School of Optics/CREOL

Industrial Affiliates' Day 2001

"Focus on PHOTONICS"

April 6, 2001

UCF School of Optics/CREOL Industrial Affiliates' Day 2001

"Focus on Photonics"

Friday, April 6, 2001
University of Central Florida, Orlando

PROGRAM

Morning Session – UCF Student Union, Cape Florida Ballroom 316CD

8:00 a.m.	Continental Breakfast & Walk-in Registration
8:30	Welcome -- **John Hitt**, UCF President **M. J. Soileau**, UCF Vice President for Research Speech: *"Florida's Push Towards a Knowledge-Based Economy"* **Eric Van Stryland**, School of Optics/CREOL Interim Director
9:00	**Richart Slusher**, Lucent Technologies, Bell Laboratories Speech: *"Quantum and Nonlinear Limits for Optical Communications: They're closer than you think!"*
9:45	**Arpad Bergh**, Optoelectronics Industry Development Association (OIDA) Speech Topic: The Optics and Photonics Industry
10:30	Refreshment Break
11:00	**Milton Chang**, New Focus, Inc. Speech Topic: Entrepreneurship in Optics and Photonics
11:45	**David Honey**, Defense Advanced Research Projects Agency (DARPA) Speech Topic: Future Directions in Photonics
12:30	Adjournment of morning session.

Afternoon Session -- CREOL Building

12:45 p.m.	Lunch Served CREOL Lobby
1:45	Awards and Honors Overview of CREOL Research Activities **Eric Van Stryland**, Interim Director, School of Optics/CREOL
2:15	Graduate Student Presentations of Current Research: "High Quality Optical Sampling Streams from a Semiconductor Diode Ring Laser" **Christopher Depriest** "Self-Pulsating DBF Lasers for Broadband Wireless Networks" **Mohammed Al-Mumin** "Low-Coherence Dynamic Light Scattering for Particulate Systems Investigation" **Gabriel Popescu** "Side-Polished Fibers for Integrated Micro-Optics Applications" **Laurent Vaissie** "Transmission and Enhanced Absorption of Frequency Selective Surfaces in the Infrared" **Irina Puscasu**
3:05-5:00	Poster Papers, Demonstrations and LabVisits
5:00-7:00	CREOL Reception *(Drinks and Hor d'Oeuvres)*

School of Optics/CREOL

Industrial Affiliates Day

April 6, 2001

Technology Demonstrations

	Room	Lab Director	Demonstrator	Demo Times
• **Volume Holography**	128	Leon Glebov	Oleg Efimov	3:25 and 3:50
• **Optical Coherence Microscopy**	153	Jannick Rolland	Avni Ackay	3:25 and 4:00 and 4:30
• **Dispersed Crystallites Up Conversion Display**	157	Michael Bass	Janet Miliez	3:25 and 4:00 and 4:30
• **Real-time Optical Motion Capture and Video Streaming**	146	Jannick Rolland	Larry Davis	3:25 and 4:00 and 4:30
• **White Light Continuum Spectroscopy**	227	Eric Van Stryland	Joel Hales	3:25 and 4:00 and 4:30
• **Hybrid OTDM-WDM Technologies for Gigabit Ethernet Applications**	254	Peter Delfyett	Michael Mielke	3:25 and 4:00 and 4:30
• **Optical Limiter in Action**	236	David Hagan	William Shenky	4:15 and 4:45

School of Optics/CREOL

Industrial Affiliates' Day 2001

Sponsored By

Analog Modules, Inc.

Applied Photonics, Inc.

Control Laser Corporation

Cubic Defense Systems, Inc.

Digital Lightwave, Inc.

E R Precision Optical Corp.

Electro Scientific Industries, Inc. (ESI)

Economic Development Commission of Mid-Florida

Florida Electro-Optics Industry Association

Melles Griot, Inc.

Noah Industries, Inc.

Optical Research Associates

OptXCon, Inc.

Photonics Spectra

Zygo Corporation

Zygo TeraAutomation

UCF School of Optics/CREOL

Industrial Affiliate Members

Memorium Member: Dr. William Schwartz

Life Member: Cobb Family Foundation

Medallion Members

Applied Photonics, Inc.
Coherent Inc., Auburn Division
Northrop Grumman Laser Systems
Schott Glass Technologies, Inc.
Paul G. Suchoski, Jr.

Senior Members

Corning Rochester Photonics
Lee Laser, Inc.
Melles Griot, Inc.
Molecular Opto-Electronics (MOEC)
Physical Sciences, Inc.
Vistakon, a Division of Johnson and Johnson Vision Care
Zygo Corporation

Affiliate Members

A C Materials
Advanced Laser and Fusion Technology, Inc
AppliCote Associates
The Boeing Company
Breault Research Organization, Inc.
Cubic Defense Systems, Inc.
DRS Optronics Inc.
Charles Gramm
Laser Science, Inc.
Lawrence Livermore National Laboratory
Microvision, Inc.
Nortel Networks
Optical Research Associates
Optium Corp.
Qusion Technologies, Inc.
Schwartz Electro-Optics, Inc.
Sinclair Optics
Solution Technology, Inc. / Rodel
SurgiLight, Inc.

School of Optics/CREOL
RESEARCH LABORATORIES
2001-2002

Dr. Bass
Solid State Lasers
- Laser Spectroscopy – 157
- Thermal Management – 158

Dr. Boreman
- Infrared Systems - 130

Dr. Delfyett
- Ultrafast Optoelectronic Devices and Networks - 252

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

Dr. Elias
- Free-Electron Laser - 180

Dr. Glebov
- Photo-Thermal Refractive Glass and Volume Holography – 128
- Grinding and Polishing Glass - 152

Drs. Hagan and Van Stryland
Nonlinear Materials Characterization Facilities:
- Femtosecond Lasers – 227
- Nanosecond YAG's – 236
- Picosecond YAG's 233 – 230
- Single Mode Nanosecond CO2 and Picosecond CO2 – 247
- Confocal Microscope with Verde Laser – 246

Dr. Harvey
- X-Ray Telescopes – still being built
- Optical Surface Scattering - 155

Dr. Jenssen
- 4μ Laser Development – 156A
- Crystal Growth – MAP 153

Dr. Johnson
- Diffractive Optics – 151

Dr. Kar
- Laser Processing Materials –

Dr. G. Li
- Optical Fiber Communications – 246A
- Semiconductor Laser Fabrication and Processing -

Dr. Li Kam Wa
- Quantum Well Optoelectronics – 223

Dr. Moharam
- Diffractive Optics Theory - 258

Dr. K. Richardson
- Glass Processing and Characterization – 255A
- ZYGO White Light Interferometer, - 177
- X-Ray Defraction and Glass Polishing - 177

