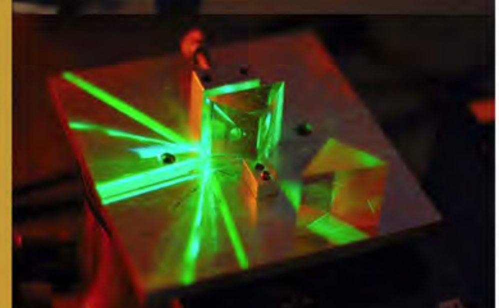
Industrial Affiliates Day 2010

Symposium Optics At The Limit



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Industrial Affiliates Day
April 9, 2010

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Program Guide

Optics at the Limits

Morning Session –UCF Alumni Center

Time	Topic	Speaker	Affiliation
8:00	Continental Breakfast and Walk-in Registrations		
8:30	Welcoming Remarks	MJ Soileau	UCF Vice-President for Research
8:50	*CREOL, The College of Optics and Photonics –Overview*	Bahaa Saleh	Dean & Director, CREOL, The College of Optics and Photonics
9:25	*"Fundamental Limits for Optical Devices"*	David Miller	Director, Solid State and Photonics Lab, Co-Director, Stanford Photonics Res. Cntr, W.M. Keck Foundation Prof. of Electrical Engineering, Stanford University
10:00	BREAK		
10:20	*"Circuits with Light at the Nanoscale: Taming the Light with Metamaterials"*	Nader Engheta	H. Nedwill Ramsey Professor of Electrical and Systems Engr, and Professor of Bioengineering, Univ. of Pennsylvania
10:55	*"Super-Resolution Fluorescence Imaging of Intracellular Structure and Dynamics"*	Sam Hess	Assoc. Professor of Physics, University of Maine, Dept. of Physics & Astronomy
11:30	Panel Discussion – *"Where is optics and photonics going in the next 5-10 years?"*	Ralph James Paul S. Drzaic David Miller Nader Engheta Sam Hess Moderator: Jim Pearson	Brookhaven National Lab. Drzaic Consulting Services Stanford University Univ. of Pennsylvania University of Maine CREOL
12:30	LUNCH		Alumni Center

Tabletop Exhibits-Alumni Center Lobby

Program Guide

Optics at the Limits

Afternoon Session
Presentations – Business Admin Bldg, BA 107
Posters, Award presentations, Reception & Light Show– CREOL Bldg

Time	Topic	Speaker	Affiliation
1:15	**Walk to Business Administration Building BA107**		
1:30	*"Attosecond Pulses: Generation, Characterization and Applications"*	Zenghu Chang	Professor of Physics, Kansas State University
2:05	Student of the Year – "Spin Transfer & Power Flow At Subwavelength"	David Haefner	CREOL, The College of Optics and Photonics
2:40	*"Industry Partnerships with CREOL"*	Jim Pearson	Special Consultant, CREOL, The College of Optics and Photonics
3:00	Walk to CREOL building		
3:10	Poster Sessions; Lab Tours; Exhibits Open; (contiguous).	CREOL Graduate Students	CREOL rooms 102 & 103; Tours start from lobby; exhibits in lobby
5:10 -6:30	Poster award presentation; laser light show; reception	Bahaa Saleh	CREOL, The College of Optics and Photonics

Tabletop Exhibits-CREOL Lobby

Exhibitors

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www.qiopticlinos.com

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407-380-1553
www.LaserInstitute.com

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www.olympusmicroimaging.com

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Santa Barbara, CA 93117
805-967-1400
www.veeco.com

OSA
The Optical Society
2010 Massachusetts Ave, NW
Washington, DC 20036
202-223-8130
www.osa.org

SPIE
The International Society for Optics
and Photonics
P.O. Box 10
Bellingham, WA 98227
360-676-3290
www.spie.com

IEEE
Institute of Electric & Electronics Engineers
2001 L Street NW, Suite 700
Washington, DC 20036
www.ieee.org

SID
Society for Information Display
145 South Bascom Ave. Ste. 114
Campbell, CA 95008
408-879-3901
www.sid.org

Invited Presentations

Fundamental Limits for Optical Devices

David Miller
W.M. Keck Foundation Professor
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Abstract

As we explore the many exciting new optical device ideas, such as those enabled by nanophotonic, nanometallic or meta-material structures, or as we look for new applications like slow light or ultracompact dispersive devices, we need new ways of understanding limits to performance. In some designs, we cannot even describe how the device works, so how can we know how good we can make it? The talk will discuss various examples, some novel general approaches and fundamental limits, and at least one surprise topic!

Biographical Note

David Miller received his B.Sc. from St Andrews University and, in 1979, the Ph.D. from Heriot-Watt University, both in Physics. He was with Bell Laboratories from 1981 to 1996, as a department head from 1987, latterly of the Advanced Photonics Research Department. He is currently the W. M. Keck Professor of Electrical Engineering, a Professor by Courtesy of Applied Physics, and a Co-Director of the Stanford Photonics Research Center at Stanford University. His research interests include physics and devices in nanophotonics, nanometallics, and quantum-well optoelectronics, and fundamentals and applications of optics in information sensing, switching, and processing. He has published more than 230 scientific papers, holds 69 patents, has received numerous awards, is a Fellow of OSA, IEEE, APS, and the Royal Societies of Edinburgh and London, holds two honorary degrees, and is a Member of the National Academy of Sciences and the National Academy of Engineering.

Invited Presentations

Circuits with Light at the Nanoscale: Taming the Light with Metamaterials

Nader Engheta
H. Nedwill Ramsey Professor
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Department of Electrical and Systems Engineering
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Abstract

Imagine circuit elements so small that you could fit many of them in a tiny microscale volume (e.g., a cell)! Imagine that such circuits could work with light at the nanoscale instead of electricity! What could you do with such optical nanocircuits? Would you be able to use them in wireless gadgets at nanoscales, like a "nanoradio", that may connect our nanoworlds? Could these tiny optical nanocircuits be coupled with biological entities and thus provide nanoscale sensors? The fields of metamaterials and plasmonic optics may provide road maps for such futuristic nanocircuits and wireless nanosystems and sensors. In my group, we have been developing and investigating some of the fundamental concepts and theories, and key features of such metaplasmonic structures, devices, and circuits. These circuit elements and components may be envisioned as a tapestry of nanostructures of sizes much smaller than the wavelengths of light. This field, for which I have coined the term *metactronics*, addresses metamaterial-inspired optical nanocircuits and nanosystems (N. Engheta, *Science*, 317, 1698-1702, 2007). . In my group, a variety of ideas and paradigms for nanocircuit functions, optical antennas and sensors for beam shaping and photonic wireless at the nanoscale, optical nanoscopy, nanospectrometer for molecular spectroscopy, cloaking of particles, nanotagging and barcodes based on these optical circuits are being studied. In this talk, I will give an overview of some of these studies, present insights into these findings, and forecast future ideas and road maps in these areas.

