Ultra-Short Pulse Lasers and Applications

Industrial Affiliates Day 2007
Friday, April 13, 2007

University of Central Florida
Student Union -- Cape Florida Room
CREOL Building
Orlando, FL
Industrial Affiliates Day
April 13, 2007

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**CREOL & FPCE , THE COLLEGE OF OPTICS AND PHOTONICS**

**Industrial Affiliates Day – Friday April 13, 2007**

**Theme: Ultra-Short Pulse Lasers & Applications**

**Morning Session – UCF Student Union, Cape Florida Ballroom - 316**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:15</td>
<td>Breakfast, &amp; Walk-in Registrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:45</td>
<td>Welcoming Remarks</td>
<td>Dr. Terry Hickey&lt;br&gt;Dr. MJ Soileau&lt;br&gt;Dr. Eric Van Stryland</td>
<td>Provost and Executive VP, UCF VP for Research, UCF Dean, College of Optics and Photonics</td>
</tr>
<tr>
<td>9:05</td>
<td>&quot;High power lasers, some applications, and their future at UCF&quot;</td>
<td>Dr. Martin Richardson</td>
<td>Northrop Grumman Professor of X-ray Photonics; CREOL &amp; FPCE, The College of Optics &amp; Photonics</td>
</tr>
<tr>
<td>9:40</td>
<td>“Attosecond Science and Technology”</td>
<td>Dr. Paul Corkum</td>
<td>Program Leader, Atomic, Molecular &amp; Optical Science (AMOS); Steacie Inst. for Molecular Sciences; CNRC</td>
</tr>
<tr>
<td>10:15</td>
<td>BREAK</td>
<td></td>
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<tr>
<td>10:35</td>
<td>“Raydiance Ultra-Short Pulse Laser Platform: Gateway to the Light Age”</td>
<td>Dr. Michael Cumbo</td>
<td>Chief Operating Officer, Raydiance, Inc., Orlando</td>
</tr>
<tr>
<td>11:10</td>
<td>“Pulse Dynamics in Mode-locked Lasers and the Linewidth of Femtosecond Combs”</td>
<td>Dr. Steven Cundiff</td>
<td>Chief, Quantum Physics Division, National Institute of Standards and Technology, JILA; CU-Boulder</td>
</tr>
<tr>
<td>11:45</td>
<td>Adjourn for LUNCH</td>
<td></td>
<td>UCF Student Union</td>
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**Afternoon Session – CREOL Building**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:30</td>
<td>Walk to CREOL Bldg.- Exhibits Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:00</td>
<td>Dedication of CREOL Building Addition</td>
<td>Dr. MJ Soileau&lt;br&gt;Dr. Eric Van Stryland</td>
<td>VP for Research, UCF Dean, Optics and Photonics</td>
</tr>
<tr>
<td>1:30</td>
<td>“Stabilized Ultrafast Pulse Generation and Optical Frequency Combs – Techniques and Applications”</td>
<td>Dr. Peter Delfyett</td>
<td>Trustee Chair Professor of Optics, ECE, &amp; Physics; CREOL &amp; FPCE, The College of Optics and Photonics</td>
</tr>
<tr>
<td>2:00</td>
<td>“CREOL &amp; FPCE, College of Optics and Photonics Research Overview”</td>
<td>Dr. Eric Van Stryland</td>
<td>Dean, CREOL &amp; FPCE, College of Optics and Photonics</td>
</tr>
<tr>
<td>2:40</td>
<td>Student of the Year – Presentation High Performance Cholesteric Liquid Crystal Lasers</td>
<td>Ms. Ying Zhou</td>
<td>CREOL &amp; FPCE, The College of Optics and Photonics</td>
</tr>
<tr>
<td>3:00</td>
<td>Poster Session &amp; Lab Tours (Tea &amp; Cookies in the Lobby)</td>
<td>Graduate Students and CAOS Leadership</td>
<td>CREOL &amp; FPCE, The College of Optics and Photonics</td>
</tr>
<tr>
<td>5:00 to 6:00</td>
<td>Reception &amp; Award presentations</td>
<td>Dr. Eric Van Stryland</td>
<td>CREOL &amp; FPCE, The College of Optics and Photonics</td>
</tr>
</tbody>
</table>

**Tabletop Exhibits – CREOL Lobby**
Invited Presentation

High Power Lasers, Some Applications, and Their Future at UCF

Dr. Martin C. Richardson
Northrop Grumman Professor of X-ray Photonics
CREOL & FPCE, The College of Optics & Photonics
mcr@creol.ucf.edu

Abstract

New developments in high power lasers are opening new opportunities for advanced technologies in next-generation micro-manufacturing, medical and defense applications. These are all areas of considerable impact to Florida’s high-tech economy. In this talk we will briefly review some advances made in the College of Optics & Photonics in high power solid state laser development, and in some select applications that show promise in each one of these areas. We will describe some exciting new results in high power fiber laser development and ultra-fast lasers. The development of high-power laser-based sources for EUV lithography, the next generation of chip manufacture has now reached a critical stage. Laser produced X-rays are also being used for high-resolution imaging of live single cells. We will also summarize some of the research underway in the use of high power lasers for defense applications including stand-off detection of explosives and biological agents. Finally we will describe the impact of the award to UCF of a new State Center of Excellence in advanced laser technology, to be called the Townes Laser Institute named after Nobel Laureate Charles Hard Townes the inventor of the maser and co-inventor of the laser. Some $4.5M in State funds for major facilities for this center were matched by UCF with five new faculty positions and startup/infrastructure funds. This follows on a similar award in 2003 for the Florida Photonics Center of Excellence. In addition, a 21st Century Scholar endowed chair in Laser Medicine was also awarded to the College by the State. These initiatives position the College to become a national leader in both advanced laser technology and photonics.