Dr. M. Richardson
Laser Plasma Lab
- X-Ray Microscopy Facility – 140, 143
- Laser Development Lab – 141A

Dr. Riza
- Photonic Information Processing Systems – 180E

Dr. Rolland
Optical Diagnostics and Applications Laboratory - ODALAB
- Texture Imaging – 153
- Augmented Reality and Virtual Reality - 146

Dr. Siders
- Ultrafast Structural Dynamics of Matter - 115

Dr. Silfvast
- Extreme Ultraviolet Source Lab - 123
- Vacuum Ultraviolet Source Lab - 125

Dr. Stegeman
Nonlinear Guided-Wave Optics
- OPG/OPA – 201
- Femtosecond - 202

Drs. Van Stryland and Hagan
- See Drs. Hagan and Van Stryland

Dr. Zeldovich
- Optical Beam Combination, Quantum Optics - 249

Summary of

Student Presentations

High-Quality Optical Sampling Streams from a Semiconductor Diode Ring Laser

Chris DePriest

Over the last several decades, the steady increase in sampling speed that has been achieved with purely electronic analog-to-digital conversion systems (ADCs) has come with a price: the simultaneous reduction in digital resolution. As an example, current state-of-the-art systems operating at multigigahertz sampling rates are capable of resolving only ~4 bits at room temperature and ~6 bits when superconducting. These high-frequency restrictions stem primarily from the response time of the constituent transistors that make up the ADC's comparators (an effect known as comparator ambiguity). The finite amount of time needed to "sample-and-hold" while the analog comparators determine the signal's bit value gives rise to a drastic reduction in effective resolution at high sampling frequencies. In an effort to circumvent these restrictions, investigations regarding the capabilities of hybrid optoelectronic ADC systems are currently underway. Well-behaved optical pulses can perform the "sample-and-hold" duties required by ADCs much more adeptly than conventional comparators. Applying the signal to be digitized to a high-bandwidth optical intensity modulator (through which the optical pulsetrain is traveling) provides a purely optical means for sampling a time-varying analog voltage. In such a system, ADC conversion accuracy is no longer limited by comparator ambiguity, but rather by the optical pulsewidth and the pulsetrain noise (associated with phase and amplitude modulation). Motivated by these factors, current research efforts are focused on the use of an actively-modelocked external-cavity semiconductor diode laser for the production of ultrahigh-quality sampling pulsetrains. Recent measurements of pulsetrain noise on our 10 GHz ring laser show the best results to date for an actively-modelocked system. Carrier offset frequency integration bands extending from 10 Hz to 10 MHz exhibit RMS levels of amplitude and residual phase noise as low as 0.12% and 43 fs, respectively. In addition, the presence of highly-organized linear chirp in the modelocked pulsetrain allows the use of a standard dual-grating dispersion compensation technique to achieve pulsewidths as short as 1.2 ps. Based on these (initial) numbers, a theoretical resolution of ~8.6 bits is achievable.

Self-Pulsating DBF Lasers for Broadband Wireless Networks

Mohammed Al-Mumin

Abstract: Two-section Self-Pulsating Lasers capable of generating millimeter-wave signals are proposed for broadband wireless access networks. The RF linewidth is reduced using optical injection locking techniques. The phase noise measurements of a harmonic and sub-harmonic injection locked selfpulsations at 40 GHz are compared, and a link experiment is demonstrated at 40 GHz and 60 GHz. Finally a network architecture based on shared self-pulsating DFB lasers is proposed. The network increases the dedicated bandwidth of each base station, maximizes the mm-carrier and fiber sharing, reduces the number of active devices at the base and the mobile unit and expands the role of photonics in the network design.

Figure 1. A schematic of the proposed WDM/selfpulsation fiber backbone for wireless networks

Figure 2. Left - Multiplexing of the two self-pulsations, right - The filtered output at the receiver.

Low-coherence dynamic light scattering

Gabriel Popescu and Aristide Dogariu

Dynamic light scattering has been established as a powerful technique for investigating dynamic processes in inhomogeneous media such as suspensions of small particles or glassy systems. An important breakthrough in the field of dynamic light scattering is represented by the extension of dynamic light scattering to strongly scattering media. In the present paper, we explore the potential of the dynamic scattering with low-coherence light to investigate the local dynamic properties of media over a broad range of optical densities. At the end of a single-mode fiber immersed in the medium under investigation, the backscattered field has two components: the static, specular light reflected at the fiber medium/interface and the dynamic, scattered component from the medium. The two components are collected through the same optical fiber at the detector, where the interference is detected. The coherence length (l_c~30 μm) and the transversal dimension of the fiber core define a coherence volume (CV) where the optical fields preserve relative phase correlations. Thus, for scattering media with mean free paths longer than l_c, the backscattered light undergoes in average only one scattering event in the coherence volume, which is defined approximately by the coherence length and the area of the fiber core. Consequently, the auto-correlation function is independent of the length of the scattering trajectory and is given by the well-established formula for the quasi-elastic light scattering. Therefore, the applicability of this technique extends over a broad range of particle number density. Our measurements are performed in the frequency domain, using a spectrum analyzer.

Fig. 1 Experimental setup. SLD- super-luminiscent diode, FC- fiber coupler, PD- photodetector, SA- spectrum analyzer, E_0, E_s, specular and scattered fields, respectively.

Side-polished fibers for integrated micro-optics applications

Microphotonics Fabrication and Integration Laboratory

CREOL/School of Optics
UCF

Laurent Vaissié

Integrated micro-optical devices are of great interest for optical communications and other applications requiring small features elements to take advantage of light versatility. It is especially interesting for tomorrow's all fibers communication networks to investigate hybrid integration of in-line optical fibers devices or silicon-based elements that can be reproduced and easily integrated.

An attractive technique to combine fiber optics and micro-optical elements is to use side-polished fibers (SPFs). Polishing of the fiber cladding enables to access the light guided in the fiber core through evanescent coupling and provides a flat surface where elements such as gratings or planar waveguides can be added more. Several very low insertion loss devices using this concept have been successfully implemented for key-devices such as intensity modulators, polarizers, filters, wavelength division multiplexing elements.

At the *Microphotonics Fabrication and Integration Laboratory (MFIL Lab),* we investigated some potential applications of side-polished fibers and the integration of fiber arrays on silicon v-groves for parallel processing. A task-designed mask is used for anisotropic etching of curved Si v-groves. Fibers are mounted on silicon arrays with epoxy and are evenly polished within +-1 micron accuracy. The flat side of fibers is then used for different purposes. We demonstrate bandwidth enhancement of a gradient index multimode fiber using coupling between two SPFs. We also present the concepts of new devices to be used as in-line WDM elements, amplifiers, and possible scalability to 2D wavelength demultiplexer.