Biographical Note

Nader Engheta is the H. Nedwill Ramsey Professor of Electrical and Systems Engineering, and Professor of Bioengineering, at the University of Pennsylvania. He received his B.S. degree in EE from the University of Tehran, and his M.S and Ph.D. degrees in EE from Caltech. Selected as one of the *Scientific American Magazine 50 Leaders in Science and Technology* in 2006 for developing the concept of optical lumped nanocircuits, he is a Guggenheim Fellow, an IEEE Third Millennium Medalist, and the Fellow of IEEE Fellow, American Physical Society (APS), Optical Society of America (OSA), and American Association for Advancement of Science (AAAS). He is the recipient of the 2008 *George H. Heilmeier Award for Excellence in Research* from UPenn, the *Fulbright Naples Chair Award*, *NSF Presidential Young Investigator award*, the *UPS Foundation Distinguished Educator term Chair*, and several teaching awards including the *Christian F. and Mary R. Lindback Foundation Award and S. Reid Warren, Jr. Award*. His current research activities span a broad range of areas including metamaterials and plasmonics, nanooptics and nanophotonics, biologically-inspired sensing and imaging, miniaturized antennas and nanoantennas, physics and reverse-engineering of polarization vision in nature, mathematics of fractional operators, and physics of fields and waves phenomena. He has co-edited the book entitled " *Metamaterials: Physics and Engineering Explorations*" by Wiley - IEEE Press, 2006.

Invited Presentations

Super-Resolution Fluorescence Imaging of Intracellular Structure and Dynamics

Samuel T. Hess
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Department of Physics and Astronomy
Institute for Molecular Biophysics
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Abstract

Diffraction limits resolution in visible light microscopy to ~200-250 nanometers. However, many biological functions are regulated at the molecular level. FPALM (fluorescence photoactivation localization microscopy), can break the diffraction limit and can achieve effective lateral resolution of 10-40 nanometers. FPALM performs successive rounds of photoactivation, imaging, localization, and photobleaching, to obtain the coordinates of large numbers of probe molecules. The image is then reconstructed using the measured positions of all localized molecules. Biological applications of FPALM to intracellular membrane, cytosolic, nuclear, and cytoskeletal proteins have been demonstrated, including results from live cells, fixed cells, and fixed tissue. Dynamics of individual molecules, including trajectories, can be recorded and quantified do determine molecular diffusion properties or velocities. Three-dimensional imaging using Bi-plane FPALM has recently been demonstrated to yield 30 nm x 30 nm x 70 nm resolution. Polarization FPALM can measure both the positions and orientations of localized probe molecules in biological samples, and has been used to image cytoskeletal and membrane proteins in cells. These powerful capabilities offer great potential for biological applications.

Biographical Note

Sam Hess received his Ph.D. in physics in 2002 after working for Watt Webb at Cornell University in Ithaca, New York. He then did a postdoctoral fellowship from 2002-2004 in the laboratory of Joshua Zimmerberg at the National Institutes of Health (NIH) in Bethesda, Maryland. In 2004, he began as an assistant professor in the Department of Physics and Astronomy at the University of Maine, received a Career Award from NIH in 2005, and was promoted to associate professor with tenure in 2009. His research interests include nanoscale membrane organization, influenza virus infection, photophysics of fluorescent proteins and quantum dots, and super-resolution microscopy. In 2006, Dr. Hess published the invention of fluorescence photoactivation localization microscopy (FPALM), which uses localization of stochastic subsets of photoactivatable fluorescent molecules to image subcellular structures with resolution (20-30 nm) well below the diffraction limit. Dr. Hess is currently pursuing the question of how the influenza virus exploits cell membrane organization for infection and assembly, using FPALM to provide unprecedented views of the clustering and dynamics of hemagglutinin, the fusion protein from influenza, in living cells.

Panel Members

Paul Drzaic
Senior Advisor
Liquidia Technologies
paul.drzaic@liquidia.com

Biographical Note

Paul Drzaic is Senior Advisor at Liquidia Technologies, Ltd., and Principal at Drzaic Consulting Services. In his current consulting roles, Drzaic provides expertise in the technical areas of electronic displays, flexible electronics, opto-electronic systems, and several areas of materials science, nanotechnology, energy conservation, energy storage, and RFID technology. He also provides guidance in business plan development and review, and intellectual property assessment. He is a Fellow of the Society for Information Display, and is currently serving as President of the SID. Previously, he has held positions as Chief Technology Officer at Unidym, Inc., Vice President for Advanced Development Programs at Alien Technology Corporation, Director of Technology at E Ink Corporation, and Principal Scientist at Raychem Corporation. Much of Drzaic's professional career has been in the development of flexible electronic technologies. He is the author of the book *Liquid Crystal Dispersions*, 20 journal publications, and 58 US patents. He is a winner of the 2002 National Team Innovation Award from the American Chemical Society, as well as an Editor's Choice award for the R&D 100 awards for 2001. He is Chair of the Editorial Board for the MRS Bulletin. Dr Drzaic has a PhD in chemistry from Stanford University, and a B.S. in chemistry from the University of Notre Dame.