Biographical Note

Professor Richardson came to UCF in 1990 to establish the Laser Plasma Laboratory. He is a graduate of Imperial College and gained his Ph.D from London University working at the UKAEA fusion laboratory at Culham. He has held academic and senior scientific positions in Canada at the Herzberg Institute of the CNRC in Ottawa, and at the University of Rochester where he was for some time the group leader responsible for laser fusion experiments on the Omega facility. He built his first high powered laser in 1964, four years after the invention of the laser, and has been researching lasers and their applications for much of his career. Together with his students, in many different universities, who now number close to 40, his research spans the development of solid-state and gas lasers, the properties and applications of lasers plasmas, especially as x-ray sources for lithography and microscopy, x-ray lasers and laser fusion, ultra-fast lasers and their applications in materials processing, stand-off laser sensing and laser-induced effects. His laboratory currently comprises 4 senior scientists and engineers, and nearly 20 graduate students, working in several teams funded by major programs from DOE, ARO, DARPA, NSF and private industry. Dr. Richardson believes strongly in the cultural and social benefits of international science. He has worked in many countries including Germany, France, UK, Canada, Australia, Japan and the former Soviet Union, and is currently on several international review boards. He directs an international NSF program providing foreign summer internship to undergraduate students and has collaborative research programs with several European and Arab universities. Dr. Richardson has published ~ 400 scientific papers and holds 17 patents and disclosures. He has held professional society positions and has organized many international conferences. He is a fellow of the Optical Society of America, a recipient of the Schardin Medal of the German Physical Society, and several UCF awards.
Invited Presentation

Attosecond Science and Technology

Dr. Paul Corkum
Atomic, Molecular and Optical Science Group Leader - Steacie Institute for Molecular Sciences
National Research Council of Canada
100 Sussex Drive; Ottawa, Canada K1A 0R6
Paul.Corkum@nrc-cnrc.gc.ca

Abstract

Attosecond pulses are formed in a seemingly very unlikely event --- an electron tunnels from atoms in a low density gas near each crest of the laser electric field, moves under the force of the time dependent electric field, and can be driven back to the parent ion where it re-collides, producing XUV light. Currently the minimum duration of optical pulses is 130 attoseconds, a decrease of factor of 40 in the past 5 years. I will describe how these pulses are produced and measured.

Quantum mechanically attosecond pulses arise from the interference between the ionized electron wave packet and its parent orbital. As we know from optics, interferometry allows everything about the waves involved to be determined. That means optical technology can simultaneously have attosecond time resolution and Angstrom spatial resolution. No competing technology offering combined imaging and time resolution. Thus, attosecond technology has the potential for broad impact --- in physics, chemistry and biology. I will describe how molecular orbitals can be imaged.

Biographical Note

Paul Corkum is a graduate of Lehigh University, Bethlehem, Pa in 1972 with a Ph. D. in theoretical physics. In 1973 he joined the staff of the National Research Council of Canada. At NRC he concentrated first on lasers technology and then on using intense laser pulses to study and control matter. Paul is best known for introducing many of the concepts of how intense light pulses interact with atoms and molecules and then confirming them experimentally. His re-collision model forms the basis of attosecond science. His experiments were among the first to measure attosecond optical and electron pulses and to use them for scientific studies.

Paul is a member of the Royal Societies of London and of Canada. Among his awards are the Canadian Association of Physicists’ Gold Medal for Lifetime Achievement in Physics (1996), the Royal Society of Canada’s Tory Award (2003), the Optical Society’s Charles H. Townes Award (2005) the IEEE’s Quantum Electronics Award (2005) and the APS’ Schawlow Prize (2006). In 2006, he also received an honorary degree from Acadia University, his alma mater.
Invited Presentation

Raydiance Ultra-Short Pulse Laser Platform: Gateway to the Light Age

Dr. Michael Cumbo
Chief Operating Officer
Raydiance, Inc.
mcumbo@raydiance-inc.com

Abstract

Despite the publication of many promising laboratory “hero experiments” powered by ultra-short pulse lasers, outside of a few high-end niche applications (e.g. micro-material processing and corrective ophthalmic surgery), widespread commercial adoption of USP photonic technology has not yet occurred. This is due to the lack of reliable, compact, affordable, and easy-to-use USP lasers with flexible optical performance specifications. In this presentation, we will describe a revolutionary, programmable laser platform that is now opening vast, previously unserved medical, dental, and life science markets to USP technology.

Biographical Note

Michael J. Cumbo is the Chief Operating Officer of Raydiance, Inc. He is responsible for the Company’s R&D, engineering, manufacturing, and supply chain management functions. Prior to joining Raydiance, Dr. Cumbo held executive level positions at BinOptics Corporation (privately held), Coherent (NASDAQ: COHR), JDS Uniphase (NASDAQ: JDSU), and Optical Coating Laboratories Inc. (NASDAQ: OCLI). He is well known as a technical innovator in the laser, fiber optic communication, and bulk optics industries. During the late 1990s, he played a key role in the development and high volume production of interference filter based wavelength division multiplexing (WDM) telecom components. Dr. Cumbo earned a B.S. in Physics, an M.S. in Optical Engineering, and a Ph.D. in Optics at the University of Rochester, and an M.S. in Electrical Engineering at Rochester Institute of Technology. In addition to his high tech business and academic accomplishments, he is also an award winning amateur wine maker.
Invited Presentation

Pulse Dynamics in Mode-locked Lasers and the Linewidth of Femtosecond Combs

Dr. Steven T. Cundiff
JILA, National Institute of Standards and Technology and
University of Colorado at Boulder
cundiffs@jila.colorado.edu

Abstract

Mode-locked lasers are an excellent “playground” for the study of nonlinear pulse dynamics, providing a unique opportunity to test many aspects of soliton theory. The development of femtosecond combs and their use for precision optical frequency metrology has provided a new impetus for further developments in the theory of mode-locked lasers, especially the effect of noise. Mode-locked laser generate trains of ultrashort optical pulses, with durations in the femtosecond regime. In the frequency domain, such a pulse train corresponds to a “comb” of very regular lines. I will present work on understanding the origins of the widths of these comb lines. Just as in a CW laser, spontaneous emission results in a fundamental quantum limit to width of the comb lines. However, the limit is not simply given by the well known Schawlow-Townes formula, but is much more complicated due to the pulse dynamics in the laser. Our experimental measurements provide the foundation for a model that can estimate the comb line width and how it depends on operating parameters.