Theoretical and Experimental Analysis of Transmission and Enhanced Absorption of Frequency Selective Surfaces in the Infrared

Irina Puscasu, and Dr. Glenn D. Boreman

Infrared Systems Group

School of Optics/ CREOL, University of Central Florida, Orlando, Fl

A periodic array consisting of conducting patch or aperture elements is known as a frequency selective surface (FSS). Similar to the frequency filters in traditional radio frequency circuits, the FSS may have low-pass or high-pass spectral behavior, depending upon the array element type (i.e., patch or aperture). FSSs are used for the microwave region in radome design, as mirrors for improving the pumping efficiency in optically pumped IR lasers. FSSs have also been used in the far-infrared region as beam splitters, filters, polarizers, output couplers for lasers and Fabry-Perot interferometers.

A comparative study between theory and experiment is presented for transmission through lossy frequency selective surfaces (FSSs) on silicon in the 2-15 μm range. Important parameters controlling the resonance shape and location are identified: dipole length, spacing, impedance, and dielectric surroundings. The primary resonance mechanism of FSSs is the resonance of the individual metallic patches. The real part of the element's impedance controls the minimum value of transmission, while scarcely affecting the location of the minimum. Varying the imaginary part shifts the location of resonance, while only slightly changing the minimum value of transmission. With such fine-tuning, it is possible to make a good fit between theory and experiment near the dipole resonance on any sample. A fixed choice of impedance can provide a reasonable fit to all samples fabricated under the same conditions. The presence of the dielectric surroundings shifts the resonance wavelength of the FSS compared to its value in air.

The presence of FSS at the surface of a substrate increases the absorptivity/emissivity of the surface in a resonant way. Such enhancements are shown for dipole and cross arrays at several wavelengths.

ABSTRACTS OF

POSTER PRESENTATIONS

ABSTRACT NUMBER	TITLE OF ABSTRACT	AUTHORS
1	Stereoscopic Rendered Images and Video Streaming	Ami Sun, Ben Del Vento, Larry Davis, Wonggang Ha, and Jannick Rolland
2	Fiber Optics Interferometer for Biomedical Imaging	Avni Ackay, Haocheng Zheng, and Jannick Rolland
3	Aberrations of Diffracted Wave Fields	Dijana Bogunovic and James E. Harvey
4	Optical Pathlengths in Dental Caries Lesions	Claudia Mujat and Aristide Dogariu
5	Photonic Information Processing Systems (PIPS) Laboratory	Zahid Yaqoob, James Chung, Sajjad Khan and Nabeel Riza
6	Real-Time Measurement of Polarization Characteristics for Spheres and Fibers	Mircea Mujat and Aristide Dogariu
7	4 μm Laser Based on Ho-Doped Fluorides	Hans P. Jenssen
8	Integrated Electro-Optic Mach-Zehnder Switches Realized by Zinc In-Diffusion	D.A. May-Arrioja, Cheolhwan Kim, and Patrick LiKamWa
9	Recent Advances in Optical Sensor Protection Systems	W. Shensky III, F. E. Hernández, V. Dubikovskiy, E. W. Van Stryland and D. J. Hagan
10	PM Noise Characterization of an Actively Modelocked External Semiconductor Ring Laser at 10GHz for ADC Applications	Tolga Yilmaz, Christopher M. DePriest, and Peter J. Delfyett
11	Fabrication of Continuous Relief Micro-Optics	Jin Wong Sung, Waleed Mohammed and Eric G. Johnson
12	GOES/SXI Team Adopts CREOL X-ray Telescope Design	Martina Atanassova and James E. Harvey
13	Optical Mems Large Deflection Micro Torsion Mirrors on Silicon	Mahesh Pitchumani and Eric G. Johnson
14	Two-Photon Fluorescence: A Nonlinear Spectroscopic Technique	Joel Hales, David J. Hagan, Kevin D. Belfield and Eric W. Van Stryland
15	SIMS and TEM on Insulators for Optical and Semiconductor Applications	Hugues Francois-Saint-Cyr, Kitty Elshot, Vadim Smirnov, Trevor Meyer and Kathleen Richardson
16	Laser Resonator Design Using Optical Ray Tracing Software: Comparisons with Simple Analytical Models and Experimental Results	Alexandra Rapaport and Michael Bass
17	Spray Cooling High Power Diode laser Arrays	Te-yuan Chung and Michael Bass
18	Sub-50 fs Cavity-Dumped Ti:Sapphire Laser for Use in Micro-machining	Lawrence Shah, Arnaud Zoubir, and Martin Richardson
19	Piezo Controlled Intracavity Wavelength Selector for the Far-Infrared p-Ge Laser	E.W. Nelson, A V. Muravjov, S.G. Pavlov, V.N. Shastin, and R.E. Peale

Stereoscopic Rendered Images and Video Streaming

Ami Sun, Ben Del Vento, Larry Davis, Wonggang Ha, and Jannick Rolland

Visualizations of anatomical joint motions are created with the use of optical motion tracking , computer generated real-time 3D graphics, and custom-designed optical technology. The animations of anatomical joint motions are created as stereoscopic images developed for the right and left eyes which, when placed together and viewed in a head mounted display or stereoscopic device, render a 3D view of the anatomical joint being examined.

These stereoscopic video streams are captured and encoded using compression methods such as MPEG-2, and are then broadcast as full motion images over Internet2 high performance networks to various remote collaborative environments. There, the images are received and decoded for visualization as 3D video in near real time. By developing the virtual environments of the future, our goal is to enhance the teaching and training of medical students, and possibly assist in guided surgery.

Fiber Optics Interferometer for Biomedical Imaging

Avni Ackay, Haocheng Zheng, and Jannick Rolland

The experimental structure and basics of an optical coherence microscopy (OCM) system are described for 3D imaging of biomedical samples, including highly scattering media. Optical coherence tomography is a novel biomedical imaging technique based on optical low-coherence interferometry, which allows for non-invasive cross-sectional imaging in scattering media with high spatial resolution (i.e. 6 um, 8 um) and high dynamic range (i.e. 80dB, 95 dB). The implementation of a fiber optic low-coherence interferometer conducted under this research will be described. The setup is operated by a superluminescent diode at center wavelength of 950 nm with 67 nm bandwidth. Heterodyne detection is applied to minimize noise and most importantly maximize signal to noise ratio. Measured interferometric data from a transparent structure, lard, onion, and a human finger are presented.