Ralph James
President, SPIE
Brookhaven National Lab
rjames@bnl.gov

Biographical Note

Dr. Ralph James is the 2009 SPIE President Elect. He served as the Associate Laboratory Director for the Energy, Environment and National Security Directorate with the U.S. Department of Energy's Brookhaven National Laboratory from 2001 -2008. He is currently a Program Manager and Senior Scientist at BNL, where he manages basic and applied research devoted to materials, electronic and imaging devices, and integrated circuits. Dr. James has authored more than 440 scientific publications, served as editor of 17 books, and holds 11 patents. He is a Fellow of the SPIE, IEEE, AAAS, OSA, and APS, and he has received numerous prestigious international honors in recognition of his scientific accomplishments, including Discover Magazine Innovator of the Year, 5 R&D100 awards, IEEE Outstanding Radiation Instrumentation Award, IEEE Harold Wheeler Award, Room-Temperature Semiconductor Scientist Award, Long Island Person of the Year in Science, 50 World's Best Technologies Award, among others.

Invited Presentations

Attosecond Pulses: Generation, Characterization and Applications

Zenghu Chang
Ernest K. and Lillian E. Chapin Professor of Physics
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Abstract

Single isolated attosecond pulses are powerful tools for exploring electron dynamics in matter. Previously, such extreme ultraviolet pulses have been generated using few-cycle lasers, which are very difficult to construct. We demonstrated a technique called double optical gating for generating isolated attosecond pulses with lasers pulses as long as 28 fs that was directly from a chirped pulse amplifier. This new gating scheme, with a relaxed requirement on laser pulse duration, makes attosecond experiments more accessible to many laboratories that are capable of producing such multi-cycle laser pulses. These XUV pulses, generated from noble gas, are characterized by reconstructing the spectrogram of the photoelectrons produced by the XUV pulse in a laser field using a new phase retrieval scheme that we recently proposed. We have used isolated 140 attosecond pulses in several applications, which include a direct characterization of laser fields and a demonstration that the two-electron dynamics in helium could be observed and controlled.

Biographical Note

Zenghu Chang is an Ernest K. and Lillian E. Chapin Professor of Physics at Kansas State University, currently working in the area of attosecond optics and physics. After received the doctorate at the Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences, in 1988, he served as an associate professor at this intuition for the next three years before visiting the Rutherford Appleton Laboratory in the UK for two years. Dr. Chang moved to the US in 1995. He conducted research at the Center for Ultrafast Optical Science at the University of Michigan for more than five years. In 2001 he joined the faculty at Kansas State University. He now serves as the chair of the Optical Attoscience Technique group of the Optical Society of America. Chang is a fellow of the American Physical Society. Chang will join the University of Central Florida as a distinguished professor in the Fall of 2010.

CREOL Student of the Year

Spin Transfer and Power Flow at Subwavelength

David Haefner
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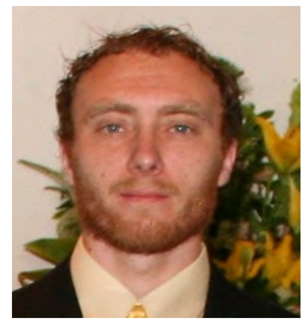
407-823-6846



Abstract

Angular momentum is exchanged when an electromagnetic wave encounters a scattering medium. We demonstrate that the spin-orbit interaction in scattering from a spherically symmetric potentials results in a spiral flow of energy in the near-field and intermediate zones. We will show how such a power flow can be observed and will discuss some consequences for field mediated interactions at subwavelength scales. As an, we will discuss the emergence of a new kind of "optical matter" where nonconservative forces and torques determine kinematic properties, which are strongly coupled to the polarization state of the exciting radiation.

Biographical Note

David Haefner, of Buffalo, NY, received his BS in physics from East Tennessee State University in 2004, where he was also a well decorated NCAA Division 1 athlete. In fall of 2004, he joined Dr. Dogariu's Photonic Diagnostics of Random Media group and started working as an experimentalist on different aspects of near-field statistical optics. In addition to experimental techniques, he also developed a series of numerical methods based on the coupled-dipole formalism for solving problems relevant to near-field optics. Since joining CREOL he has been part of 10 peer-reviewed publications and delivered 17 conference presentations. David was also the recipient of an SPIE Scholarship in Optical Science and Engineering in 2009 and the Incubic/Milton Chang Student Travel. Award in 2008.

Poster Abstracts

Poster 1

Materials for infrared surface plasmon resonance biosensor

J. W. Cleary[1*], R. E. Peale[1], G. D. Boreman[2], I. Oladeji[3], R. Soref[4], W.R. Buchwald[4]
[1]*Department of Physics, University of Central Florida, Orlando, Florida 32816, USA*
[2]*College of Optics (CREOL), University of Central Florida, Orlando, Florida 32816, USA*
[3]*Sisom Thin Films, LLC, 1209 West Gore StreetOrlando, FL 32805*
[4]*Sensors Directorate, Air Force Research Laboratory, Hanscom Air Force Base, Massachusetts 01731, USA*
For information contact: *Justin Cleary, jcleary@physics.ucf.edu, 407-823-3076*

Abstract

Surface plasmon resonance biosensors are well established at visible and near-IR wavelengths, but sensitivity and selectivity might be enhanced if they were operated instead in the infrared molecular-finger print region of characteristic vibrations. Needed are surface plasmon hosts with plasma frequencies one order lower than found in noble metals, so that modes are sufficiently confined adequately overlap with biological analytes. Also, for sharp resonances, sufficiently long electron relaxation times are needed. Original complex permittivity data was collected to theoretically evaluate the potential of silicides, heavily-doped semiconductors, and semimetals. Resonant absorption by surface plasmons of long-wave IR laser radiation was measured using lamellar grating couplers coated with suitable materials to experimentally verify the predictions.

Poster 2

Fabrication of three dimensional photonic crystals on the end face of an optical fiber using direct laser writing

Marco A. Melino[1], Henry E. Williams[2], Daniel J. Freppon[2], Kristen E. Lynch[2], Toufic G. Jabbour[1], Raymond C. Rumpf[4], Stephen M. Kuebler[*1,2,3]

[1]*CREOL, The College of Optics and Photonics,* [2]*Chemistry Department, and*
[3]*Physics Department, University of Central Florida, Orlando, FL 32816*
[4]*Prime Research, LC, Blacksburg, VA 24060-554*
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Abstract

This work is the first report of a method for fabricating functional three-dimensional nanophotonic structures onto the end-face of an optical fiber using multi-photon direct laser writing. The fragility of optical fiber and small size of the end-face, which serves as the fabrication substrate, required the development of new processing steps that are not typical of direct laser writing. Among these, a thermal reflow was used to deposit resist at controlled thickness onto the fiber end-face, as conventional spin coating methods cannot be used. The approach was used to fabricate a woodpile photonic crystal onto a multi-mode fiber using the SU-8 photoresist. Data are presented that illustrate how the polymeric photonic crystal alters the output of the optical fiber. Several unique features of this device, such as high surface-to-volume ratio of photonic crystals, suggest their use as a new platform for all-optical sensing.