Biographical Note

Steven T. Cundiff received the Ph.D. in Applied Physics from the University of Michigan in 1992. His thesis was on picosecond coherent spectroscopy of excitons in semiconductor heterostructures and the role of structural disorder. After graduation he was awarded an Alexander von Humboldt Fellowship to pursue research at the University of Marburg, Germany. While at Marburg, he continued working on the coherent spectroscopy of semiconductors and observed evidence for Rabi flopping in semiconductors, confirming the predicted change in Rabi-flopping due to Coulomb effects. Subsequently, he took a post-doctoral position at Bell Labs, Holmdel. There he branched out from coherent spectroscopy to also work on second harmonic spectroscopy of interfaces, dynamics of mode-locked lasers and the use of ultrashort pulses in telecommunications. In 1997 he moved to JILA, a joint institute between the National Institute of Standards and Technology (NIST) and the University of Colorado, in Boulder, Colorado. At JILA he began working on the development of femtosecond combs for optical frequency metrology and optical atomic clocks. Currently, Cundiff is Chief of the NIST Quantum Physics Division, which is the NIST component of JILA, a JILA Fellow and an adjoint Associate Professor in the University of Colorado Departments of Physics and Electrical and Computer Engineering. He is a Fellow of the Optical Society of America and the American Physical Society.
Invited Presentation

Stabilized Ultrafast Pulse Generation and Optical Frequency Combs
– Techniques and Applications

Dr. Peter J. Delfyett
University Trustee Chair Professor
CREOL & FPCE, College of Optics & Photonics
University of Central Florida
delfyett@mail.ucf.edu

Abstract

Recently, the development of stabilized modelocked lasers has enabled unprecedented advances in ultrafast optical sciences and in the resolution in metrology applications. In order to exploit the unique performance characteristics that stabilized modelocked lasers possess in other commercial applications, compact and efficient approaches to their generation must be developed. In this presentation, we discuss some of the technical approaches towards the generation of stabilized optical frequency combs from modelocked semiconductor diode lasers and highlight applications enabled by their existence, specifically in the areas of optical communications and signal processing.

Biographical Note

Peter J. Delfyett received the Ph.D. degree from The Graduate School & University Center of the City University of New York in 1988 where his work focused on developing a real time ultrafast spectroscopic probe to study molecular and phonon dynamics in condensed matter using optical phase conjugation techniques. After obtaining the Ph.D. degree, he joined Bell Communication Research as a Member of the Technical Staff, where he concentrated his efforts towards generating ultrafast high power optical pulses from semiconductor diode lasers, for applications in applied photonic networks. Some of his technical accomplishments were the development of the world’s fastest, most powerful modelocked semiconductor laser diode, the demonstration of an optically distributed clocking network for high speed digital switches and supercomputer applications, and the first observation of the optical nonlinearity induced by the cooling of highly excited electron-hole pairs in semiconductor optical amplifiers. Dr. Delfyett joined the faculty at the Center for Research and Education in Optics and Lasers (CREOL) in 1993, and currently holds the positions of University Trustee Chair Professor of Optics, ECE & Physics.

Dr. Delfyett is the Editor-in-Chief of the IEEE Journal of Selected Topics in Quantum Electronics. He is a Fellow of the Optical Society of America, and of IEEE/LEOS, and is a member of the Board of Directors of the Optical Society of America. Dr. Delfyett has received numerous awards including the National Science Foundation’s Presidential Early Career Award for Scientists and Engineers (PECASE), which is awarded to the Nation’s top 20 young scientists. He has also received the University of Central Florida’s 2001 Pegasus Professor Award which is the highest honor awarded by the University. He was selected as one of the “50 Most Important Blacks in Research Science in 2004” and as a “Science Trailblazer in 2005 and 2006” by Science Spectrum Magazine. Dr. Delfyett has also endeavored to transfer technology to the private sector, which helped to found “Raydiance, Inc.” which is a spin-off company developing high power, ultrafast laser systems, for applications in medicine, defense, material processing, biotech and other key technological markets. Most recently, Dr. Delfyett was elected to serve as President of the National Society of Black Physicists. Dr. Delfyett has published over 400 articles in refereed journals and conference proceedings, has been awarded 20 United States Patents.
Student of the Year Presentation

High Performance Cholesteric Liquid Crystal Lasers

Ph.D. Student: Ms. Ying Zhou

Advisor: Professor Shin-Tson Wu
CREOL & FPCE, College of Optics & Photonics
University of Central Florida
yzhou@mail.ucf.edu

Abstract

Regarded as one-dimensional photonic crystal, cholesteric liquid crystals (CLC) shows the selected reflection band for the circularly polarized light in the same sense as the cholesteric helix. By doping an active medium into cholesteric liquid crystals, circularly polarized laser emission is generated at the photonic band edge where CLC provides the polarization-dependent distributed feedback. By adding a cholesteric liquid crystal passive reflector or a cholesteric external resonator, we demonstrated a high performance CLC laser with emission efficiency enhanced by ~800X and beam divergence reduced by one order of magnitude. This discovery opens a new way for future applications in portable biomedical sensors using high efficiency micro laser sources.