Aberrations of Diffracted Wave Fields

by

Dijana Bogunovic and James E. Harvey

ABSTRACT

The Rayleigh-Sommerfeld diffraction integral can be written in the form of a Fourier transform integral of a generalized pupil function that contains phase variations, which can be identified with wave aberrations. Fraunhofer diffraction is thus aberration-free, as it is precisely the reference from which our aberrations are defined, and Fresnel can be described as a defocused Fraunhofer diffraction pattern. These aberrations, which are inherent to the diffraction process, provide new insight and understanding to a variety of diffraction phenomena. For example, a precise distance to the "far field" can be based upon a tolerance upon the allowable amount defocus for a particular application. In addition, we will show that the presence of field curvature and distortion are an artifact of the geometrical configuration chosen for observing and analyzing diffraction patterns. If the grating equation is expressed in terms of the *direction cosines* of the incident beam and the resulting diffracted orders, field curvature and distortion vanishes and (for narrow beams) the diffraction pattern becomes shift-invariant with respect to incident angle. The use of a simple direction cosine diagram thus provides insight and understanding concerning the diffraction grating behavior for non-paraxial obliquely incident beams. For converging beams with a small focal ratio (such as in many grating spectrographs) coma and astigmatism are frequently present. Their behavior can be studied and controlled by understanding that they are not caused by some "flaw" in the grating; but rather, the field and pupil dependence of the spectrograph configuration.

Optical pathlengths in dental caries lesions

Claudia Mujat and Aristide Dogariu

The average pathlength of light inside dental enamel and incipient (i.e. white spot) lesions is measured and compared, in order to quantitatively confirm the prediction that incipient lesions have higher scattering coefficients that sound enamel. The technique used, called optical pathlength spectroscopy (OPS), provides experimental access to the pathlength distribution of light inside highly scattering samples. This is desirable for complex biological materials, where current theoretical models are very difficult to apply. To minimize the effects of surface reflections the average pathlength is measured in wet sound enamel and white spots. We obtain values of *367μm* and *272μm* average pathlength for sound enamel and white spots respectively. We also investigate the differences in between open and subsurface lesions, by measuring the change in the pathlength distribution of light as they go from dry to wet.

Experimental set-up and raw data example: LCS - low coherence source, RM - reference mirror, BS - beam splitter and D - detector

The quantification of light paths may potentially be used for monitoring incipient lesions in vivo to determine, for instance, the effect of improved oral hygiene.

Photonic Information Processing Systems (PIPS) Laboratory

Prof. Nabeel A. Riza

Sponsors: ARO, OIDA, DARPA

Students: Zahid Yaqoob, James Chung, Sajjad Khan

The Photonic Information Processing Systems (PIPS) Laboratory at the School of Optics/CREOL is involved in exploring the principles of optics and information processing to solve important problems in system science relevant to academia, government, and industry.

Today, the rapid maturity of microelectromechanical system (MEMS) fabrication techniques and devices has opened up many new possibilities for MEMS-based optical systems such as optical disk pickup heads, femtosecond autocorrelators, spatial light modulators, optical scanners, and fiber-optic switches. The advantages of micromachined-based optical switches include polarization independence, high isolation, compactness, and low power consumption. In addition, MEMS technology presently promises to be the featured choice for a space-based environment compared to other switch technologies. We have demonstrated a MEMS based 2×2 fiber optic switch. These switches can be cascaded in a Banyan network to form an $N \times N$ optical switch. The group has proposed practical approaches to realize an add-drop switch, which is a key component to enhance the versatility of the current wavelength division multiplexed (WDM) technology for high data rate optical communications.

The group is actively engaged in applied research using liquid crystal (LC) devices such as FLCs, NLCs, and PDLCs. The motivation at present for going to NLC technology has to do with the great success of NLC displays, where high performance arrays have been built and fabricated on a large scale. This maturity of LC technology lends itself to low fabrication costs and well-understood fabrication procedures that can lead to high performance devices in terms of high optical isolation (> 1000:1) and low optical loss (e.g., < 1 dB) for phased array application. Efficient architectures for LC-based optical attenuators, photonic delay lines, and polarization independent optical switches have been proposed.

Applications using laser beams such as for infrared countermeasures, target designation, and laser communications presently require substantial improvements in laser beam steering technology. Specifically, there is a need to realize small, low power consumption, lightweight, low cost, rapidly (e.g., a few microseconds or less) reconfigured laser beam scanners for steering, pointing, and tracking. Other useful features of these scanners include the ability to generate multiple simultaneous laser beams in space, eye safe operation, wide scan angles (e.g., $\pm 45^{\circ}$), low sidelobes (e.g., < -30 dB), large apertures (e.g., 10 cm diameter) to provide high resolution scans, and true rapid three dimensional (3-D) beamforming to accurately control beam position, power and shape.

We propose such a scanner by using large area phase sensitive plates having a high storage capacity addressed by high speed no-moving parts electronically controlled multiplexing optics to form a large aperture high speed scanner. Multiplexed Optical Scanner Technology called MOST has four key high space bandwidth product multiplexing schemes; namely, polarization (P-MOS), time (T-MOS), wavelength (W-MOS), and code (C-MOS).

Real-time measurement of polarization characteristics for spheres and fibers

Mircea Mujat and Aristide Dogariu
School of Optics/CREOL, University of Central Florida, Orlando, Florida

In material sciences and biomedical applications, a laser beam propagating through particulate systems or biological tissues is depolarized due to multiple scattering. The transfer function of the state of polarization is given by the Mueller matrix associated to that system. An electronically-agile technique was developed for measuring in real time the Stokes vectors of light incident on and emerging from a scattering medium. Subsequently, the Mueller matrix associated with the medium is determined. We focus our attention on forward scattering from systems with various optical densities, consisting of spherical silica particles, polyhedral alumina particles, as well as random or partially oriented synthetic fibers. We discuss the effects of: the shape of individual scattering centers, collective scattering, and the optical density of the scattering medium.

Starting from the measured Mueller matrix, the degree of polarization of the scattered light can be calculated for any input state of polarization, and in particular for linear (PL) and circular (PC) input. The ratio R = PL/PC can be used as an indicator of size for spherical particles, but this does not hold for either random or partially oriented nonspherical particles.

This study is intended for real-time, in line monitoring and characterization of particulate systems, as well as particle shape identification.

4 μm Laser based on Ho-doped Fluorides

Advanced Solid State Laser Materials Group

Hans P. Jenssen, Principal Investigator

Laser sources in the 3-5 μm range are of interest for a variety of applications from infrared countermeasures and eyesafe lidar, to remote sensing and environmental agent detection. Nonlinear frequency conversion and semiconductor lasers can access this spectral region, but often cannot satisfy constraints on beam quality, average power, or reliable and rugged packaging. As an alternative, we are developing a room-temperature, all-solid-state source lasing directly at 4 μm. This is the most practical way to produce high energy in the mid-infrared while minimizing overall system complexity.