Poster 3

High Numerical Aperture Axial and Transverse Beam

Craig A. Ament1, Toufic G. Jabbour, Stephen M. Kuebler*1,2,3
1 *Department of Physics,* 2 *Department of Chemistry, and*
3 *CREOL, The College of Optics and Photonics*
*For information contact: *kuebler@mail.ucf.edu,407-823-3720*

Abstract

This work describes the implementation of a nature-inspired search algorithm called particle swarm optimization (PSO) to the design of binary phase diffractive optical elements (DOEs) that produce a targeted irradiance distribution in both the axial and transverse directions upon high numerical aperture focusing. The vector character of the focused electromagnetic field is rigorously accounted for using vector diffraction theory. The PSO-based algorithm is applied to improve an extension of multi-photon direct laser writing called resolution augmentation through photoinduced deactivation or, RAPID. In RAPID, nanofabrication is performed using two spatially overlapped beams, one for excitation and the other for simultaneous de-excitation. Using the PSO-based algorithm, DOEs are identified that shape both the excitation and deexcitation beams to optimize the resolution that can be achieved with RAPID.

Poster 4

The Development of Scalable Side Pumping for GG-IAG Fiber Lasers

William Hageman, Y. Chen, X, Wang, M. Bass, V. Sudesh, T. McComb, M. Richardson, G. Kim
Faculty Supervisor: M. Bass
*For information contact: bass@creol.ucf.edu

Abstract

Diode side pumping of a gain guided, index-antiguided (GG-IAG) fiber laser is demonstrated. While other gain guided index-antiguided fibers lasers have been demonstrated in the past, none have used a pump technology capable of pumping with the efficiency, uniformity, and necessary length to allow for scaling the fiber lasers to high output powers. The developed side pumped scheme demonstrates a 6 W pulsed output power fiber laser with high beam quality (M^2 = 1.4) utilizing a pump technology capable of scaling to higher powers and longer fibers. The results of optical modeling of pump uniformity and efficiency, as well as thermal modeling of the fiber side pump geometry are presented. These results show the potential for continued improvement in pump efficiency and laser beam quality.

Poster 5

An Optical Quantum Information Network:

Matthew Weed* and Huber Seigneur
Nanophotonic Device Group, Winston Schoenfeld
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Abstract

The field of quantum information science has traditionally been divided into theory and experiment. Theorists have looked toward the future to develop quantum information constructs and algorithms capable of magnificent things but that are frequently void of ties to physical reality, while experimentalists have focused on perfecting the behavior of isolated quantum systems with infrequent concern for scalability or integration. It is with this research landscape in mind that the motivation for the work presented here stems - to bridge this gap. Pulling from both sides, this work makes strides toward drawing the two communities more closely together. From theory, results are presented from the modeling of state decoherence in a three particle entangled system (electron-photon-electron) providing useful, physical limitations for design and implementation. From experiment, the design of the optical system that will house a Quantum Information Network (QIN) is shown using on chip photonic crystal devices to manipulate photon 'flying qubit' messengers between nodes. Focusing on a strict set of design criteria fed from both quantum models and physical device architectures, a monolithic and scalable nanophotonic QIN is proposed.

Poster 6

Passive Coherent Locking of Fiber Lasers using Volume Bragg Gratings

Apurva Jain*, Oleksiy Andrusyak, George Venus, Vadim Smirnov[1], Leonid Glebov
[1] OptiGrate. 3267 Progress Dr. Orlando, FL 32826, USA
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Abstract

Five-channel spectral beam combining (SBC) using volume Bragg gratings (VBGs) in photo-thermo-refractive (PTR) glass with 0.5 nm spectral separation between channels and combined power >750 W has been recently reported. We report on improvements in this technique with the use of thermal control of VBGs that allows precise high-power alignment required for dense SBC with 0.25 nm spectral separation of channels. Experimental results of passive coherent beam combining (CBC) of fiber lasers using multiplexed VBGs are presented and analyzed. Methods for achieving several 100s of kW level output power using novel hybrid architectures that combine both coherent and spectral beam combining are discussed.

Poster 7

Optical Transmission Properties of C-shaped Subwavelength Apertures on Silicon

Lena Tirpak and Jichi Ma
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Abstract
Plasmonic enhancement in C-shaped apertures has been recently studied in order to improve the performance of sub-wavelength integrated photonic devices such as photodetectors, waveguides, and surface-emitting lasers. There have been a number of numerical reports investigating the optical transmission properties of C-shaped apertures. Most of these works, however, studied free-standing apertures in metallic films. In this work, the results of a numerical study of the transmission properties of a C-shaped aperture in silver films on real substrates, particularly silicon, are reported. It is shown that the optical transmission properties are altered quite dramatically by the refractive index of its surrounding media. Both the peak wavelengths of the different transmission modes as well as their power throughput were found to be affected. It is particularly shown that the fundamental Fabry-Perot-like mode attains the highest power throughput at the telecommunication wavelengths on silicon substrates.

Poster 8

Unambiguous high resolution optical ranging using frequency chirped pulses from a mode locked laser

Mohammad Umar Piracha*, Dat Nguyen, Ibrahim Ozdur, Dimitrios Mandridis, and Peter J Delfyett
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Abstract
A chirped fiber Bragg grating with a dispersion of 1651 ps/nm is used to generate temporally stretched, frequency chirped pulses from a passively mode locked fiber laser that generates pulses of ~1ps (FWHM) duration at a repetition rate of 20 MHz. The use of a chirped fiber Bragg grating enables the generation of temporally stretched pulses with low peak power so that non-linear effects in the fiber can be avoided. A fiber based interferometeric arrangement is used for interfering a reference signal with the target echo signal to realize a coherent heterodyne detection scheme. In the RF domain, the detected heterodyne beat frequency shifts as the target distance is changed. A target distance of ~15 km in air is simulated using optical fiber and sub-millimeter resolution is observed. For unambiguous range measurements, a heterodyne setup for generating a frequency swept RF signal is used for individually tagging pulses using phase modulation, at a simulated round trip target distance of ~90 m (in air) with > 30 dB CNR.