Biographical Note

Ms. Ying Zhou is currently a 4th year Ph. D. student in the College of Optics and Photonics, UCF. Before she joined CREOL in 2003, she received her BS and MS degrees in Optical Engineering from Zhejiang University, China. Her Ph.D. work is on liquid crystal photonic devices, liquid crystal lasers, and polarization devices. So far she has published 17 peer-reviewed journal papers and 12 conference proceedings. She is a recipient of a 2007 OSA New Focus/Bookham Student Award, and the 2007 CREOL Student of the Year.
Exhibitors - Exhibitor tables will either be in the atrium of the Student Union (am) or the CREOL lobby (pm).

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www.rohde-schwarz.com/USA

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800-835-9433
www.spie.org

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435-753-3729
www.spiricon.com

**Tektronix**

14200 SW Karl Braun Drive
Beaverton, OR 97077
800-835-9433
www.tek.com

**Varian Vacuum Technologies, Inc.**

2435 Aloma Ave.
PMB 301
Oviedo, FL 32765
407-366-8602
www.varianinc.com
**Laboratory Tour Schedule**

NOTE: There will be Guided Group Tours through several CREOL labs today.

Groups form up in the CREOL Lobby.

Schedule for guided lab tour that will be conducted in five groups: A, B, C, D and E.

<table>
<thead>
<tr>
<th>Laboratories</th>
<th>Tour time for each group</th>
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<tbody>
<tr>
<td><strong>Martin Richardson</strong></td>
<td>3:15 3:35 3:55 4:15 4:40</td>
</tr>
<tr>
<td>Laser Plasma Laboratory Virtual Tour by Flat Screen</td>
<td>A E D C B</td>
</tr>
<tr>
<td>Lab. #140</td>
<td></td>
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<tr>
<td><strong>Dennis Deppe</strong></td>
<td>B A E D C</td>
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<tr>
<td>Quantum dot growth for laser diodes</td>
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<tr>
<td>Lab. #180</td>
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<tr>
<td><strong>CREOL new addition [(a) The new &quot;Donor Recognition Wall,&quot; (b) New offices, (c) New Labs, (d) High Bay lab for fiber draw tower, (e) New machine shop</strong></td>
<td>C B A E D</td>
</tr>
<tr>
<td><strong>Peter Delfyett</strong></td>
<td>D C B A E</td>
</tr>
<tr>
<td>Optical Frequency Comb and Applications</td>
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<tr>
<td>Lab. #256</td>
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<tr>
<td><strong>S.T. Wu</strong></td>
<td>E D C B A</td>
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<tr>
<td>Tunable-Focus Lens</td>
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<tr>
<td>Lab. #260</td>
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</table>
**Poster - 1**

**Fabrication of Three-Dimensional Micron-Scale Metal Photonic Crystals by Multi-Photon Direct Laser Writing**

Amir Tal*, Yun-Sheng Chen*, Henry Williams¹, and Stephen M. Kuebler¹,²

¹Department of Chemistry; ²CREOL, The College of Optics and Photonics

Three-dimensional (3D) metal photonic crystals (MPCs) have been shown to possess interesting optical properties, such as ultra-wide photonic band gaps, selectively tailored thermal emission, extrinsically modified absorption, and negative refraction. At present, MPCs functioning at infrared and optical wavelengths have only been partly explored, largely due to the challenges associated with fabricating such micron-scale materials, as well as the highly dispersive and absorptive properties of metals in these regimes. Recent reports demonstrate the successful realization of 3D MPCs via planar semiconductor fabrication techniques coupled with metal vapor deposition, gold sputtering of free-standing polymer photonic crystal templates fabricated by soft-lithography, and metal-infiltrated self-assembled dielectric photonic crystals. However, each of these methods is limited in that only a small sub-set of MPC geometries can be accessed; including non-periodic functional defects within a structure is difficult or impossible; and the fabrication processes tend to be very complex, involving multiple bonding and planarization steps. Here we demonstrate that 3D micron-scale metallized polymeric structures having a face-centered-tetragonal geometry can be created by multi-photon direct laser writing of polymeric photonic crystal templates followed by selective electroless metal deposition. The resulting metal-polymer micro-structures exhibit optical properties that are markedly different from that of the polymeric templates and are consistent with that expected for MPCs.

For information contact: kuebler@mail.ucf.edu

*These students contributed equally to the work.

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**Poster - 2**

**Micro-Raman Spectroscopy of Single Red Blood Cells Following Infection by a Malaria Parasite**

W. Carter¹, L. Ayong³, D. Chakrabarty³, A. Schulte²

¹UCF Department of Physics; ²UCF Department of Physics and the College of Optics and Photonics; ³UCF Department of Molecular Biology and Microbiology

Raman micro-spectroscopy provides a non-destructive probe with potential applications as a diagnostic tool for cell disorders. We have measured Raman spectra of single living red blood cells with a spatial resolution of one micron. At an excitation wavelength of 633 nm the spectral bands are dominated by hemoglobin vibrations yielding information on structure and spin state of the heme moiety. We present micro-Raman spectra of live erythrocytes infected with a malaria parasite and investigate the potential of this probe to monitor molecular changes which occur during differentiation of the parasite inside the cell.

