffractive array of holes etched into a top layer of Plasma Enhanced Chemical Deposition (PECVD) grown SiO_2 on top of a PECVD grown waveguide layer of Si_xN_y. Using this grating waveguide structure, externally propagating waves are coupled into the waveguide by phase matching diffracted orders with allowable modes of the waveguide. Due to index modulation on the surface of the waveguide, guided modes become leaky and recombine with the incident wave creating a resonance. Spectral reflectivity was characterized by placing GMRFs in the beam path of an amplified spontaneous emission source showing 0.4-1.0 nm FWHM with 30-50% reflectivity depending on properties of individual filters. Laser spectral output was stabilized at ~1985 nm with ~30 pm linewidths at ~20 W pump powers. Slope efficiency of a GMRF stabilized laser was 44% with a maximum of 5.8 W CW output.

Laboratory Tour Schedule

There will be guided group tours through several CREOL laboratories today. Each guided tour will cover four labs, and will last approximately 60 minutes.

All tours start at 3:20pm in the CREOL lobby after the "Student of the Year" presentation. Successive tour groups will be assembled starting with Group A (see schedule below).

Lab	Description	A	B	C	D	E	F	G	H	I	J
A105	**Fiber Drawing Tower** Dr. Ayman Abouraddy	1				3				4	2
130 / 125	**Infrared Systems Lab** Dr. Glenn Boreman http://ir.creol.ucf.edu	2				4	1				3
154	**Volume Holographic Elements and Bragg Laser** Dr. Leonid Glebov http://ppl.creol.ucf.edu	3	1				2				4
180	**Molecular Beam Epitaxy Lab** Dr. Winston Schoenfeld http://npdg.creol.ucf.edu	4	2				3	1			
140 / 141	**Laser Development and Materials Processing** Dr. Martin C. Richardson http://lpl.creol.ucf.edu		3	1			4	2			
233	**White Light Continuum Generation** Dr. David Hagan and Dr. Eric Van Stryland http://nlo.creol.ucf.edu		4	2				3	1		
256	**Optical Frequency Combs and Clocks** Dr. Peter Delfyett http://up.creol.ucf.edu			3	1			4	2		
260	**Sunlight Readable Liquid Crystal Displays** Dr. Shin Tson Wu http://lcd.creol.ucf.edu			4	2				3	1	
264	**Laser Materials Processing Lab** Dr. Aravinda Kar				3	1			4	2	
115	**Laser Spectroscopy and Sensing** Dr. Martin C. Richardson http://lpl.creol.ucf.edu				4	2				3	1

Note: There is a live video view of our 3,000 sq ft class 1000 / class 100 cleanroom, just off one side of the Lobby, near the front windows, including views of the Leica 5000+ e-beam writer.

In addition, presentations of work in the group of Dr. Richardson are shown on monitors near several laboratories, including [1] the Northrop Grumman EUV Laboratory, [2] the Laser Development Laboratory, [3] the Laser Spectroscopy Laboratory, [4] the Laser Plasma Laboratory, and [5] the Laser Processing Technology Laboratory. Please look for the signs directing you to these displays.

CREOL Laboratory Directory

Creating the Future of Optics and Photonics

Dr. Ayman Abouraddy
- Optical Fiber Characterization and Mid-infrared Nonlinear Fiber Optics – Rm. A114
- Optical Fiber Draw Tower – Rm. A105
- Thin-film Thermal Evaporation – Rm. 216
- Multi-material Fiber Preform Fabrication – Rm. A302

Dr. Michael Bass
Solid State Lasers
- Laser Spectroscopy and Optically Written Displays – Rm. 157
- Thermal Management of Diode and Solid State Lasers – Rm. 158
- Microscopy, Electronics, Wave Propagation Studies – Rm. 175

Dr. Glenn Boreman
- Infrared Systems – Measurements & Characterization – Rm. 130
- Infrared Systems – E-Beam Lithography – Rm. 130A
- THz Laser Facility – Rm. 125

Dr. Demetri Christodoulides
- Soliton Theory – Rm. 210
- Nonlinear Guided Wave Lab – Rm. 203

Dr. Peter Delfyett
- Femtosecond Semiconductor Lasers & Dynamics – Rm. 252
- Modelocked Erbium Fiber & Glass Waveguide Laboratory – Rm. 254
- Femtosecond Optical Frequency Comb Lab – Rm. 255
- Optical Clocks for Photonic Sampling and Waveform Synthesis – Rm. 256
- High Power Ultrafast Semiconductor Laser Laboratory – Rm. 245A
- OCDMA & Chip Scale WDM Technologies – Rm. 244A
- Quantum Dot Semiconductor Laser Laboratory – Rm. 243A