Poster 9

What is the size of the smallest feature that can be included in a multi -material optical fiber?

Soroush Shabahang, Joshua Kaufman, Esmaeil Banaei, and Ayman F. Abouraddy.
Faculty Supervisor: Ayman F. Abouraddy
For information contact: soroush@knights.ucf.edu

Abstract

Combining materials having different optical, mechanical, and thermal properties in a single optical fiber allows the fabrication of optoelectronic devices at optical-fiber length-scale and cost. Drawing such a fiber from a preform in the viscous state presents multiple challenges. In particular, hydrodynamic instabilities set the limit on the smallest axially continuous feature size that may be incorporated in such a fiber. We report the first observation of the onset of the Rayleigh-Plateau (RP) capillary instability in a multi-material fiber core during tapering. The core is a glassy semiconductor and the cladding is an amorphous polymer. After the onset of the RP instability, the core breaks up into a periodic stream of micro- and nano-scale semiconductor spherical droplets embedded in the polymer cladding. We observe several phenomena associated with this well-known instability such as droplet pinch-off and satellite and sub-satellite formation. While setting the lower limit on the size of axially continuous features in a multi-material fiber, we simultaneously present a novel top-down non-lithographic approach to producing micro- and nano-particles out of a variety of materials and in different.

Poster 10

Micro-spectroscopy of biomolecules and cells at variable pressure in a Micro-capillary

Sanghoon Park, S. Arora, A. Schulte*.
Physics Department and *CREOL/ UCF, Orlando, FL32816, USA
For information contact: s.park@knights.ucf.edu

Abstract

Pressure is an ideal parameter for reversible changes in soft condensed matter systems. Combining Raman microscopy with a micro-capillary compartment enables spectroscopic studies of small amounts of biological material at variable pressure. We present experiments over the pressure range from atmospheric pressure to 4 kBar (400 MPa) in a micro-capillary that use less than 100 nanoliters of sample. We investigate pressure dependent structural changes in model polypeptides and lipids through measurements of the Raman spectrum in fingerprint region.
The micro-capillary also allows to enclose living cells and to optically interrogate them through a microscope. This is illustrated through Raman spectroscopy and direct optical imaging of individual red blood cells at variable pressure.

Poster 11

Fourier method for a spatial resolved measurement of refractive index changes in bulk glasses

René Berlich*, Jiyeon Choi, Mark Ramme and Martin Richardson

* ATLANTIS MILMI Student† from Friedrich Schiller University, Dept of Physics, Jena, Germany

Abstract

Femtosecond laser direct-writing has become a promising tool to create 3D photonic devices in transparent materials. The ability to change the refractive index of glasses has already been applied in various optical components such as waveguides [1] and diffractive optical elements [2]. However, for efficient design of those elements, detailed information about the refractive index modification is essential. Most common techniques to measure refractive index changes are either costly in terms of required facilities or based on assumptions that only provide adequate results for ideal structures. Therefore we have developed a new practical method based on an Iterative Fourier Transform Algorithm (IFTA) capable of analyzing complex structures accurately. By combining the dimensions of the modified region with the corresponding phase change extracted from far field intensity measurements, we are able to spatially resolve the amount of refractive index change. We will present our initial results using this method to analyze basic grating structures written in borosilicate glass. In addition to evaluating the accuracy and the limits of this technique, we demonstrate the influence of the writing power on the femtosecond laser modified region.

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Poster 12

Multiheterodyne detection of optical frequency combs and applications in arbitrary waveform characterization

Josue Davila-Rodriguez, Charles Williams and Peter J. Delfyett
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Abstract

Mixing products from multi-heterodyne detection of frequency combs with detuned repetition rates are used to characterize multi-gigahertz spaced frequency combs from semiconductor mode-locked lasers. The repetition rate detuning allows for the generation of an array of beat-notes in the RF domain that shares the characteristics of the optical domain comb-lines, effectively mapping an optical comb into a radio-frequency comb. Time domain and frequency domain measurements are presented, demonstrating the ability to measure comb characteristics across several THz of bandwidth.

Poster 13

High Energy Q-Switched Polarization Maintaining Thulium Fiber Laser

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Abstract

Thulium doped silica fiber is a new and rapidly developing laser source in the 2 mm wavelength regime providing high-power, high-efficiency, and nearly diffraction-limited beam quality. In addition to the standard benefits of fiber lasers, the ~2 mm wavelength and broad bandwidth of the thulium laser transition (relative to that of ytterbium at 1 mm and erbium at 1.55 mm) enable several new applications and can be an important advantage in the generation of high peak-power fiber laser sources.

We are developing several Tm:fiber laser systems utilizing novel methods for spectral and temporal control of laser performance. Here we report an actively Q-switched polarization maintaining (PM) Tm:fiber laser. The laser is based on large mode area, 25 mm core and 400 mm cladding diameters, silica fiber doped with 4wt% thulium^{3+} and is pumped using high power 793 nm laser diodes. We utilize three feedback elements: a high reflective (HR) mirror, a gold-coated reflective diffraction grating, and a volume Bragg grating (VBG); and compare the laser performance in terms of pulse energy, pulse duration, slope efficiency, and spectral linewidth.

The highest slope efficiency we have obtained is 40.16% using the HR mirror and a 100 kHz Q-switch frequency, with >20 W average power. Sub-nanometer spectral line width was obtained when using the diffractive reflection grating and the VBG, at the expense of a ~10% penalty in slope efficiency. A maximum peak power in the fiber of 6.85 kW, corresponding to an output energy of 480 mJ and 70 ns duration with spectral width of <0.25 nm (FWHM), was producing using the diffractive reflection grating at a 20 kHz repetition rate.