For information contact: wcarter@physics.ucf.edu
POSTER PRESENTATION ABSTRACTS

Poster - 3

Nanofabrication of Quantum Boxes by Deep Etching of Multiple Quantum Well Structures

Nathan Bickel and Patrick LiKamWa

High resolution electron beam lithography and reactive ion etching techniques are employed for the purpose of realizing multilayered quantum box arrays from epitaxially grown multiple quantum well structures. Our interest in these materials stems from the advantages they possess over both quantum wells and self-assembled quantum dots. As with conventional quantum dots the imposition of lateral confinement should yield several properties which are relevant to the production of electro-optical and all-optical switches. These include a reduced spectral linewidth, a controllable alpha parameter, and enhanced carrier transport. In addition, quantum boxes etched from multiple quantum wells also show a high degree of size uniformity, and, as a consequence, a low spread in electron transitional energies. Quantum dots ensembles created using the Stranski-Krastanow self-assembled growth method often display significant size distribution and consequently a broadening of the absorption spectrum, making them ill-suited for electro-optical and all-optical switching devices. To date GaAs pillars with a diameter of approximately 45-nm and height of 550-nm have been produced. Further work is planned to reduce the pillar diameter into the range of 20- to 30-nm, while increasing the etch depth. Transfer of the nanofabrication process to multiple quantum well material along with characterization of the optical properties and incorporation into devices will follow.

For information contact: nbickel@creol.ucf.edu

Poster - 4

Novel Dopants in Silicon Carbide for Light Emission

Sachin Bet, Nathaniel Quick1 and Aravinda Kar
1Applicote Associates, LLC, 1445 Doigner Pl., Ste. 23, Sanford, FL 32771

This work presents the study on the effects of various dopants incorporated in silicon carbide (6H-SiC and 4H-SiC) substrates using novel laser doping for light emitting device (LED) applications. The defect levels (donor and acceptor) created within the forbidden band gap of SiC due to various dopants onsets the donor acceptor pair (DAP) recombination mechanism for luminescence commonly observed in SiC. Change in these defect levels due to different dopant species tunes the emission wavelengths of these LEDs. Novel unconventional dopants such as Chromium (Cr) and Selenium (Se) were laser doped in SiC along with conventional dopants such as Boron (B), Aluminum (Al) and Nitrogen (N) to fabricate different color LEDs. Cr, B and Al behave as acceptors in SiC while N and Se behave as donors. The dopant profiles have been characterized using secondary ion mass spectrometry. Electroluminescence studies showed that combination of dopants can be effectively utilized to obtain violet (411 nm), blue (481 nm), blue-green (507 nm), green (521 nm), orange (677 nm), red (738 nm) and even white light LEDs (380-900 nm) enfolding the entire visible spectrum.

For information contact: sbet@creol.ucf.edu
POSTER PRESENTATION ABSTRACTS

Poster - 5

Terahertz Wavelength-Scanning Aperture Filter

Justin W. Cleary¹, Chris J. Fredricksen¹, Andrei V. Muravjov¹, Jasen Enz¹, Maxim V. Dolguikh¹, Robert E. Peale², Todd W. Du Bosq, William R. Folks, Sidhartha Pandey, Glenn Boreman, Ravi Todi³, Kalpathy Sundaram² and Oliver Edwards⁴

¹UCF Department of Physics; ²UCF Department of Physics and College of Optics and Photonics; ³UCF Electrical Engineering and Computer Science; ⁴Zyberwear, Inc.

A scanning Fabry-Perot transmission filter composed of a pair of dielectric mirrors has been demonstrated at millimeter and sub-millimeter wavelengths. The mirrors are formed by alternating quarter-wave optical thicknesses of silicon and air in the usual Bragg configuration. Characterization was performed at sub-mm wavelengths using a gas laser together with a Golay cell detector and at millimeter wavelengths using a backward wave oscillator and microwave power meter. A finesse value of 422 for a scanning Fabry-Perot cavity composed of three-period Bragg mirrors was experimentally demonstrated. Finesse values of several thousand are considered to be within reach. This suggests the possibility of a compact terahertz Fabry-Perot spectrometer that can operate in low resonance order to realize high free spectral range while simultaneously achieving a high spectral resolution. Such a device is directly suitable for airborne/satellite and man-portable sensing instrumentation.

For information contact: jcleary@physics.ucf.edu

Poster - 6

Surface Plasmon Mediated Optical Limiting

Dana Kohlgraf-Owens and Pieter G. Kik

Optical limiters are used to protect sensors including the eye. An ideal optical limiter has 100% transmission at low irradiance but absorbs all irradiance above a certain threshold. Such behavior can be achieved with bulk materials that possess a large nonlinear absorption coefficient. In order to achieve the desired magnitude of the nonlinear response, however, existing optical limiters use external focusing to reach sufficiently high irradiance. As a result such limiters are bulky, requiring multiple lenses for focusing and re-collimation.

It has been demonstrated that instead of macroscopic focusing it is possible to achieve enhanced nonlinear response by making use of resonant local field enhancement around metal nanoparticles, effectively causing ‘nanoscale focusing’. Currently we are exploring the use of surface plasmon enhanced fields to achieve an enhanced nonlinear response with the ultimate goal of completely removing the need for external lenses. An extension of the Maxwell Garnett effective medium theory has been used to analytically compute the effective linear and nonlinear response of a composite material consisting of small non-interacting spherical metal nanoparticles embedded in a nonlinear host. We show computed trends in the achievable enhancement of the nonlinear properties for this system and how the response depends on a balance between linear and nonlinear absorption. We explain the counterintuitive result that a good nanostructured nonlinear absorber requires a host material with minimal nonlinear absorption and high nonlinear refraction. Finally we compare the performance of a bulk nonlinear film with the performance of a surface plasmon enhanced composite nonlinear material.