Our approach makes use of a $Ho:BaY_2F_8$ (Ho:BYF) crystal resonantly pumped by a Cr:LiSAF laser. Fig. 1 shows the absorption spectrum of Ho:BYF and the energy levels of the Ho^{3+} ion. The Cr:LiSAF laser pumps the $^5I_5$ upper laser level directly, and lasing occurs on the $^5I_5$—$^5I_6$ transition. The lifetime of the upper laser level is much shorter than that of the lower level (50 μs vs. 5 ms), requiring: 1) a pump pulse-width comparable to 50 μs for efficient lasing, and 2) an upper limit on repetition rate to allow for emptying of the lower laser level. The host crystal BYF was chosen to maximize the upper level lifetime, since phonon energies in this material are low, keeping nonradiative relaxation at a minimum.

Fig. 1. *Ho:BYF absorption, and energy levels.*

In our initial laser experiments, using crystals doped with 10% and 20% Ho, we have obtained over 30 mJ at 3.9 μm, and a slope efficiency of 14% with repetition rates up to 10 Hz. Laser threshold was relatively low, but the HR mirrors coated onto the input face of the Ho:BYF crystals suffered frequent damage. To mitigate damage and to enable scaling to higher output energies the resonator has been redesigned to employ a brewster-cut laser crystal, and to position the pump waist well away from coated surfaces.

Now that the basic concept has been validated, work is focused on determining the optimal Ho concentration and crystal orientation for the laser. BYF is a complex crystal, with three independent polarization directions, and absorption and emission which are both strongly anisotropic. We know absorption is strongest when the pump radiation is polarized along the crystal's (001) direction. Previous experience with BYF suggests the strongest emission will be polarized along the b-axis or (001) direction, but this remains to be seen. Characterizing emission may be complicated by the presence of magnetic dipole radiation on the laser transition. Both spectroscopic measurements and laser experiments will be needed to understand the preferred emission direction in this crystal.

Fig. 2. *Ho:BYF boule grown recently at AC Materials*

This research is conducted in collaboration with, and with support from AC Materials in Winter Park, FL under an SBIR contract with the Air Force Research Laboratory. AC Materials is developing the crystal growth of both Ho:BYF and Cr:LiSAF, which will be critical to the success of the 4 μm laser since power scaling will require larger, high-quality crystals of both materials.

INTEGRATED ELECTRO-OPTIC MACH-ZEHNDER SWITCHES

REALIZED BY ZINC IN-DIFFUSION

D.A. May-Arrioja, Cheolhwan Kim, Patrick LiKamWa

School of Optics/CREOL
University of Central Florida
Orlando, FL 32816-2700

Monolithic integration is crucial for the development of optoelectronic integrated circuits[1] that possess higher functionality than discrete devices. One of the main requirements in any integrated circuit is the ability to address different parts of chip either electrically or optically. For electro-optic devices, these different areas need to be electrically isolated from one another. One approach that is routinely used in the semiconductor industry is the proton implantation, which very effectively produces high resistivity material for the electrical isolation. However, the process also leads to defects that are harmful to the performance of active optoelectronic devices. In this work, we report the use of selective zinc in-diffusion[2] in n-type semiconductors as a viable method of creating isolated islands of p-n junctions. We used this process to fabricate a symmetric integrated Mach-Zehnder switch in which only one arm is subjected to an applied electric field for electro-optic modulation.

The slab waveguide structure that was grown by molecular beam epitaxy on an undoped substrate was doped n-type and consisted of a multiple quantum well (MQW) core bounded on the top by a 0.5μm thick $Al_{0.3}Ga_{0.7}As$ cladding layer and on the bottom by a 2.5μm thick $Al_{0.3}Ga_{0.7}As$ lower cladding layer. The MQW core contained 38 alternating GaAs quantum wells each 8nm thick and $Al_{0.3}Ga_{0.7}As$ barriers each also 8nm wide. The whole structure was capped by a 50nm thick n-doped GaAs layer. Zinc was diffused into the sample from the vapor source by placing the sample and elemental zinc together inside a semi-sealed graphite box and annealing it inside a tube furnace with flowing high purity nitrogen gas. Figure 1 shows the distribution profile of the in-diffused zinc after the sample has been subjected to a 60 minute diffusion at a temperature of 475°C. It is observed that the zinc concentration exceeds 10^{18} cm^{-3} throughout the top 550nm and then abruptly drops down to the background level of the measuring instrument. Since the initial doping level was 10^{17} cm^{-3}, a p-n junction is formed just before the MQW region is reached.

Fig. 1. Zinc concentration profile measured by dynamic secondary ions mass spectroscopy.

Using this process zinc was then diffused into a silicon nitride coated sample through 100μmx500μm windows that were opened by photolithography and reactive ion etching. A symmetric integrated Mach-Zehnder interferometer was fabricated by photolithography and wet chemical etching such that only one arm of the interferometer overlapped with the zinc diffused region. Ni/Au/Zn/Au contact pads were deposited by vacuum evaporation and "lift-off" on the

surface of the p-doped regions only. Several Ni/Ge/Au contacts pads were also deposited by evaporation and "lift-off" on non-diffused areas of the sample. The pads were electrically addressed using micro-probe tips. Figure 2 shows a typical I-V response of the p-n junction that has a breakdown voltage of ~12V.

The device was cleaved to an overall length of 2.5mm and was tested using an end-fire coupling set-up. A cw Ti:sapphire laser operating at 880nm was used as the source of the optical signal. The beam was mechanically chopped before it was launched into the device and the output beam was monitored both on a CCD camera and a photodetector simultaneously. The photodetector was in turn connected to a lock-in amplifier. The transmitted signal was recorded as function of the applied voltage and the response of the modulator is shown in figure 3. In this non-optimized device, a ~10dB contrast ratio was observed with 5V applied bias.

A dual output Mach-Zehnder interferometer was fabricated using a 3db coupler at the output, and zinc was diffused in both arms. The device exhibited a 30 dB contrast ratio with about 4.5V bias.

We are currently working with InGaAs/InP MQW structures to operate the device at 1.55 μm. InP based materials are quite different compared with GaAs based materials, and processes as wet chemical and Zn in-diffusion behave in a very different way.

Fig. 2. I-V response of p-n junction formed by the zinc diffusion

Fig. 3. Response of the integrated Mach-Zehnder modulator.

Acknowledgements:

The AlGaAs MQW wafers were grown by Dr. Jagadeesh Pamulapati at the US Army Research Laboratory, Adelphi, Maryland.

