Industrial Affiliates' Day

Friday, April 28, 2000

University of Central Florida
Student Union, Key West Ballroom 218B
Orlando, Florida

- ***Plenary speakers from industry and government on the future of optics and laser technology***
- ***Networking and interaction with national and state trade organizations***
- ***The School of Optics/CREOL partnerships and funding support from national and state governments***
- ***Access to graduating students***
- ***Demonstrations of new optical and laser technologies***
- ***Laboratory visits***
- ***Poster presentations by students & members of industry***

INDUSTRIAL AFFILIATES' DAY
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School of Optics/CREOL Industrial Affiliates Day

PROGRAM
Friday, April 28, 2000
University of Central Florida, Orlando, Florida

ıdent Union, Key West Ballroom 218B – Session I

8:30 a.m.	Continental Breakfast & Registration
9:00	Welcome & Introduction M. J. Soileau, Vice President for Research Eric W. Van Stryland, Professor & Interim Director, School of Optics/CREOL
9:15	Overview of CREOL's Research Activities Eric W. Van Stryland
9:45	Overview of Industrial Affiliates Program Martin Richardson, Professor, School of Optics/CREOL
10:00	"Advances in Commercially Deployed Components for DWDM Fiber Optic Systems" Fred E. Leonberger, Senior Vice President & Chief Technology Officer, and Paul Suchoski, Vice President and General Manager, JDS Uniphase

EOL Building

10:50	Refreshment Break
11:15	Demonstrations and Lab Visits
12:15 p.m.	Lunch and Posters, CREOL Building Lobby

dent Union, Key West Ballroom 218B – Session II

2:00	Awards and Honors

Opportunities for Optics & Photonics in Florida

2:10	Randy Berridge, President, Florida High Tech Corridor Council
2:20	Darrell Kelley, President & CEO, Economic Development Commission of Mid-Florida, Inc.
2:30	"The World Leader in Commercializing Military Technology" Mark Crumblish, Vice President of Business Development, MILCOM Peter Atwal, Vice President, Communications Ventures, MILCOM
3:20	Overview of Florida Electro-Optics Industry Association (FEOIA) Steve Qualls, Executive Vice President, Laser Photonics Inc.
3:30	Overview of Central Florida Business and Technology Development Center (CFBTDC) M. J. Soileau, Vice President for Research

EOL Building

3:40	Refreshment Break
4:00	Demonstrations and Lab Visits
5:00-7:00	Reception, CREOL Lobby
7:00	Board of Visitors Dinner Meeting, UCF President's Dining Room

LABORATORY DEMONSTRATIONS

Session 1 – 11:15-12:15 AM:

"Optically Written Displays Based on Two Photon Processes"
Location: Room 157
Contact: Alexandra Rapaport/Mike Bass

"Augmented Reality Technology,"
Location: Room 146
Contact: Yann Argotti and Larry Davis/Jannick Rolland

"Metal powder deposition"
Location: Room 264
Contact: Franz-Josef Kahlen/Aravinda Kar

Session 2 – 4:00-5:00 PM:

"Hybrid WDM-TDM Technologies for Gigabit Ethernet Applications"
Location: Room 254
Contact: Mike Mielke/Peter Delfyett

"High-Speed All-Optical Clock Recovery."
Location: Room 246A
Contact: Mohammed Al-Mumin/Guifang Li

"Debris-free, Highpower, Laser Plasma X-ray and EUV Sources"
Location: Room 140
Contact: Christian Keyser/Martin Richardson

ABSTRACTS OF

POSTER PRESENTATIONS

Laser Design

By Steven Lindauer
Alexandra Rapaport and
Michael Bass

Dynamic modeling:

An in-house code implementing the Xiao-Bass model of passively Q-switched intracavity optical parametric oscillators has been developed. The code can provide performance data for a particular design, or it can allow any input parameter (e.g. signal output coupler reflectivity) to be varied over a specific range to allow the user to find the optimum parameters for that design.

Resonator modeling using the commercial software ASAP:

ASAP allows the user to visualize a resonator, optimize it, and study the tolerancing on each element without having to build a prototype. It is also possible to calculate the diffraction effects due to each aperture in the system.