Poster 14

Biophotonics: Two-photon Fluorescence Microscopy, Probes & Target-specific Bioimaging

Ciceron O. Yanez, Alma R. Morales, Dao M. Nguyen, Xuhua Wang, Carolina D. Andrade, Sanchita Biswas, Hyo-Yang Ahn, Sheng Yao, and Kevin D. Befield
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Abstract

Molecular imaging is an increasingly important tool for studying the chemical biology, non-invasive diagnosis, and treatment of a number of diseases. Two-photon fluorescence microscopy (2PFM) is a powerful technique in fluorescence biological imaging, both *in vitro* and *in vivo*, due to its high 3D spatial resolution, minimal photo-bleaching, relatively deep penetration depth, and non-invasive potential. Some approaches to attain successful imaging take advantage of proteins that are expressed in tumors to target and image specific cancer types; or, more recently, new technologies that are based on the targeting of vasculature around the tumors rather than tumors themselves. We are investigating a number of approaches for the development of target-specific imaging agents, including small molecule, block copolymers, functionalized nanoparticles, and stabilized micelles. The synthesis, photophysical characterization, and bioimaging of several novel two-photon absorbing (2PA) fluorescent probes conjugated to an oligopeptide, folate derivative, or an antibody that confers selectivity towards a specific receptor is reported. In particular, angiogenesis and tumor cell markers, such as vascular endothelial growth factor 2 (VEGFR-2), folate receptor, and the adhesive protein $\alpha_v\beta_3$ integrin were targeted. We report cell viability, colocalization, blocking studies, confocal fluorescence imaging, and 2PFM imaging demonstrate the selectivity and versatility of new small molecule, block copolymer, and nanoparticle probes.

Poster 15

Multi-level sensitization of Er^{3+} with temperature-independent internal Er^{3+} relaxation efficiency in Si-rich SiO_2 films

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Abstract

The technological implementation of silicon-sensitized Er excitation in erbium-doped gain media requires a detailed understanding of the exact excitation mechanism. It is demonstrated that Si-excess-related indirect excitation of Er is fast (transfer time τ_{tr} < 27 ns) and occurs into higher lying Er^{3+} levels as well as directly into the first excited state ($^4I_{13/2}$). Consequently, two types of excitation of the $^4I_{13/2}$ state are present: a fast excitation process (τ_{tr} < 27 ns) directly into the $^4I_{13/2}$ level and a slow excitation process due to fast excitation into Er^{3+} levels above the $^4I_{13/2}$ level, followed by internal Er^{3+} relaxation with a time constant $\tau_{32} > 2.3\ \mu s$. Despite the strongly temperature-dependent relaxation rates from the $^4I_{11/2}$ and $^4I_{13/2}$ Er^{3+} levels in the range 15 – 300K, the erbium internal relaxation efficiency from the second ($^4I_{11/2}$) to the first ($^4I_{13/2}$) excited state is found to be remarkably temperature independent, suggesting a near unity value of the internal relaxation efficiency. Internal relaxation is shown to account for 50%–55% of the $^4I_{13/2}$ excitation events in the entire temperature range. These results demonstrate that high pump efficiency and stable operation of devices based on this material will be possible under varying thermal conditions.

Poster 16

EUV Spectral Analysis of Laser Plasmas from Sn, In, and Sb-doped Droplet Sources

Reuvani Kamtaprasad, Omar Rodriguez, Nathan Bodnar, John Szilagyi, Moza Al-Rabban and Martin Richardson
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Abstract

The need for ever shorter wavelengths for next generation nano-printing has been a major motivating factor in the development of high power extreme ultraviolet (EUV) light sources. Laser plasmas have many attractive features for EUV generation. Laser energy is delivered by optical coupling allowing source infrastructure to be located away from stepper tools unlike discharge plasmas. 13.5 nm has been fixed as the wavelength for EUV lithography due to the availability of multilayer optics with high reflectivity centered at this wavelength.

Concerns regarding high quantities of debris from solid material led to the development of the mass-limited droplet target. The configuration of this target involves mixing high-Z compounds in low-Z liquids. Droplets are generated at high repetition rates and are synchronized in phase with laser pulses allowing for the complete ionization of target material and eliminating debris mitigation mechanisms. This work demonstrates the generation of hot dense laser plasmas from tin, indium and antimony mass-limited targets. Tin targets have radiation centered at the necessary 13.5 nm wavelength for lithography purposes. The use of indium and antimony as target material demonstrates adaptability of the droplet system and creates new sources of EUV radiation for EUV microscopy. Spectral emissions from these plasmas are assessed using a flat-field spectrometer. The identification of ion stages for each of the plasmas are determined by comparing spectral output to synthetic spectra, constructed by convolving oscillator strength quantities from COWAN simulations with Gaussian functions of narrow width.

Poster 17

Femtosecond Laser-induced breakdown spectroscopy for detection of bioaerosols

Khan Lim, Yuan Liu, Matthew Weidman, Christopher Brown, Matthieu Baudelet, Michael Sigman, Martin Richardson

Abstract

Fast detection of microbiological samples (bacteria, spores, viruses, molds, fluids, ...) is of interest for clinical applications (sample analysis), environmental monitoring (bacterial activity in liquids) and defense (stand-off detection of bio-threats). Laser-Induced Breakdown Spectroscopy (LIBS) has shown promising results in this area thanks to its ability to reveal atomic inorganic signatures representative of the biological medium [1,2]. Furthermore, sampling and plasma formation by femtosecond lasers is known to enhance the detection of low-concentration constituents thanks to the multiphoton absorption character of the ablation, showing less energetic electronic continuum emission at the early times of the radiative emission of the plasma. But the presence of the atmosphere and its constituents (dust, salts) and the water in which the biological agents are transported make the detection and discrimination difficult.

This study presents the unique integration of a micro-nozzle droplet generator for 30-μm aerosol generation with a compact femtosecond system (600 fs, 1.8 mJ, 250Hz) and an integrated broadband spectrometer showing the capability of compact systems for short-distance stand-off detection of airborne biological agents. The presence of organic material in the droplets was easily detectable and its inorganic constituents identified from the spectra. Limits of detection and quantification as well as discrimination potential in an interfering background (dust, water, salts present in the atmosphere) are studied on a variety of biological samples.