For information contact: kik@creol.ucf.edu
POSTER PRESENTATION ABSTRACTS

Poster - 7

Tunable Focus Liquid Lens

David Fox; H. Ren, Shin-Tson Wu, P. A. Anderson, and B. Wu

We demonstrated a liquid lens whose focal length can be controlled by a servo motor. The lens cell is composed of elastic membrane, planar glass plate, a periphery sealing ring, and a liquid with a fixed volume in the lens chamber. Part of the periphery sealing ring is excavated to form a hollow chamber which functions as a reservoir. This hollowed periphery is surrounded by an exterior rubber membrane. The arm of a servo motor is used to deform the elastic rubber and squeeze the liquid contained in the reservoir into the lens chamber. Excess liquid in the lens chamber will push the lens membrane outward, resulting in a change in the lens shape. Due to the compact structure and easy operation, this liquid lens has potential applications in zoom lenses, auto beam steering, and eyeglasses.

For information contact: swu@creol.ucf.edu

Poster - 8

Comprehensive Modeling of Nitride Based Core/Multishell Nanowires as a Guiding Tool for the Growth and Fabrication of Future High Efficiency Nanowire Devices

Clarisse Mazuir, Christine Klemenz, and Winston V. Schoenfeld

InGaN core/multishell nanowires (CMS NWs) appear promising components for integrated circuits and particularly as low lasing threshold lasers and high efficiency light emitting diodes (LEDs). The capability to grow such nanowires with accurate control of the thickness, composition, and doping of the different layers involved has been demonstrated in literature through metal organic chemical vapor deposition (MOCVD) and vapor-liquid-solid (VLS) growth techniques. In order to guide the growth/fabrication process and establish the detailed structure that needs to be grown, we have developed a comprehensive theoretical model for InGaN CMS NW LEDs that accurately predicts both the electrical and optical properties of nitride based CMS NW structures. By modeling the electron and hole injection in an InGaN CMS NW LED we show that the InGaN quantum shell (QS) serves as a high mobility channel for electrons while the intrinsically poor conductivity of the p-doped GaN outer shell confines the hole injection to an area directly underneath the p-contact. As a direct result of the confined hole injection, light generation in the CMS NW was found to occur in the InGaN QS directly below the p-contact. After comparison with published experimental results the model is found to accurately predict the optical emission properties, including the spectral output changes due to the thickness and indium composition variation of the InGaN QS. Finally, piezoelectric effects in the CMS NW LEDs are found to play an insignificant role, suggesting that the full width at half maximum (FWHM) of the optical output is mostly determined by alloy broadening and excitonic emission.

For information contact: winston@creol.ucf.edu
POSTER PRESENTATION ABSTRACTS

Poster - 9

Chromatic Dispersion Compensation using Digital All-Pass IIR Filtering

Gilad Goldfarb and Guifang Li

Digital infinite impulse response (IIR) filtering is proposed as a means for compensating chromatic dispersion in homodyne-detected optical transmission systems with subsequent digital signal processing. Compared to finite impulse response (FIR) filtering, IIR filtering achieves dispersion compensation using a significantly smaller number of taps. Dispersion compensation of 80km and 160km in a 10Gbp/s binary phase-shift-keying is experimentally compared for the two filtering schemes.

For information contact: gilad@creol.ucf.edu

Poster - 10

Axial Field Shaping Under High Numerical Aperture Focusing

Toufic G. Jabbour, Stephen M. Kuebler

R. Kant reported (J. Mod. Optics, 2000, 47, 905) a formulation for solving the inverse problem of vector diffraction, which accurately models high-numerical-aperture focusing. Here, Kant's formulation is adapted to the method of generalized projections to obtain an algorithm for designing diffractive optical elements (DOEs) that re-shape the axial point-spread-function (PSF). The algorithm is applied to design a binary phase-only DOE that superresolves the axial PSF with controlled increase in axial side lobes. An eleven-zone DOE is identified that axially narrows the PSF central lobe by 29% while maintaining the side lobe intensity at or below 52% of the peak intensity. This DOE could improve the resolution achievable in several applications without significantly complicating the optical system.

For information contact: kuebler@mail.ucf.edu

Poster - 11

Influence of Three Dimensional Quantum Confinement on the Nonlinear Optical Properties in Semiconductor Quantum Dots

Gero Nootz, Lazaro Padilha, Eric Van Stryland, David Hagan

Semiconductor quantum dots (QDs) in their different forms are promising candidates for a wide field of applications such as 3-D imaging, all-optical switching and quantum computing. Understanding the linear and nonlinear optical properties of these nano-structures is, therefore, important in order to improve their desirable characteristics by choosing the appropriate fabrication process.

We studied the nonlinear optical properties of colloidal CdSe QD’s of different sizes at non resonance and resonance excitation by Z-Scan and two-photon fluorescence. Two different theoretical models for resonant and off- resonant excitation are proposed and discussed.

For information contact: gnootz@creol.ucf.edu
POSTER PRESENTATION ABSTRACTS

Poster - 12

Spectrophotometric Characterization of Complex Refractive Index of Cd$_x$Zn$_{1-x}$O
for Photonic Device Applications

Matthew Falanga, Jeremy W. Mares, Andre Osinsky, Brian Hertog, and Winston V. Schoenfeld

Epitaxially grown Cd$_x$Zn$_{1-x}$O epilayers ($x=0.02$ to 0.18) were characterized by spectrophotometry to
determine their complex indices of refraction through the UV and visible wavelength range. Transmission
spectra were analyzed using an evolutionary algorithm based on a transmission-matrix formalism. The real
and imaginary parts of the refractive index ($n$ and $k$) were derived in conjunction with the respective band
gap energies as a function of cadmium concentration. The resultant data along with associated simulations
of optical structures such as distributed Bragg gratings will be presented.
For information contact: jmares@creol.ucf.edu

Poster - 13

Three-Photon Absorption in Semiconductors

Peter D. Olszak, Scott Webster, Lazaro A. Padilha, Milton Woodall, David J. Hagan,* and Eric W. Van Stryland
*DRS Infrared Technologies, LP  P.O. Box 740188  Dallas, TX  75374