Thermal Management of Diode Laser Arrays

Jennifer Huddle, Louis Chow (MMAE Department)
Steven J. Lindauer II, Michael Bass (School of Optics/CREOL)

Even though diode lasers have high optical efficiencies (up to ~50%), a modest amount of waste heat is generated. The heat must be dissipated from the microscopic footprint of the device, which drives the heat flux density to extreme values on the order of kW/cm^2. The performance, reliability, and lifetime of diode lasers can seriously degrade if the waste heat is not efficiently removed. Also, the emission wavelength is a function of temperature. The interesting feature of spray cooling is the two-phase nature of the heat removal process. This allows for the cooling of each emitter to be done in parallel. Therefore, spray cooling promises a uniform temperature (wavelength) across an entire laser array (regardless of the array's size).

Optical pathlength spectroscopy

G. Popescu, C. Mujat, L. Denney, and A. Dogariu

Inhomogeneous systems of high industrial importance such as particulate suspensions, porous media, etc., multiple scatter light, their optical characterization being a challenging task. We have developed a methodology which, based on fundamental understanding of multiple scattering processes, offers direct information regarding the structural properties of these random media.

Based on the principle of low-coherence interferometry, the new technique called optical pathlength spectroscopy (OPS), measures the pathlengths distribution *P(s)* of waves backscattered in a specific geometry. From the shape of this distribution, the structural information can be determined. A typical OPS signal consists of backscattered intensity contributions corresponding to waves scattered along closed loops that have the same optical pathlengths. This is similar to the information obtained in time-resolved reflectance measurements where the diffusion approximation makes a reasonable description of the experimental data.

OPS data from powders with particle sizes of 3 and 10 μm. The inset shows a fit with the diffusion model.

This technique has been successfully applied to characterize both liquid and solid particulate systems.

Diffracted Radiance: The Fundamental Quantity in Non-paraxial Scalar Diffraction Theory

by

Andrey Krywonos and James E. Harvey

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It is well-known that the irradiance distribution on a plane in the far-field (Fraunhofer region) of a diffracting aperture is given by the squared modulus of the Fourier transform of the complex amplitude distribution emerging from the diffracting aperture. However, the Fraunhofer approximation, and even the Fresnel approximation, implicitly contain a *paraxial* limitation!

We have developed a linear systems formulation of non-paraxial scalar diffraction theory by normalizing the spatial variables by the wavelength of light, and recognizing that the reciprocal variables in Fourier transform space are the direction cosines of the propagation vectors of the resulting angular spectrum of plane waves. It is then shown that wide-angle scalar diffraction phenomena are shift-invariant with respect to changes in incident angle *only in direction cosine space*. Furthermore, it is the diffracted *radiance* (not intensity or irradiance) that is shift-invariant in direction cosine space. This realization greatly extends the range of parameters over which simple Fourier techniques can be used to make accurate calculations concerning wide-angle diffraction phenomena. In extreme cases, the radiance distribution function will extend beyond the unit circle in direction cosine space. Evanescent waves are then produced, and the radiance distribution function must be re-normalized to satisfy Parseval's theorem (and the conservation of energy).

$$L'(\alpha,\beta-\beta_o) = K\,\gamma_o \frac{\lambda^2}{A_S}\left|\mathrm{F}\left\{U_o(\hat{x},\hat{y};0)\exp(i2\pi\beta_o\hat{y})\right\}\right|^2 \quad \text{for } \alpha^2+\beta^2 \le 1$$

$$L'(\alpha,\beta-\beta_o) = 0 \quad \text{for } \alpha^2+\beta^2 > 1$$

If theoretical predictions of diffracted intensity are desired, the radiance obtained from the simple Fourier treatment must then be subjected to Lambert's cosine law. This new formulation of scalar diffraction theory provides new insight and understanding to the scalar diffraction process and allows accurate calculations to be made over a much broader range of conditions than previously thought. Many of the severe limitations usually attributed to scalar diffraction theory are actually the result of the completely unnecessary paraxial assumption, not the scalar theory itself. Particular applications of this work include inherently wide-angle diffraction phenomena such as grating analysis, and the analysis of surface scatter phenomena (image degradation due to residual optical fabrication errors).