Poster 18

A novel adaptive mechanical-wetting lens for visible and near IR imaging

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Abstract

We demonstrated a novel tunable-focus liquid lens for visible and near infrared imaging applications. To reduce image aberrations and overcome the gravity effect, a common bottleneck to all liquid lenses, we have designed an adaptive mechanical-wetting lens with a concentric reservoir. Our lens adopts liquid pressure to change the interface between two immiscible liquids which, in turn, changes the focal length. High optical performance, high resolution, and a wide dynamic range of both positive and negative optical power could be achieved. Since no PDMS membrane is employed, this lens can expand the working range to near infrared (IR) region, and even mid-IR and far-IR region by choosing proper liquids. Compared to the previous design in which the reservoir is on one side of the lens area, our new design with a concentric reservoir could pump liquid into the lens area uniformly through the entire periphery, helping to eliminate the gradient effect in liquid pressure and stabilize the lens' optical performance during the transition process.

Poster 19

Toward attosecond science at CREOL: A multi-mJ, multi-kHz, CEP-stabilized, few-cycle, OPCPA system

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Abstract

For the first time, attosecond science makes it possible to control and measure the motion of electrons in atoms, molecules, solids and plasmas on an attosecond time scale to study fundamental processes. Starting with a high-intensity optical pulse, it is possible to use high-harmonic generation (HHG) to generate coherent extreme ultraviolet photon bursts that enable experiments with attosecond time resolution, photon energies from 10 eV to 1 keV and/or sub-10-nm spatial resolution.

The High-Energy, Repetition rate-Adjustable, Carrier-Locked-to-Envelope System (HERACLES) is currently being completed and first experiments with the output are expected for summer 2010. The carrier-envelope phase (CEP)-stabilized system is designed to provide optical pulses with 1.5 mJ within a duration of 9 femtoseconds at 800 nm center wavelength. The repetition rate is freely adjustable from single shots up to 12 kHz without significantly affecting pulse energy or duration.

Besides HHG, the laser system can be used as an optical field synthesizer. It is possible to generate tailored waveforms for coherent control experiments on an attosecond time scale. Together with the laser-induced breakdown spectroscopy (LIBS) and filamentation capabilities at the Townes Laser Institute, new physical phenomena will be observable due to the extreme electric field strengths and the ability to tailor the waveform. This ultrashort pulse duration is also beneficial in "athermal" and quasi-deterministic material processing to avoid collateral heating of the substrate leading to undesirable strain and damage. In addition, the pump laser source for the optical parametric chirped-pulse amplifier (OPCPA) provides 60 picosecond pulses of 15 mJ at 1064 nm or 12 mJ at 532 nm, and can be used as a standalone facility in high-energy experiments.

Poster 20

CUBIC ZnxMg1-xO AND NixMg1-xO thin films grown by molecular beam epitazy for deep -UV optoelectronic-applications

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Abstract

Wide bandgap semiconductors are inherently of central interest for deep-ultraviolet (DUV) technologies. Sufficient advancement in DUV optoelectronics would enable the efficient and affordable realization of UV medical devices, high density optical data storage, solar blind detection and important water purification technologies. Among the many avenues into the DUV that are being researched, binary and ternary oxides have been among the notable candidates. Successes with ZnO (Eg = 3.37 eV) based films in particular show tremendous promise for near UV applications and have already been exploited as such. However, to reach increasingly wide bandgap energies alternative materials must be interrogated.

In this work, we explain progress in the application of molecular beam epitaxy to such wide bandgap (Eg > 4 eV) oxide compounds. In particular, we have focused on the cubic oxide semiconductors ZnxMg1-xO and NixMg1-xO which have bandgaps reaching into the UVC region (lambda < 280 nm). Oxygen plasma-assisted molecular beam epitaxy (MBE) has proven to be a superior film growth technique for these oxide epitaxial films and represents an essentially new approach to such cubic oxides. The general growth procedures and methodologies will be explained, film characterization will be presented and new results on recently fabricated devices will be shown.

Poster 21

Engineering of Non-Diffracting Beams: from the simulation to the experiment

Nicholas Barbieri, Matthew Fisher, Matthew Weidman, Benjamin Webb, Matthieu Baudelet, Martin Richardson
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Abstract

Diffraction-free beams have several promising applications such as control of laser plasma filamentation [2-5], remote energy guidance and unique modes of beam propagation [4,6-8]. To enable these applications, the underlying physics of diffraction-free beams and the means to generate them must first be understood. Diffraction free beams are a class of idealized beams containing infinite energy whose transverse irradiance profiles remain invariant with propagation distance. Such ideal diffraction-free beams are unrealizable. But two classes of beams approximating diffraction-free behavior can be achieved in the laboratory, Bessel-Gauss beams [1] and Airy-Gauss beams [6], by generating aperture-limited versions of classic diffraction-free beams.

Airy beams, showing a curved propagation of the main lobe, are created by imprinting a cubic phase to the beam and are of interest for interaction along interfaces. An interesting feature of Airy beams is their ability to regenerate their main intensity peak along propagation if obstructed. This property is investigated and quantitatively applied for long propagation applications.

Bessel intensity profiles have also been created to produce helical patterns through the constructive interference of Bessel beams. Multiple diffraction-free beams may be superimposed to achieve a transverse irradiance profile that rotates periodically with propagation distance but otherwise maintains diffraction-free behavior.

Laboratory Tour Schedule

Industrial Affiliates Day 2010

There will be ongoing **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 tours groups will be assembled starting with group A (See schedule below).

Lab	Description TOUR:	A	B	C	D	E	F	G	H	I	J
A105	**Fiber Draw Tower** Dr. Ayman Abouraddy	1				3				4	2
125	**Millimeter-wave imager & THz laser** Dr. Glenn Boreman http://ir.creol.ucf.edu	2				4	1				3
130	**IR Antenna-coupled sensors & IR metamaterials** Dr. Glenn Boreman http://ir.creol.ucf.edu	3	1				2				4
140 / 141	**Laser Development and Materials Processing** Dr. Martin C. Richardson http://lpl.creol.ucf.edu	4	2				3	1			
201	**Fiber Optic Device Characterization** Dr. Axel Schulzgen		3	1			4	2			
227	**Femtosecond Nonlinear Optics** Dr. David Hagan and Dr. Eric Van Stryland http://nlo.creol.ucf.edu		4	2				3	1		
244A	**Optical Signal Processing with Frequency Combs** Dr. Peter Delfyett http://up.creol.ucf.edu			3	1			4	2		
247	**Surface Plasmon NanoPhotonics** Dr. Pieter Kik http://kik.creol.ucf.edu			4	2				3	1	
260	**Adaptive lens** Dr. Shin Tson Wu http://lcd.creol.ucf.edu				3	1			4	2	
115	**Laser Spectroscopy and Sensing** Dr. Martin C. Richardson http://lpl.creol.ucf.edu				4	2				3	1