Multi-photon absorption processes have been a topic of research for almost a century dating back to the
early work of Maria Goeppert-Mayer in the early 1930s. Shortly after the laser was developed,
experimental verification of two-photon absorption (2PA) was made in 1961 and a generalized theory was
developed over the following decades. A theory for three-photon absorption (3PA) in semiconductors
using different energy-band models was investigated by Yee in 1971. He allowed the effective mass to be
anisotropic and included more than one degenerate valence band in his model. The theory of scaling rules
for multiphoton interband absorption assuming an isotropic effective mass and only two parabolic bands
was generalized to N-photon absorption by Wherrett in 1983. He predicted the absorption coefficient to
be inversely proportional to the bandgap energy as $E_g^{4N-5}$ leading to $E_g^{-7}$ for 3PA with $\alpha_3$ given by:

$$
\alpha_3 = K_3 \frac{\sqrt{E_p^3}}{n E_g^7} \left( \frac{(3\hbar \omega / E_g) - 1}{3\hbar \omega / E_g} \right)^{1/2},
$$

where $n$ is the refractive index, $K_3$ is a material independent constant, and $E_p \approx 21$eV is the Kane
momentum parameter. The bandgap and wavelength scaling of three-photon absorption (3PA) is studied
in several semiconductors by the Z-scan technique. The 3PA coefficient is found to vary as $E_g^{-7}$ as
predicted by theory.
For information contact: polszak@creol.ucf.edu, ewvs@creol.ucf.edu
POSTER PRESENTATION ABSTRACTS

Poster - 14

Pressure Effects on Ligand Binding Kinetics in Myoglobin

Silki Arora\textsuperscript{1}, Oleg Galkin\textsuperscript{2}, Alfons Schulte\textsuperscript{1}

\textsuperscript{1}Department of Physics and College of Optics and Photonics, \textsuperscript{2}Department of Chemical Engineering, Univ. of Houston, Houston TX

In heme proteins, pressure in the 200 MPa range causes subtle conformational changes, and it affects the binding kinetics of CO or O\textsubscript{2} to the central iron atom. Flash photolysis experiments performed on myoglobin over wide ranges of time and temperature have shown that ligand binding involves multiple intermediate states. We present kinetic absorption measurements over eight decades in time of CO and O\textsubscript{2} binding to (horse) myoglobin at variable pressure (0.1 - 190 MPa) and temperature (180 - 300 K) in aqueous and 75 \% glycerol/buffer solutions. The data demonstrate that pressure significantly affects the amplitudes (not just the rates) of the component processes. Various numeric approaches to obtain the rate distribution from inversion of the complex kinetics are investigated. The amplitude of the geminate process increases with pressure corresponding to a smaller escape fraction of ligands into the solvent and a smaller inner barrier. This suggests that the ligand pathways are controlled by internal cavities in the protein and by the dynamics of the solvent and the hydration shell.

For information contact: afs@physics.ucf.edu

Poster – 15

Control and Stabilization of Tin-Doped Droplet for Extreme Ultraviolet Lithography

Jose A. Cunado, Kazutoshi Takenoshita, Tobias Schmid, Simi George, Robert Bernath, Christopher Brown, Somsak Teerawattanasook, & Martin Richardson

Extreme Ultraviolet (EUV) sources rely on droplet laser plasmas for EUV generation. These sources consist of a small (30 µm diameter) droplet which is excited into plasma emitting EUV around 13.5 nm, the industry’s chosen wavelength for EUV lithography (EUVL). These sources are the best candidates for the commercialization of EUVL allowing mass production of computer chips at 32 nm nodes and below. However, the biggest challenges which EUV source developers encounter today are the issues of conversion efficiency (CE) and debris. In order to satisfy the technology requirements, the source will need to meet high levels of stability, performance, and lifetime. Our tin-doped droplet plasma has demonstrated high CE and low debris resulting in long lifetime. Long term stability is obtained through the use of novel tracking techniques and active feedback.

The laser plasma targeting system combines optical illumination and imaging, cutting-edge droplet technology, dedicated electronics, and custom software which act in harmony to provide complete stabilization of the droplets. Thus, a stable, debris-free light source combined with suitable collection optics can provide useful EUV radiation power. Detailed description of the targeting system and the evaluation of the system with CE and debris measurements will be presented.