References:

J. E. Harvey, C. L. Vernold, A. Krywonos, and P. L. Thompson "Diffracted Radiance: A Fundamental Quantity in Non-paraxial Scalar Diffraction Theory", Appl. Opt. 38, 6469-6481 (Nov. 1, 1999).

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J. E. Harvey, "A Fourier Treatment of Near-field Scalar Diffraction Theory", Am. J. Phys. **47**, 974-980 (1979).

Design and Analysis of Grazing Incidence X-ray Telescopes for Wide-field Imaging Applications

by

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The Solar X-ray Imager (SXI) is a grazing incidence Wolter Type I X-ray Telescope to be fabricated and flown on the National Oceanic and Atmospheric Administration's (NOAA) Geo-stationary Operational Environmental Satellite (GOES). The SXI will image the full sun at wavelengths between approximately 6 and 60 angstroms with a detector having 5 arc sec pixels. The goal for SXI is to forecast "space weather", i.e., effects of charged particles that are produced at the Sun as they interact at the earth. Major contributors to space weather include: variations in the Sun's solar wind, solar flares, and solar coronal mass ejections. Effects of space weather include: radiation damage and particle events in high-inclination orbit spacecraft, disruption of various kinds of communications equipment, degradation of navigational tools such as GPS, potential health hazard during space walks, and power blackouts and damage to power company generators.

CREOL Professor James E. Harvey and graduate student Patrick Thompson are providing technical support to the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL), prime contractor in the design and fabrication of the SXI telescope for the GOES N and O satellites. Raytheon Optical Systems, Inc. of Danbury, CT is the X-ray mirror manufacturer. NASA's Goddard Space Flight Center in Greenbelt, MD is serving as the contract monitor for the Lockheed Martin contract. CREOL's role was initially to make optical performance predictions as degraded by surface scatter to help determine realistic optical fabrication tolerances for the X-ray mirrors. However, this analysis led to the formulation of a new image quality criterion for wide-angle X-ray imaging applications and then to the development of a whole new family of optimal hyperboloid-hyperboloid grazing incidence X-ray telescope designs, where each member of the family is optimized for a different operational field-of-view (FOV). One member of this new family of generalized Wolter Type I telescope designs, designated as H-T#17, yields a predicted **80% increase** (over the baseline design) in the number of average spatial resolution elements in an 18 arc min radius FOV. The GOES/SXI team formally adopted the H-T#17 optical design for the GOES N and O satellites at the Lockheed Martin SXI Critical Design Review (CDR) briefing on July 15-16, 1999.

References

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J. E. Harvey, "Scattering Effects in X-ray Imaging Systems", **Invited paper** presented in the *X-ray and Extreme Ultraviolet Optics* Conference at SPIE's International Symposium on Optical Science, Engineering, and Instrumentation, San Diego, CA, 9-14 July 1995; published in Proc. SPIE **2515**-32 (1995).

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POSTER
INDUSTRIAL CAROL SEIDEL

Efficient, room temperature mid-infrared laser at 3.9 μm in $Ho:BaY_2F_8$

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Abstract

Lasers that operate in the mid-infrared region are of great interest to the technical community. Applications for these lasers include remote sensing, imaging, IR countermeasures, eye-safe lidars and environmental agent detection; to name a few.

Lasers based on rare-earth doped fluorides are an attractive alternative to currently existing mid-infrared sources such as semiconductor lasers or frequency down-shifters using nonlinear conversion processes: OPO or Raman conversion approaches.

Previously, we demonstrated cascade laser action involving the $^5S_2$, $^5I_5$, and $^5I_6$ manifolds in Ho^{3+} doped BaY_2F_8 pumped at 532 nm by a Q-switched frequency doubled Nd:YAG laser. Pulsed laser oscillation was achieved at 1.4 μm and 3.9 μm with low thresholds. A slope efficiency of 10.4%, was demonstrated for the 3.9 μm transition, corresponding to near-theoretical quantum efficiency.