Dr. Dennis Deppe
- MBE Lab – Rm. 180C
- PL Lab – Rm. 177
- Nanophotonics Fabrication Facility – Rm. 180

Dr. Aristide Dogariu
- Photonic Diagnostics in Random Media – Rms. 142, 144

Dr. Sasan Fathpour
- Integrated Semiconductor Photonic Device Characterization Laboratory Rm. – A212

Dr. Leon Glebov
- Volume Holographic Elements: recording – Rm. 153
- Photo-Thermo-Refractive Glass: metrology, photoinduced processing – Rm. 151
- Photo-Thermo-Refractive Glass: Melting – Rm. 152
- Volume Bragg semiconductor lasers, spectral beam combining – Rm. 154
- Volume holographic elements: high power applications (with Boris Zeldovich) – Rm. 249
- Photo-Thermo-Refractive Glass: Grinding, polishing – Rm. 150

Drs. David Hagan and Eric Van Stryland
- Femtosecond Lasers – Rm. 22
- Nanosecond Tunable OPO (400-1,500 nm) – Rm. 236
- Picosecond tunable OPA lab (400nm–16microns) – Rm. 230
- Single Mode Nanosecond CO2 – Rm. 233
- Two-Photon Confocal Microscope with Femtosecond OPO – Rm. 246
- Near-infrared picoseconds laser lab – Rm. 242

Dr. James Harvey
- X-Ray Telescopes – Rm. A113
- Optical Surface Scattering – Rm. 155
- Generalized Scalar Diffraction Theory – Rm. A113
- Launch Vehicle Imaging Telescopes – Rm. A113
- Interferometry (with Jannick Rolland) – Rm. 146

Dr. Aravinda Kar
Laser Advanced Materials Processing (LAMP)
- Laser Advanced Manufacturing – Rms. 263, 264
- Laser Synthesis of Materials – Rms. 263, 264
- Laser Processing of Wide Bandgap semiconductors – Rms. 263, 264
- Modeling and Simulation for materials processing and materials synthesis – Rms. 263, 264

Dr. Pieter Kik
Nanophotonics and Near-field Optics
- Nanophotonics Characterization Lab – Rm. 247
- Near-infrared picoseconds laser lab – Rm. 242

Dr. Stephen M. Kuebler
3D Micro- and Nano-fabrication
- Fabrication of 3D micro- and nano-scale structures – CHM Rm. 324

Dr. Guifang Li
- Optical Fiber Communications – Rms. 246A, 248, 278(office)

Dr. Patrick LiKamWa
- Quantum Well Optoelectronics – Rms. 220, 223

Dr. Jim Moharam
- Diffractive Optics – Rm. 258

Dr. Martin Richardson
Laser Plasma Laboratory
- Northrop Grumman Extreme Ultraviolet Photonics Laboratory (Rm. 143)
- Multi-TW Femtosecond Laser Interaction Facility (Rm. 140)
- High Intensity femtosecond laser interactions (Rms. 140, 112-117)
- Laser Development Laboratory (Rm. 141)
- X-ray microscopy Rm. 140
- Femtosecond THz Laboratory Rm. 140
- Femtosecond Laser Waveguide Writing & Micromachining Lab Rm. 141
- Laser Development Lab: New Solid State Laser Development Rm. 141B
- Laser induced breakdown spectroscopy (LIBS) laboratory Rms. 140, 123 & 123A, 112-117
- Zygo New View 6300 Interferometer – 2nd Floor Cleanroom Rm. 211

CREOL Laboratory Directory
(continued)

Dr. Nabeel Riza
- Photonic Information Processing Systems – Rms. 250, 251, 253

Dr. Jannick Rolland
ODALab – Optical Diagnostics and Applications Laboratory
- 3D Visualization (Augmented Reality, Vision, 3D Lungs Alive) – Rm. 147
- 3D Optical Imaging (Optical Coherence Imaging, Curvature Sensing) – Rm. 146
- Optical System Design (Head Mounted Displays, Biophotonics) – Rms. 146-147

Dr. Winston Schoenfeld
Nano-Photonics Device Group (NPDG)
- Nanophotonics Devices Lab – Rm. 156
- Nanophotonics Fabrication Facility – Rm. 180
- Wide Band Gap Characterization Lab – Rm. 156A
- Oxide MBE Lab – Rm. 180C

Dr. William Silfvast
- Short Wave Length Source Lab – Rm. 123 (123A)

Dr. George Stegeman
Nonlinear Guided Wave Optics
- Ti:sapphire Laser – Solitons in Semiconductor Optical Amplifiers – Rm. 243

Dr. Eric Van Stryland (See Drs. Hagan and Van Stryland)