CREOL Laboratory Directory

Dr. Ayman Abouraddy
- Optical Fiber Characterization and Mid-infrared Nonlinear Fiber Optics – Rm. A114
- Optical Fiber Draw Tower – Rm. A105
- Laser Spectroscopy and Optically Written Displays – Rm. 157
- Thin-film Thermal Evaporation – Rm 216
- Multi-material Fiber Preform Fabrication – Rm. A302

Dr. Michael Bass
- 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
- Frequency Comb technology – Rm. 254
- Photonic Analog to Digital Converter Technology – Rm. 255
- Microwave Photonics -- Rm. 256
- Laser Radar Technology and Systems – Rm. 245A
- Advanced Optical Signal Processing Technology -- 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 – Rm. 142, 144

Dr. Sasan Fathpour
- Integrated Semiconductor Photonic Device Characterization Laboratory – Rm. 202

Dr. Leon Glebov
- Volume Holographic Elements: recording – Rm. 153
- Photo-thermo-refractive glass: X-ray analysis – Rm. 156
- 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 Laser/OPA lab (300-11,000 nm) – Rm. 227
- Nanosecond Tunable OPO (400-1,500 nm) – Rm. 236
- Picosecond tunable OPA lab (400nm–16microns) – Rm. 230
- Femtosecond Laser/OPA and Single Mode Nanosecond CO_2 – Rm. 233
- Two-Photon Confocal Microscope with Femtosecond OPO – Rm. 246

Dr. James Harvey

- X-Ray Telescopes – Rm. A113
- Optical Design & Image Analysis – Rm. 155
- Generalized Scalar Diffraction Theory – Rm. 155
- Optical surface Scattering – Rm. 155
- Launch Vehicle Imaging Telescopes – A113

Dr. Aravinda Kar

- Laser Advanced Manufacturing – Rm. 263, 264
- Laser Synthesis of Materials – Rm. 263, 264
- Laser Processing of Wide Bandgap semiconductors – Rm. 263, 264
- Modeling and Simulation for materials processing and materials synthesis – Rm. 263, 264

Dr. Pieter Kik

- Nanophotonics Characterization Lab – Rm. 247
- Near-infrared picosecond laser lab – Rm. 242

Dr. Stephen M. Kuebler

- Fabrication of 3D micro- and nano-scale structures – CHM Rm. 324

Dr. Guifang Li

- Optical Fiber Communications – Rm. 246A, 248, 278(office)

Dr. Patrick LiKamWa

- Quantum Well Optoelectronics – Rm. 220, 223

Dr. Jim Moharam

- Diffractive Optics – Rm. 258

Dr. Martin Richardson

- Northrop Grumman Extreme Ultraviolet Photonics Laboratory NG-EUV – Rms. 140,143
- Multi-TW Femtosecond Laser Facility (TW) – Rm 140
- Secure Laser Test Range SLTR – (access Rm 140)
- High Intensity Laser Interactions Science laboratory HILISL – Rms. 140, 112-117
- Fiber Laser Development Laboratory – Rm 143
- X-ray microscopy XRM – Rm 123
- Laser Materials Processing LMP – Rm. 141
- High Intensity CEP Laser HICEP – Rm. 117
- New Solid State Laser Development – Rm. 140

Dr. Martin Richardson (continued)

- Laser Spectroscopy and Sensing Laboratory LSSL – Rms. 140,123 & 123A, 112-117
- Laser Tissue Interaction Laboratory LTI – Rm. 26
- **Zygo New View 6300 Interferometer - 2nd Floor Cleanroom Rm. 211**

Dr. Nabeel Riza

- Photonic Information Processing Systems – Rm. 251, 253

Drs. Anand Santhanam & Jannick Rolland

- 3D Visualization (Augmented Reality, Vision, 3D Volumetric lung modeling, Radiotherapy Beam Modeling, Real-time Lung Dosimetry) -- Rm. 147

Dr. Bahaa Saleh

- Quantum Optics Lab – Rm. 204

Dr. Axel Schülzgen

- Fiber Optics Lab (FOL) – Rm. 201

Dr. Winston Schoenfeld

- Nanophotonic Devices Lab – Rm. 156
- Nanophotonics Fabrication Facility – Rm. 180
- Wide Band Gap Characterization Lab – Rm. A112
- Oxide MBE Lab – Rm. 180C

Dr. Eric Van Stryland

See Drs. Hagan and Van Stryland

Dr. Shin-Tson Wu

- 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
- Clean room – Rm. 211
- Class 1000/ Class 100 Clean Room – Rm. 180 – Nano-Fabrication Facility
- Fiber Tower – Rm. A105
- Machine Shop – Rm. A106
- Olympus Nomarski Interference Microscope – Rm. 159
- SEM – Rm. 176

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Why Florida?

Florida is a High-tech Leader

All high-tech companies benefit from Florida's business environment that emphasizes innovation, collaboration, and talent formation for today's global markets. From start-ups focused on turning the latest academic research into commercially viable products and technologies, to established industry giants, Florida has what high-tech companies need.

Florida Photonics Industry Cluster

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.

Business Friendly Climate

Florida's low taxes and smart growth policies have placed it among the top 5 "Best States for Starting a Business," according to *Fortune Small Business.* Florida continues to rank among the top states for best tax climates for business, with no state income tax, low corporate taxes, a low unemployment insurance tax rate, and sales tax exemptions for certain business transactions.

Excellent Quality of Life

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

eflorida.com

FLORIDA high tech Corridor
floridahightech.com
A regional economic development initiative of: University of Central Florida, USF University of South Florida, UF University of Florida

For more information on "Why Florida" to grow your business, visit Enterprise Florida at www.eflorida.com and the Florida High Tech Corridor at www.floridahightech.com.

Thank you for attending!

We look forward to seeing you at the next CREOL Affiliates Day Friday, April 29, 2011