Recent experimental observations and theoretical calculations provided evidence that direct pumping of the upper level $^5I_5$ of the 3.9 μm transition will increase the power efficiency of the 3.9 μm laser. Both BaY_2F_8 (BYF) and $LiYF_4$ (YLF) doped with Ho^{3+} ions exhibit ground state absorption at 890 nm to the metastable $^5I_5$ level. We proposed to use a flashlamp pumped Cr:LISAF laser with wavelength tuning as the pump source. We have demonstrated 1 J 70 μs long pulse Cr:LISAF laser tuned to 890 nm.

In this work pulsed laser oscillation at 3.9 μm involving the $^5I_5$, and $^5I_6$ manifolds is demonstrated for Ho^{3+} in BaY_2F_8 pumped at 890 nm by flashlamp pumped Cr:LISAF laser for the first time. Laser action was achieved at low threshold of 3 mJ of pump energy. A slope efficiency of 4.7 % was demonstrated with maximum energy of 22 mJ of 3.9 μm laser pulse. We expect significant improvement of the efficiency of 3.9 μm laser by further optimization of key cavity parameters.

Laser-Aided Manufacturing, Materials and Microprocessing (LAMMMP) Laboratory (Dr. A. Kar)

Graded materials are fabricated using a metal-based laser rapid manufacturing process. The hardness of the parts is of the same magnitude as conventionally manufactured parts (Fig. 1). As a result, the ductility is expected to be high. A mathematical model to calculate the magnitude and direction of residual stresses created in the fabricated parts is derived. The sum of the calculated residual stresses and the measured yield strength equals to the nominal yield strength of conventionally manufactured stainless steel SS 304 (Fig. 2).

Fig. 1. Vickers hardness of laser-fabricated graded material and SS 304 part and local nickel concentration over location in the fabricated part.

$\dot{m}_{del}$:	6.2 g/min	6.2 g/min	8.0 g/min
Power:	300 W	400 W	400 W

Fig. 2. Measured yield strength and calculated residual stresses of laser-fabricated SS 304 parts.

Laser Micro-welding of 50 and 100 μm thin metal sheets is investigated experimentally and analytically. The results identify (Fig. 3) a region of high process controllability for low laser powers (regions AB, low penetration depths) and low process controllability at higher laser powers (regions CD, penetration depths).

Fig. 3. Relationship between weld depth and laser power (modeling and experiments).

Ultrafast All-Optical Monolithically Integrated Optic Switch

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In this work, we developed a symmetric Mach-Zehnder all-optical switching device (Fig. 1) using GaAs/AsGaAs multiple quantum well structures along with quantum well intermixing technique[1]. Although the switching is based on the carrier-induced nonlinearities[2], the switching speed is not restricted by the slow relaxation time[3].

The all-optical device consists of a single-mode multiple quantum well waveguide Mach-Zehnder interferometer(MZI) with 3dB directional couplers. The nonlinear sections were defined within the MZI using SiO_2-capping quantum well intermixing. For this preliminary experiment, we have tested a simplified version of the switch by cutting the front part of the device (dashed line), just before the non-disordered nonlinear sections. This was necessary because the losses arising from scattering in the curved waveguide sections were prohibitively large. The scattering losses were primarily attributed to an inferior photolithographic mask that was used to fabricate the device.

Fig. 1. Integrated All-Optical Interferometric Switch

The switching characteristices of the device was tested using a conventional pump-probe measurement set-up. A Kerr-lens mode locked Ti:sapphire laser operating at 845nm was used as the source of the optical signal and control pulses. Pulses from the laser were stretched to 1.2 ps using a grating-pair pulse stretcher. The stretched pulses were split into two signal beams and two control beams. The signal beams were mechanically chopped before they were launched into the device using a 40X microscope objective lens. The output beam was captured using another 40X microscope objective lens and monitored simultaneously on both a CCD camera and a photodetector that was connected to a lock-in amplifier. The output intensities from the two ports as a function of the time delay between the control pulses and the signal pulses are shown in Fig. 2. In this initial experiment, we achieved a 9 dB contrast ratio with a 10 ps switching window.