The work using InGaAs/InP MQW wafers is sponsored by a research grant from Technology Capital Funding Group/Qusion Technologies, Princeton, New Jersey and the I4-High Tech. Council, Orlando, Florida

References:

1. O. Wada, A. Furuya, M. Makiuchi, IEEE Photon. Technol. Lett., 1(1), pp. 16-18, 1989.
2. N.H. Ky, J.D. Ganiere, M. Gailhanou, B. Blanchard, L. Pavesi, G. Burri, D. Araujo, F.K. Reinhart, J. Appl. Phys., 73(8), pp3769-81, 1993.

Recent advances in optical sensor protection systems

W. Shensky III, F. E. Hernández, V. Dubikovskiy,
E. W. Van Stryland[†] and D. J. Hagan[†].
School of Optics -CREOL, University of Central Florida, Orlando, Florida 32816-2700.
[†] Also with the department of Physics and the School of Electrical Engineering and Computer Science.
Tel: 407-823-6800, Fax: 407-823-6880, will@mail.creol.ucf.edu.

Abstract

Recently, we reported the highest dynamic range (DR > 30000) optical sensor protection system using an f/5, cascaded-focus optical geometry, nanosecond pulses, and working at a wavelength of 532 nm. The device composed of a nonlinear element in each of the two foci, limits the total output encircled energy below 1 μJ for inputs up to 62 mJ without damaging. The strong scattering due to laser breakdown and bubble generation in a 2 cm thick cell containing pure carbon disulfide (CS_2), which is placed at the first focus, protect a second 100 μm thick cell with a reverse saturable absorber solution ($PbPc/CHCl_3$) positioned at the second focal plane.

Now we present our most recent advance in this field. We found that replacing the reverse saturable absorber solution with a carbon-black suspension (CBS) in CS_2 we can make this sensor protection device wavelength independent, preserving the total output encircled energy below 1 μJ and the high dynamic range (DR > 20000). Carbon black was chosen because of its broadband absorption spectra and excellent power limiting behavior. Using AR coatings and a 5 mm CBS cell, the low irradiance transmittance for the whole system was 28 %. Until this moment we have done experiment working at 532 nm. Further experiments at different wavelengths within the visible spectrum are in progress.

We also present a windows-based numerical code that is used to model the propagation of the laser beam through the device, in both the linear and nonlinear regimes.

PM Noise Characterization of an Actively Modelocked External Semiconductor Ring Laser at 10GHz for ADC Applications

Tolga Yilmaz, Christopher M. DePriest, Peter J. Delfyett

Low timing jitter of optical pulses is one of the important parameters for applications such as analog-to-digital-converters (ADCs) and optical time division multiplexing (OTDM) systems. The way to avoid the limited resolution of electronic ADCs is to employ optical sampling. In optical ADCs the accuracy is determined by the phase modulation (PM) noise and amplitude modulation (AM) noise in the sampling pulses. In OTDM systems, the requirement for low timing jitter becomes more severe with increasing data capacity as the time slot of the receiver becomes shorter. These applications also make the accurate measurement of timing jitter a challenge.

PM noise characteristics of a 10 GHz actively modelocked external ring cavity semiconductor laser was measured using the standard phase detector method as well as the intensity crosscorrelation method in the time domain. The crosscorrelation measurement was performed using a modified Michelson optical frequency discriminator. The extracted timing jitter was 45 fsec (10 Hz – 10 MHz offset). The phase noise was also measured out to the Nyquist frequency of 5 GHz (for a 10 GHz laser), giving an upper limit on the extracted RMS timing jitter of 121 fsec.

The pulse-to-pulse optical carrier phase jitter was also studied to further characterize the stability of the laser. The Michelson interferometer was used to measure field correlations of the modelocked pulsetrain. The RMS phase jitter in the optical carrier oscillating at 200 THz (1550 nm) was estimated to be 50 asec ($50 \cdot 10^{-18}$ sec) pulse-to-pulse.

FABRICATION OF CONTINUOUS RELIEF MICRO-OPTICS

Jin Wong Sung, Waleed Mohammed and Dr. Eric G. Johnson

ABSTRACT

The term continuous relief micro-optics covers a wide range of refractive and diffractive microstructures. Several techniques are used to generate these structures such as a direct writing and gray-scale photolithography.

Using gray-scale photolithography, the structure is generated by exposing a photo-resist material through a gray-scale mask in which the optical density varies as a function of position. This technique has a substantial advantage over conventional multi-phase level binary optics, because there is no need to fabricate or align multiple masks for each phase level. Therefore it is very cost efficient mass fabrication tool for diffractive optical elements. Also, there is a reduction in the scattered light.

Our research group makes use of both contact exposure and stepping projection for gray-scale lithography. Once the remaining photoresist thickness versus exposure energy relation is established, we can properly design gray-scale photomask that has a continuously varying optical density as a function of position on the mask. With this gray-scale photomask we can readily perform photolithographic process to fabricate the final continuous-relief diffractive element. These elements can then be used in conjunction with MEMs and other devices for micro-photonic systems.

CREOL's GCA Optical Stepper for Grayscale Lithography

GOES/SXI Team Adopts CREOL X-ray Telescope Design

by

Martina Atanassova and James E. Harvey

ABSTRACT

The Solar X-ray Imager (SXI) is a complementary, add-on instrument for use on the Geosynchronous Operational Environmental Satellite (GOES) by the National Oceanic and Atmospheric Administration (NOAA). Its primary mission is to continuously observe the full solar disc at X-ray wavelengths; including coronal holes, active regions, flares, and coronal mass ejections. These coronal mass ejections are eruptions through the lower corona of the Sun of enormous "bubbles" of superheated plasma. The plasma, estimated in volume to be the equivalent of 17,000 Earths, spews charged particles out into space at velocities of over one million miles an hour. Solar scientists are studying the elusive voids left behind by these colossal events in attempt to better understand the Sun's corona and how it throws off solar wind and transports energy.

Solar flare induced space weather and its detrimental effects include: geomagnetic storms (malfunction of compass and GPS systems); electromagnetic interference (communication systems failure); ionospheric expansion (satellite de-orbit); power grid overloads (blackouts); radiation overdose (astronaut health hazard); and single event upsets (satellite electronics malfunction). Unlike the Chandra Observatory (primarily a stellar telescope) where on-axis resolution is of prime importance, an image quality criterion has been formulated that maximizes the number of spatial resolution elements over a given operational field-of-view (OFOV). This has lead to the development of a whole new family of optimal grazing incidence X-ray telescope designs where each member of the family is optimum for a different OFOV. A complete systems engineering analysis of image quality, including the effects of diffraction and surface scatter from residual optical fabrication errors, indicates that our new design will result in an 80% increase in the number of spatial resolution elements over the full solar disc. As a result of this analysis, the GOES/SXI team has adopted our design. The grazing incidence X-ray mirrors are currently being fabricated at Raytheon Optical Systems, Inc.