For Information Contact: Jcunado@creol.ucf.edu
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Dr. Michael Bass
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CREOL & FPCE, The College of Optics and Photonics
Faculty Contact Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Phone</th>
<th>E-Mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Michael Bass</td>
<td>CREOL 161</td>
<td>407-823-6977</td>
<td><a href="mailto:bass@creol.ucf.edu">bass@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Glenn D. Boreman</td>
<td>CREOL 136</td>
<td>407-823-6815</td>
<td><a href="mailto:boreman@creol.ucf.edu">boreman@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Demetrios Christodoulides</td>
<td>CREOL 210</td>
<td>407-882-0074</td>
<td><a href="mailto:demetri@creol.ucf.edu">demetri@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Peter J. Delfyett</td>
<td>CREOL 272</td>
<td>407-823-6812</td>
<td><a href="mailto:delfyett@creol.ucf.edu">delfyett@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Aristide Dogariu</td>
<td>CREOL 164</td>
<td>407-823-6839</td>
<td><a href="mailto:adogariu@creol.ucf.edu">adogariu@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Dennis Deppe</td>
<td>CREOL 169</td>
<td>407-823-6850</td>
<td><a href="mailto:ddeppe@creol.ucf.edu">ddeppe@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Leonid B. Glebov</td>
<td>CREOL 285</td>
<td>407-823-6983</td>
<td><a href="mailto:lbglebov@creol.ucf.edu">lbglebov@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. David J. Hagan</td>
<td>CREOL 208</td>
<td>407-823-6817</td>
<td><a href="mailto:hagan@creol.ucf.edu">hagan@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. James E. Harvey</td>
<td>CREOL A113</td>
<td>407-823-6818</td>
<td><a href="mailto:harvey@creol.ucf.edu">harvey@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Aravinda Kar</td>
<td>CREOL 284</td>
<td>407-823-6921</td>
<td><a href="mailto:akar@creol.ucf.edu">akar@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Pieter Kik</td>
<td>CREOL 270</td>
<td>407-823-4622</td>
<td><a href="mailto:kik@creol.ucf.edu">kik@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Stephen Kuebler</td>
<td>Chem 221</td>
<td>407-823-3720</td>
<td><a href="mailto:kuebler@creol.ucf.edu">kuebler@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Guifang Li</td>
<td>CREOL 278</td>
<td>407-823-6811</td>
<td><a href="mailto:li@creol.ucf.edu">li@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Patrick L. LiKamWa</td>
<td>CREOL A211</td>
<td>407-823-6816</td>
<td><a href="mailto:patrick@creol.ucf.edu">patrick@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. M. G. &quot;Jim&quot; Moharam</td>
<td>CREOL 274</td>
<td>407-823-6833</td>
<td><a href="mailto:moharam@creol.ucf.edu">moharam@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Martin C. Richardson</td>
<td>CREOL 126</td>
<td>407-823-6819</td>
<td><a href="mailto:mcr@creol.ucf.edu">mcr@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Nabeel A. Riza</td>
<td>CREOL 290</td>
<td>407-823-6829</td>
<td><a href="mailto:riza@creol.ucf.edu">riza@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Jannick Rolland</td>
<td>CREOL 172</td>
<td>407-823-6870</td>
<td><a href="mailto:jannick@odalab.ucf.edu">jannick@odalab.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Winston Schoenfeld</td>
<td>CREOL A215</td>
<td>407-823-6898</td>
<td><a href="mailto:winston@creol.ucf.edu">winston@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. William Silfvast</td>
<td>CREOL A115</td>
<td>407-823-2066</td>
<td><a href="mailto:silfvast@creol.ucf.edu">silfvast@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. M.J. Soileau</td>
<td>Millican 243</td>
<td>407-823-3558</td>
<td><a href="mailto:mj@creol.ucf.edu">mj@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. George I. Stegeman</td>
<td>CREOL 215</td>
<td>407-823-6915</td>
<td><a href="mailto:george@creol.ucf.edu">george@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Eric W. Van Stryland</td>
<td>CREOL 206</td>
<td>407-823-6835</td>
<td><a href="mailto:director@creol.ucf.edu">director@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Shin-Tson Wu</td>
<td>CREOL 280</td>
<td>407-823-4763</td>
<td><a href="mailto:swu@creol.ucf.edu">swu@creol.ucf.edu</a></td>
</tr>
<tr>
<td>Dr. Boris Y. Zeldovich</td>
<td>CREOL 234</td>
<td>407-823-6831</td>
<td><a href="mailto:boris@creol.ucf.edu">boris@creol.ucf.edu</a></td>
</tr>
</tbody>
</table>

FACULTY JOINT & COURTESY APPOINTMENTS
COLLEGE OF OPTICS & PHOTONICS

26. Dr. Larry C. Andrews 125 Math & Physics 407-823-2418 landrews@mail.ucf.edu
27. Dr. Kevin D. Belfield 222 Chemistry Bldg 407-823-1028 kbelfiel@mail.ucf.edu
28. Dr. Kurt Busch Karlsruhe University 49-721-608-6054 kurt@tfp.uni-karlsruhe.de
29. Dr. Bruce Chai Crystal Photonics 407-328-9111 Chai@crystal photonics.com
30. Dr. Louis Chow 219 Engineering Bldg 407-823-3666 lchow@mail.ucf.edu
31. Dr. Alfred Ducharme 118 Engineering Bldg 407-823-0070 ducharme@mail.ucf.edu
32. Dr. Florencio Eloy Hernandez 224 Chemistry Bldg 407-823-0843 florenzi@mail.ucf.edu
33. Dr. Hans Jenssen AC Materials 727-937-4135 h.jenssen@ac-materials.com
34. Dr. David Kaup 202C Math & Physics 407-823-2795 kaup@ucf.edu
35. Dr. Michael Leuenberg 12424 Research Pkwy 407-882-2846 mleuenbe@mail.ucf.edu
36. Dr. Robert E. Peale 404 Math & Physics 407-823-5208 rep@physics.ucf.edu
37. Dr. Ronald L. Phillips Florida Space Inst. 321-452-3091 philips@mail.ucf.edu
38. Dr. Kathleen Richardson Clemson University 864-656-0549 richard3@clemson.edu
39. Dr. Alfonso Schulte 427 Math & Physics 407-823-5196 afs@physics.ucf.edu
40. Dr. Mubarak A. Shah 238 Computer Science 407-823-5077 shah@cs.ucf.edu
41. Dr. Arthur Weeks 453 Engineering 407-275-3220 weeks@mail.ucf.edu
42. Dr. Emil Wolf CREOL 101 585-275-4397 ewlupus@pas.rochester.edu

ADDITIONAL CONTACTS -- COLLEGE OF OPTICS & PHOTONICS

Dr. James Pearson CREOL 207 407-823-6858 jpearson@creol.ucf.edu
Mr. Mark Wagenhauser CREOL 109 407-823-6878 markw@creol.ucf.edu
Mr. Courtney Lewis CREOL 209 407-823-6986 clemwis@creol.ucf.edu
Ms. Diana Randall CREOL 205 407-823-6834 drandall@creol.ucf.edu
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