It can be clearly observed from the plots of fig. 2, that the rise-time and fall time of device switching response are both on the order of 2ps which corresponds very closely to the pulse width of the switching pulses. The gating window is fully adjustable from 2ps onwards. This particular experimental device had a long carrier lifetime on the order of several ns and therefore no noticeable recovery was observed in the switching response if only one switching pulse is employed.

On-going experiments are currently underway to fabricate the fully integrated device using a higher quality photolithographic mask. The tolerance of the device operating characteristics to high repetition rate switching will then be determined.

Fig.2. Time resolved switching achieved using a 10ps delay between the two control pulses.

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[3] S. Nakamura, K. Tajima, and Y. Sugimoto, Appl. Phys. Lett., vol. 65, 1994

A Three Channel Optical Switch Realized by Beam Steering on a Semiconductor Planar Structure

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We present the experimental results of a semiconductor guided-wave device in which two electrical currents are used to direct a train of optical pulses to one of three output channels. Cross-talk between adjacent output ports is better than –19dB and the device works over a spectral bandwidth of more than 40nm. Furthermore, no appreciable degree of polarization dependence was detected.

The device shown in fig. 1. is fabricated on a standard laser diode double heterojunction structure and consists of two sections. The first section contains two parallel contact stripes through which electrical currents are injected into the device and drained through a common substrate contact. Electrons injected into the active layer create localized anti-guiding regions[2]. When currents are injected through the stripes, electrons accumulate in the active area and spread out beyond the areas directly underneath the stripes. Consequently the regions of lower refractive index extend laterally. Depending on the current levels, a region of the active layer between the two stripes will have the least distribution of electrons and therefore that region will have the highest refractive index relative to its immediate surroundings. A localized channel waveguide is hence formed. By balancing the currents on each stripe, the spreading of the free electrons can be controlled and the position of the channel waveguide can be shifted in the lateral direction. In the second section of the device, three parallel rigde waveguide channels are delineated next to the beam-steering section. These channel waveguides serve to collect the light as it leaves the beam-steering section.

Fig. 1 *Schematic drawing of the active device structure*

Fig. 2. *Images of the output facet under various combinations of current injection with a fixed input beam.*

With very low current injection through the stripes, lateral confinement is absent and the beam of light launched into the device spreads out laterally and couple to all three of the rib waveguides (Fig.2 top picture). When equal levels of current are injected to both contact stripes, the beam of light is guided directly towards the center output rib waveguide. For both TE and TM polarized light, the cross-talk between adjacent channel is measured to be better than –19dB. In these experiments, the wavelength of the laser beam was tuned from 910nm all the way to 950nm, and similar results were obtained.

References

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Micro-Electro-Mechanically Actuated Integrated Optic Switch for NxN Optical Cross-Connect Matrix Array

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We propose an electrostatically driven 1x2 switch implemented using planar SiO_xN_y waveguide technology [1]. The device structure and operational principle are depicted in the Fig.1. A cantilever beam carries two vertically displaced output waveguides. In the quiescent state, an input beam launched into the fixed lower waveguide propagates through the narrow air-gap and get captured in the lower waveguide in the cantilever bar. When a voltage is applied between the substrate and a chromium electrode embedded inside the cantilever bar, electrostatic forces pull the cantilever bar towards the substrate. As a result, the lower input waveguide carrying the signal, becomes aligned with the top output one and the signal is switched to the upper output port. The waveguide structure is made of interleaved layers of PECVD grown SiO_xN_y films deposited on a silicon substrate with an intermediate silicon oxide film. The cantilever bar is fabricated using a combination of photolithography, reactive ion etching and wet chemical etching.

Fig.1. Schematic representation of 1x2 opto-mechanical switch. a) parallel state; b) crossed state.

Fig.2 shows the intensity profiles for the top and bottom waveguiding slabs depending on the presence of the applied electric field. The performance of the switch was tested using a cw Ti:sapphire laser. The "pull-in" voltage required for the tip of the beam to undergo a total switch of the optical signal between the waveguides was around 85V and the release voltage was 35V. This "pull-in" voltage can be significantly decreased with a slight modification of the cantilever topology.