Dr. Shin-Tson Wu
Photonics and Displays
- Liquid Crystal Displays – Rm. 245
- Liquid Crystal Materials Processing – Rm. 257
- Tunable Photonics Devices – Rm. 259
- Adaptive Lens – Rm. 260

Dr. Boris Zeldovich
- Optical Beam Combining Quantum Optics – Rm. 249

Other CREOL User Facilities
- Varian Cary 500 Scan UV-Vis-NIR Spectrophotometer – Rm. 159
- Olympus Nomarski Interference Microscope – Rm. 159
- Clean room – Rm. 211
- Class 1000/ Class 100 Clean Room – Rm. 180 (Nano-Fabrication Facility)
- Fiber Tower – Rm. A105
- Machine Shop – Rm. A106

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Florida's photonics cluster is the 4th largest in the US, with some 270 companies employing over 5,700 professionals focused on the design, development, manufacturing, testing, and integration of photonics and related systems. The photonics & optics cluster in Florida spans a very broad range of industry sectors, including lasers, fiber optics, optical and laser materials, thin film coatings, optical components, optoelectronic fabrication and packaging, and optical systems integrators, addressing almost all applications from energy to medicine to defense. The state's colleges and universities have established interdisciplinary programs and centers focusing on photonics/optics, which graduate about ~100 photonics specialists each year.

Innovation Economy

Florida companies attracted more than $608 million in venture capital in 2007 – nearly double the 2006 total.

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Florida continues its reign as one of the most desirable places to live in the US, second only to California in 2007 in a Harris Poll. *Source: eflorida.com, Enterprise Florida, Inc., 2008*

It's no surprise why Florida has become a top destination for high-tech industry and in particular for the photonics industry. In 1971, thanks to what Walt Disney termed "Imagineering," Central Florida took its place on the high-tech map. Since then, with the growth of the high-tech industry throughout the state, spawned by space programs at Cape Canaveral and establishment in 1987 of CREOL, the Center for Research and Education in Optics and Lasers at the University of Central Florida, "the mouse" has taken on a whole new meaning. Inspired by Disney's initial vision, the imagination and genius of the world's leading research scientists and engineers have made Florida the hub for a wide range of industrial companies and venture capitalists from around the world and in nearly all application areas from energy to medicine to aerospace.

On the Earth's grid, Florida is a 3-D landmark for the photonics industry. CREOL, The College of Optics and Photonics, the Florida Photonics Cluster, several vigorous university incubators and regional economic development organizations, and a dynamic grouping of cutting-edge companies form a photonics hub focused on advancing Florida's photonics industry.

Florida Photonics Cluster

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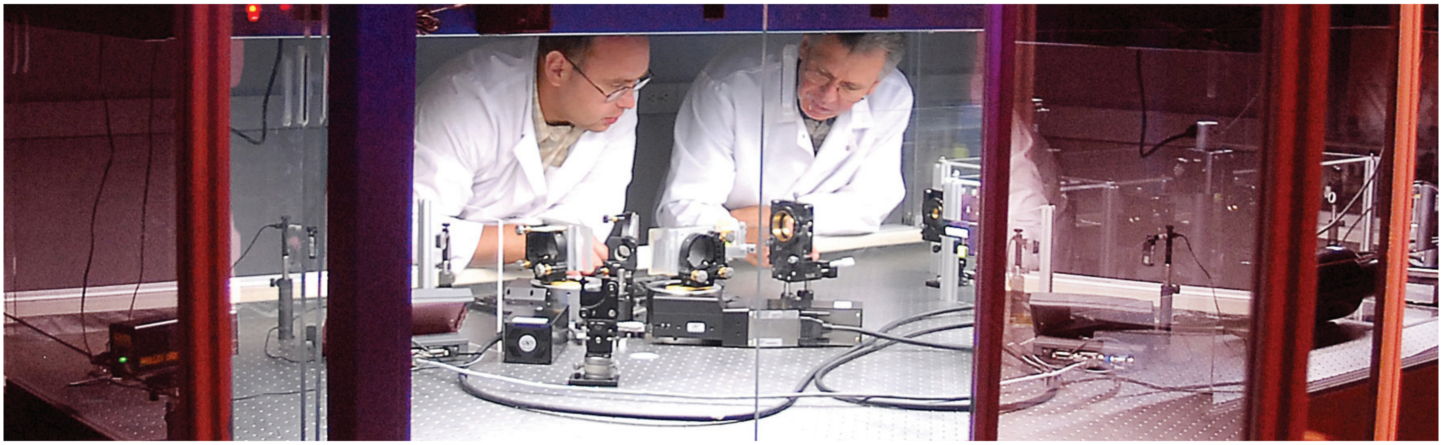

To learn more about CREOL research collaborations, go to www.optics.ucf.edu/Partnerships/Collaboration.aspx