OPTICAL MEMS
LARGE DEFLECTION MICRO TORSION MIRRORS ON SILICON

Mahesh Pitchumani and Dr. Eric. G. Johnson

ABSTRACT

The rapid growth in Micro Electro-Mechanical Structures (*MEMS*) initiated by the need for miniaturization and integration in the Electronics Industry has shown potential applications in various fields. Components such as micro-fluid injectors, pressure sensors, biomedical sensors, accelerometers, optical gratings, adaptive micro mirrors have been already deployed. MEMS provide scaled down, robust and sensitive components while being cost effective by using well known Silicon (*Si*) or Poly-silicon batch processing Integrated Circuit technology.

With the advent of Optical communication networks, high bit rate systems using Dense Wavelength Division Multiplexing (*DWDM*), Ultra-DWDM and Optical Time Domain Multiplexing (*OTDM*) represent major application areas for Optical MEMS sometimes called Micro Opto-Electro-Mechanical Structures (*MOEMS*). Components like Mirrors, Micro lenses, V-grooves with optical fibers and other waveguide components can be integrated and cascaded for use in λ-switching and routing.

In our *Microphotonics Fabrication and Integration Laboratory* we investigate large deflection Micro Torsion mirrors for optical switching. These are much more stable and require simpler control as compared to the vertical standing structures. We study these structures using the software package, Intellisuite. Intellisuite modules allow us to build models define the material properties and simulate the Electro Mechanical characteristics of large deflection mirrors. We can look at the final device by running through each step of the fabrication process using Intellifab where standard Multi User MEMS Processes (MUMPS) and/or user-defined processes can be interleaved. The study of anisotropically etched structures in Silicon is also possible. These devices can then be fabricated either in single crystal Si or Poly-Si both of which are mechanically very robust. Single crystal Si structures have low stress and can be readily fabricated in our laboratory using bulk and surface micro machining techniques to be integrated with fiber optic components using anisotropically etched Si V-Grooves fabricated in our laboratory. Poly-Si structures can be fabricated using standard MUMPS foundries and then tested at our facilities. The goal of our group is to integrate these MOEMS devices on Si substrates with other fiber optic and micro-optic components for applications in various fields.

Figure 1 shows the configuration for switching a light beam from input port to either output port 1 or port 2.

Figure 2 shows the 3-Dimensional model of the Torsion mirror and the simulation results obtained using the software package INTELLISUITE.

Two-Photon Fluorescence: A Nonlinear Spectroscopic Technique

Joel Hales, David J. Hagan, Kevin D. Belfield and Eric W. Van Stryland

Abstract

Determining the two-photon absorption spectra is useful in identifying which materials have the strongest 2PA cross-sections. This is crucial when deciding which materials should be used in such applications as two-photon laser scanning microscopy and optical limting. There are several methods that can be utilized to determine these spectra. One way is to directly measure the nonlinear transmission of light through the medium. However, such a direct measurement of two-photon absorption may present the problem that only a small fraction of photons are usually absorbed, providing a small detectable signal.

However, if the material has a strong, known, quantum efficiency, the 2PA spectrum can be determined directly from the measurement of the integrated two-photon fluorescence. Although some materials may only fluoresce weakly, the small detectable signal is easier to measure (with photo-multiplier tubes) since it is against an essentially zero background. We have found that the method we use to acquire the 2PF spectra provides a reliable and accurate determination of the two-photon absorption spectra in the many organic solvent samples we have measured.

Glass Processing and Characterization Laboratory

MS and TEM on insulators for tical & semiconductor applications.

Assoc. Prof. Kathleen Richardson

Sponsors: Lucent/Cirent, BMDO, NSF

dents: *Hugues Francois-Saint-Cyr, Kitty Elshot (Materials Science Engineering/SoO), Vadim Smirnov, Trevor Meyer(SoO).*

laborators: *Drs. Lucille Giannuzzi, Dan Zhou (MMAE /AMPAC), Dr. Lee Chow (UCF-Physics), Fred Stevie (Lucent/Cirent),Drs. Leon Glebov,Oleg Efimov (SoO), Mrs. L.Glebova (SoO).*

ause of its high sensitivity and excellent depth lution, Secondary Ion Mass Spectrometry (SIMS) is xcellent analytical tool for determining contaminant dopant profiles in materials. Diffusion of impurities emiconductors leading to poisoning of electronic ces must be controlled and our research is aiding in understanding of diffusion of these species in single polycrystalline Si and other materials [1,2]. Using ismission Electron Microscopy (TEM) as a plementary tool with SIMS assists in understanding diffusion behavior of dopants and micro-crystalline e formation in Photo-Thermo-Refractive Glasses RG) for hologram recording applications [3].

igure 1 illustrates SIMS depth profiles of Chromium as-implanted into Silicon (blue) and annealed at C (green). Shown below are corresponding TEM ographs aimed at providing a visual depiction of the rphized layer associated with the initial implantation) and the diffusion behavior of Cr accompanied by ystallization in Si upon annealing (bottom). The Pt r shown is used to protect the thin section surface ng FIB preparation.

Current research is investigating both sample aration and analysis methodologies for insulators g FIB (Focus Ion Beam) and Tripod Polishing (TP). stematic study examining diffusion of ion-implanted ies in single and polycrystalline materials, and rphous materials in thin film, bulk and multi-ponent glasses, to monitor differences in diffusion avior, in underway.

Ion implantation and diffusion simulations are run to ide a reference to experimentally determined results Fig. 2 illustrates a simulation of 120 keV Chromium implantation in Silicon. The most probable location r ions is 0.1 μm below the surface. The amorphous age interface due to ion-implantation is calculated TRIM simulations to be located nearly 0.2μm erneath the surface.

Fig. 1 Ion implanted profile of Cr in Si with corresponding TEM cross-section micrographs

Fig. 2

0A Target Depth 3000A

IMS characterization of the diffusion properties of 17 elements implanted into Silicon", H. Francois-Saint-Cyr, E.Anoshkina, F. Stevie, ow, K.Richardson and D.Zhou, J. Vac. Science Tech., (submitted October,1999).

iffusion Properties of Cu in Nanocrystalline Diamond Thin Films", D. Zhou, F. Stevie, E. Anoshkina, H. Francois-Saint-Cyr , K. ardson,A. Hussain, and L. Chow, MRS (submitted Dec. 1999).

igh Efficiency Bragg gratings in Photothermal Refractive glass," O. M. Efimov, L.B. Glebov, L.N. Glebova, K.A. Richardson and V.I. nov, Appl. Optics **38** 619-627 (1999)

Stopping and Range of Ions in Matter, SRIM 2000", J.Ziegler, IBM Research, Yorktown, NY, 10598, USA.