The dynamic response of the device was measured while it was driven by a square wave with 1kHz repetition frequency. The switching time response is shown in the Fig.3. The fall time corresponding to the attraction mode of the switch was about 25 microseconds. We have also carried out a cycling test of the switch. The switch was operated for over 300 million cycles and no functional degradation of the device was observed.

Fig. 2 Output intensity profiles scanned vertically showing switching between the two channels

Fig. 3. Dynamic Response of 1x2 Switch

We are currently working on an improved version of the device that will require a significantly reduced voltage for operation. We will also implement an integrated 4x4 switch that can readily be scaled up to a large array cross-connect switch with obvious applications in optic fiber networks.

References.

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Photo-thermo-refractive glasses for high-efficiency Bragg gratings in UV, visible, and IR regions

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Abstract: A photosensitive medium has been developed for phase hologram recording which exhibits transparency from 300-4000 nm, photosensitivity from 280-370 nm, refractive index variations of 10^{-3}, spatial frequencies up to 10000 mm^{-1}, absolute diffraction efficiency of 95% at exposures of 0.1-1 mJ/cm^2 at 325 nm.
© 1999 Optical Society of America
OCIS codes: (050.1970) Diffractive optics, (160.2900) Holographic recording materials

The wide spread use of holographic elements is constrained by the lack of available holographic materials. Hariharan's recent book [1] notes that among the photosensitive materials available for high efficiency hologram recording, each have merits, as well as drawbacks. This paper describes properties and performance of inorganic glass as a medium for volume hologram recording, which meets most requirements cited. The use of inorganic photosensitive glasses for phase hologram recording was described several years ago (see survey in Ref. [2]). The two-step process of exposure to UV radiation and thermal development (photo-thermo-refractive process) has been used to record phase patterns in glass defined as photo-thermo-refractive (PTR). Relative diffraction efficiency of up to 90% was recorded at that time, however, strong scattering from the thermal development process resulted in a low absolute diffraction efficiency, not exceeding 45%.

Recent efforts have successfully concentrated on the proper choice of glass processing technology and exposure and thermal development conditions, to eliminate undesirable scattering. The results of recent progress in photosensitive glass with approximate composition (mol.%) $15Na_2O$-$5ZnO$-$4Al_2O_3$-$70SiO_2$-$5NaF$-$0.01Ag_2O$-$0.01CeO_2$, have been summarized [3]. Glasses were exposed with 325 nm radiation and developed at 520°C to obtain gratings with spatial frequencies ranging from 250 mm^{-1} to 9200 mm^{-1}.

The photosensitivity of PTR glass ranges from 280 to 360nm. Absorption of PTR glass was found to be less than 0.01 cm^{-1} in the visible and near IR regions and below 1 cm^{-1} in spectral ranges 280 – 380 nm and 2700 – 4200 nm. Thus, holograms in this glass can be successfully used for all lasers and optical communication wavelengths in

Fig. 1. Diffraction efficiency of transmitting Bragg gratings in PTR glass for different wavelengths in UV, visible and IR spectral regions. 1 – relative and 2 – absolute diffraction efficiency.

Femtosecond Laser Micromachining

Lawrence Shah, Jesse Tawney and Martin Richardson

Abstract

In recent years, many groups have begun to use femtosecond laser systems for laser processing applications. Experiments using ultrashort laser pulses to remove solid materials, such as metals, dielectrics, and ceramics, reveal that femtosecond laser pulses are capable of producing smaller more repeatable features without significantly modifying surrounding material. The fact that femtosecond lasers can be used to produce holes on the order of 1 micrometer in diameter in a variety of "delicate" materials, make such laser systems particularly useful in micromachining and microstructuring applications.

To date most femtosecond machining experiments have been performed in vacuum in order to reduce laser interaction with the atmosphere. However, most commercial applications demand in-air processing in order to be viable. Therefore our research has focused on gathering femtosecond ablation data in air. Our initial experiments have been focused on measuring ablation parameters (such as ablation rate, maximum ablation depth, and feature morphology) in transparent media such as commercial glasses and plastics, although we have also performed experiments on a variety of other materials including metals, ceramics, and carbon composite materials. In these experiments, we are working to fully characterize the variation of the ablation parameters in relation to laser pulse energy and duration, atmospheric pressure, and material being processed.

Thus far, our research has confirmed that femtosecond laser pulses are capable of producing smaller more uniform holes with greatly reduced heat affected zones (at atmospheric pressures) when compared to holes made using nanosecond laser pulses under the same experimental conditions. Our research also indicates, that ablation parameters exhibit strong material dependence.

Figure 1: Holes produced by 1000 laser pulses (left: t_p=100fs, E_p=1mJ; right: t_p=250ps, E_p=3mJ) in glass.

Figure 2: Depth of femtosecond machined hole as a function of incident laser pulses.

LASER PLASMA LABORATORY

X-ray and EUV Sources for Advanced Lithography

Christian Keyser, Guido Shriever & Martin Richardson

As industry prepares to further decrease the structure size of IC components to less than 100 nm, there is a pressing need for a bright, debris free, source of Extended Ultra Violet radiation for EUV lithography. This source should be capable of providing 30-60 W of radiation in a 2.5% band width. The source should emit at 11.5 or 13 nm due to the availability of EUV mirrors at these wavelengths. At the Laser Plasma Laboratory an effort is under way to create a source meeting these requirements. The effort involves focusing an intense laser, ~ 10^{12} W/cm, onto a liquid droplet of diameter around 60μm to create a plasma. The plasma, a high-energy mixture of ions and electrons, can produce the needed EUV radiation.

A liquid droplet is used as the target instead of a solid due a reduction of the flux of plasma produced debris (ions, neutrals, electrons, and clusters) by several orders of magnitude. It is important to minimize the debris from the plasma to ensure that any optics in the vicinity of the source will not be damaged. Water is used as the target liquid due to the availability of emission at 11 and 13.5 nm from lithium-like oxygen ions. The oxygen spectra can be seen in figure 1. The conversion efficiency from laser light to EUV has been measured to be 0.63%/4πsr.

The experiment is run in vacuum to avoid absorption of the EUV radiation by the air. The laser operates at 100 Hz and delivers pulses having energies of 250 mJ, a duration of about 10ns and a wavelength of 1.064 μm. Drops are produce at a rate of about 50 kHz. A delay generator is used to adjust the delay between the laser and the drops to ensure that the laser pulse strikes a single droplet. Figure 2 shows a layout of the experimental set up.

Long time experiments, in which the reflectivity of the EUV mirror is measured as a function of the number of laser pulses incident on the mirror. The EUV mirrors last about 7 x 10^5 shots when exposed to the plasma source alone and about 5.6 x 10^6 shots when exposed to the plasma source and special debris repelling techniques.

An effort is under way at LPL to produce a 1nm soft x-ray source for soft x-ray lithography for GaAs structures using a similar technique. To Produce 1 nm radiation the drops are doped with elements such as zinc and the required laser intensity is around 10^{14} W/cm^2.

Figure 1

Figure 2

WHERE SCIENCE MEET THE ARTS —The Newest Art Form in Photography
A Collaboration between the School of Optics/CREOL and SmARTlens™
University of Central Florida

Jannick P. Rolland[1] and Steve Hylen[2]

In the Optical Diagnostic and Applications (ODA) Laboratory in the School of Optics and CREOL at the University of Central Florida, we are striving to model, design, and fabricate optics in collaboration with SmARTlens™ that encode various artists' styles with all-optical devices. While we are also pursuing computer simulations to achieve such effects, our ultimate aim is to achieve these ART form effects at the speed of light.

It is all about texture, a form of random pattern. Mathematically, we define texture as an ergodic random process. In simpler words, we mean that each texture image could be a sample cut out of a larger "fabric" where each possible sample is point to point different from the other ones, yet visually they cannot be distinguished from each other no matter where in the fabric the samples are cut.