University of Central Florida ~~CREOL~~
School of Optics/CREOL

Laser Resonator Design Using Optical Ray Tracing Software: Comparisons with Simple Analytical Models and Experimental Results

By Alexandra Rapaport, Michael Bass

Software simulation of complex resonator and optical system designs offers the potential to couple traditional opto/mechanical tolerance analysis with the required system performance. One such software platform, ASAP, and the methodology to perform tolerance analyses has been evaluated and validated for the case of the crossed Porro prism resonator.

Fig. 1: Picture of the breadboard cavity studied and experimental set-up for measuring displacements and energies.

The resonator studied is shown in Fig.1. The simulation results are presented and compared to the analytical solution obtained and to experimental measurements. An excellent agreement is found for any motion of any of the optical elements.

The main advantage of ASAP over an analytical solution is that the complexity of the solution does not increase with the number of elements in the cavity. We are currently in the process of analyzing and characterizing the performances of a cavity for which analytical solutions could not be obtained. We showed that we could use those calculations to predict the behavior of a laser cavity without having to build expensive prototypes.

Another advantage of ASAP os that it exactly calculates the mode volume seen by the cavity without making the approximations necessary to obtain an analytical solution, which can sometimes bring more information about the output beam (see Fig.2).

Fig. 2: Plot of the profile of the beam oscillating in the cavity as seen on one face of the rod. a) azimuth angle of 55 deg. b) azimuth angle of 60 deg.

Spray Cooling High Power Diode Laser Arrays

By Te-yuan Chung, Michael Bass

All lasers are inefficient. This means that there is always waste heat to be removed. This is commonly done with a flowing coolant (e.g. water) to remove the heat through a temperature differential. It is inefficient, bulky, weighty, and inconvenient for diode arrays and slab lasers. We introduce spray-cooling which utilizes the latent heat of vaporization to remove heat from a hot item when a liquid droplet vaporizes. This could be applied to cooling diode laser arrays and slab lasers in a convenient manner. The result will be smaller, lighter, more efficient laser sources. Basically, droplets are deposited from nozzle to a heated surface to create surface nucleation, evaporation, enhanced convection, and 'secondary nucleation'. The highest heat flux removal capability of all two-phase techniques can easily achieve 1000 W/cm^2 for water. We apply spray cooling on diode laser array and show the capability for handling the high heat flux. Also, spectrum information and temperature estimation of single diode is shown as well. Fig.1 shows the spectrum information of a spray-cooled diode array. Fig.2 shows the Cooling Performance of Water and Ammonia.

Fig.1 60W Spray-cooled array

Fig.2 Cooling performance of water and ammonia

Sub-50 fs Cavity-Dumped Ti:Sapphire Laser for Use in Micro-machining

Lawrence Shah, Arnaud Zoubir, and Martin Richardson

The advantages of femtosecond machining include increased precision, decreased Heat Affected Zone (HAZ), and lower ablation threshold fluence, in comparison to conventional nanosecond laser processing techniques [1,2]. However, amplified femtosecond laser systems are relatively costly and complicated. Here we report upon the development of a sub-50 fs cavity-dumped Ti:Sapphire laser (see Figure 1), with unique characteristics ideal for femtosecond laser micro-structuring and mirco-processing.

Figure 1: The FWHM of the autocorrelation is ~60 fs, indicating a pulse duration of ~45 fs

Cavity-dumping bypasses the output coupler, allowing access to the energy oscillating inside the laser cavity (see Figure 2). Thus it is possible to generate pulses with ~200 nJ of energy [3], compared to the typical 5-20 nJ/pulse obtained from a standard Ti:Sapphire oscillator. With hundreds of nanojoules per pulse, it is possible produce target intensities in excess of 10^{12} W/cm^2 given a focal spot 10 μm in diameter. Such a laser bridges the gap in pulse energy between simple oscillators and amplified laser systems, providing the necessary energies to conduct micro-machining experiments while being significantly less expensive and less complicated than standard Chirped Pulse Amplification (CPA) laser systems.

Figure 2: Trace of the modelocked pulse train and selected cavity-dumped pulse

References:

1. C. Momma, et al Opt. Comm. 129. 134 (1996).

2. S .Nolte et al CLEO 98, paper CFD3, p 510 (1998)

3. G. Gibson, et al Opt. Letts. 21. 1055 (1996).

Piezo controlled intracavity wavelength selector for the far-infrared p-Ge laser

E. W. Nelson,* A. V. Muravjov,*

S. G. Pavlov,** V. N. Shastin,** and

R. E. Peale*

*Department of Physics, University of Central Florida, Orlando, Florida 32816

**Institute for Physics of Microstructures, Russian Academy of Sciences, GSP-105, Nizhny Novgorod 603600, Russia.

The p-Ge solid-state laser is the only solid state laser in the 1-10 THz region of the electromagnetic spectrum. It is broadly tunable over the range 70-200 micron wavelengths (50-140 cm-1, 1.5-4.2 THz) with high spectral density (1 W in MHz linewidth). The broad gain spectrum makes it suitable for picosecond pulse generation. Applications include chemical sensing and communications. This paper presents the first demonstration of an electrically-controlled wavelength selector. The tunable intracavity interference device was driven by a piezo element. This design allows very small controllable displacements of the tunable mirror that were impossible in previous mechanical systems.

NOTES

University of Central Florida

School of Optics/CREOL

Industrial Affiliates Program
Membership Form

Company _____

Point of Contact _____ Title _____

Address _____

_____

City _____ State _____ Zip _____

Phone _____ Fax _____ E-mail _____

Products/Services _____

Company web site URL _____
(Complimentary link provided from our site to yours)

Donation information:

Value of Donation $_____ Cash ☐ In-Kind ☐ Equipment ☐

Industrial Affiliates Program Levels of Membership

1. Affiliate Member. Any individual, corporation, or organization that donates $1,000 in cash, or $3,000 of new equipment, annually to the Center*.

2. Associate (or Senior) Member. Any individual, corporation, or organization that donates $3000 in cash, or $10,000 of new equipment, annually to the Center.

3. President's Medallion Member. Any individual, corporation, or organization making a donation in excess of $10,000 in cash annually.

4. Life Member. Any individual, corporation, or organization that participates in the University's Eminent Scholar's Program and endows a Chaired Professorship in the School of Optics/CREOL with a minimum donation of $600,000. These donations are eligible for the State Matching Gifts Program.

*(*We invite companies with 10 or fewer employees to apply at a reduced donation.)*

Please mail donations and original form (retain copy for your files) to :

Director, Industrial Affiliates Program
School of Optics/CREOL
University of Central Florida
4000 Central Florida Blvd.
P.O. Box 162700
Orlando, FL 32816-2700
(407) 823-6800 / (407) 823-6880 (fax)
http://www.creol.ucf.edu