We like to believe that real-world images are mainly texture images, and that painting is the art of reconstructing nature from brush strokes, a form of texture. With such a perception, paintings can be optically created by superimposition of texture forms.

Optical Superimposition

Optics as described are thus being designed in the ODA Laboratory in collaboration with SmARTlens™ to combine textures, part of it being the scene while the other part is the man-made texture of a brush stroke or some similar effect. The brush strokes are optically encoded as a transparent texture pattern on a plate and positioned close to the film plane or relayed to the film plane. A new optical modeling has been created to describe the complete optical process,

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Augmented Reality Technology

Larry Davis, Yann Argotti, and Jannick Rolland

One of the most promising and challenging research areas is the development of applications where virtual environments enhance rather than replace real environments. This is referred to as Augmented Reality (AR). To obtain an enhanced view of the real environment, users wear see-through head-mounted displays (HMDs) to observe three-dimensional computer-generated objects that are superimposed on their real-world view.

As a driving application for the advancement of such technology, we are developing a Virtual Reality Dynamic Anatomy (VRDA) Tool. The VRDA Tool allows medical practitioners to visualize anatomical structures superimposed on their real counterparts, effectively allowing the practitioner to have "x-ray vision". To realize this effect, the medical practitioner wears a HMD that currently superimposes a computer graphics model of the knee on the real knee of a model patient. In the future, the tool will also be adaptable to other anatomical structures. In developing this technology, we have research efforts in the areas of HMD Development, tracking, visualization, and remote collaboration.

HMD Development

An important part of any AR application is the viewing device used. We are developing cutting-edge HMD technologies. We currently have a bench-mounted prototype HMD with custom optics that we use for visualization. Furthermore, we have recently completed the design of a novel, projective HMD to be used in medical AR applications. Another novel HMD we are deveolping is one that includes eyetracking capabilities. These two systems are unique among see-through head-mounted displays.

Tracking

Virtual and real objects must be placed *into register*, that is spatial coincidence, in AR environments. To correctly visualize knee-joint anatomy, the head of the medical practitioner must be accurately tracked. Additionally, the anatomy of the model patient must also be accurately tracked. We are currently developing a framework to accurately predict the accuracy and precision attainable from optical tracking probes (a rigid collections of markers). Moreover, we are developing methods to track non-rigid objects in virtual environments. Our laboratory is equipped with a commercially available optical tracking system, capable of sub-millimeter accuracy and precision.

Visualization

In AR applications, the computer-generated objects must be properly rendered to appear at the correct depth in the field of view of the user. Additionally, the complex models must move realistically. To this end we have extensively researched rendering method to properly display objects in three dimensions. Also, we have developed an in-house physical model of the knee so that the computer-generated knee moves accurately with respect to the model patient's knee. We currently render our models on two, high-end Silicon Graphics workstations.

Near-IR Multi-Photon Absorbing Organic Dyes, Multiphoton Microfabrication, 3-D Imaging and Photochemistry

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The quest for organic materials exhibiting high nonlinear optical (NLO) absorptivities has increased dramatically over the past several years. One nonlinear absorption process, two-photon absorption (2PA), is the subject of fast growing interest in the chemistry, photonics, and biological imaging communities. Several current and emerging technologies exploit the 2PA phenomenon, including optical power limiting materials, two-photon fluorescence imaging, two-photon photodynamic cancer therapy, and two-photon microfabrication. Emerging device technologies such as microelectromechanical systems and integrated sensors are placing increased demands on the development of materials processing and fabrication techniques. In response, the characteristic three-dimensional (3-D) spatial resolution of the simultaneous two-photon absorption (2PA) process is being harnessed for 3-D photoinitiated polymerization and microlithography. We have undertaken a comprehensive program to create organic fluorophores with high nonlinear absorptivities and develop nondestructive 3-D imaging techniques based on multiphoton fluorescence imaging. Our program includes two-photon induced polymerization as a means of microfabrication and two-photon induced (nonlinear) photochemistry for photodynamic cancer therapy and photochromism for holographic imaging.

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*(*We expect that these levels will rise in the future.)*

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