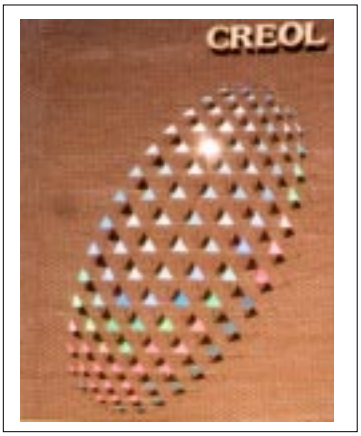
School of Optics/CREOL

HIGHLIGHTS

University of Central Florida



Fall 2001

www.creol.ucf.edu

Spray Cooling: Enabling High Average Power Diode Pumped Solid State Lasers

Mike Bass, Louis Chow and Dan Rini

Recent development of high efficiency, diode laser arrays to pump solid-state lasers enables the possibility of deploying high average power (>100 kW) lasers that are small enough to be mobilized on ground and air vehicles. An important issue that must be addressed is thermal management. Consider the following example of a hypothetical 100 kW diode pumped solid-state laser.

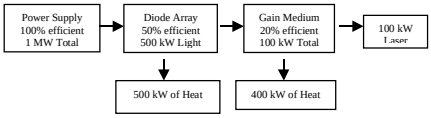


Figure 1. Power Budget

It is easily shown that a laser of this power level generates a tremendous amount of heat, even if generous diode and gain medium efficiency values are used. The vehicle that transports this laser weapon must be able to dissipate 9 times the laser energy! Laser weapon development must include a thermal management solution that provides both the removal of heat from the diode array and gain medium, as well as the dissipation of the collected energy into the surrounding environment.

To simplify this discussion and demonstrate the complexity of the issue, let us only focus on the 500

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Infinite Photonics, Inc. Selects Orlando for GCSEL Facility

Infinite Photonics, Inc. has selected the Central Florida Research Park, for its Grating Coupled Surface Emitting Laser (GCSEL) development facility. "We selected Orlando for its quality of life, qualified workforce, Florida's commitment to the photonics industry, and the quality of research staff and facilities at CREOL," stated Jeff Bullington, Infinite Photonics' President. "Our CFO, Bruce Garreau, was notified that we were certified by the Governor's Office as a Semiconductor Diode (Silicon) Facility and were exempted from sales and use taxes under the Florida's Semiconductor, Defense and Space Technology Facility program, and that helped seal the decision for us. We intend to ramp up product development, the GCSEL manufacturing capability in Florida, and develop additional sales, marketing and administrative infrastructure."

Infinite Photonics, Inc. develops and sells laser diodes based on its proprietary, patented and patent pending IP GCSEL technology platform. IP GCSEL product applications include high power pump lasers used for EDFA and Raman amplification, tunable lasers used in optical transmitters and receivers for telecommunications, and material processing applications. Researchers at CREOL and at IP are working on collaborative research projects involving this diode laser technology.

Director's Corner

Dr. Eric Van Stryland

Our Industrial Affiliate's Day was a roaring success. Everyone I spoke to praised our assembly of speakers – Arpad Bergh, Milton Chang, David Honey, and Richard Slusher. Please see the article on the Affiliates' Day by Martin Stickley.

We are always looking to improve our Affiliates Day as well as Affiliate offerings, so please contact me with your suggestions.

We are continuing to interview potential faculty in the photonics area. Shin-Tson (ST) Wu is one of our new hires in this area (see the last issue of Highlights for an article on ST). Several of the uses of his liquid crystal devices are for optical telecommunications. In addition to looking for photonics faculty, the University received an additional $2.5 million base funding for nanoscience and technology. These dollars are to be used for hiring faculty in this area. For optics, this means potential new faculty in the area of "nanophotonics".

We already have considerable expertise in this area with faculty members such as Glenn Boreman who just installed a new electron-beam lithography system for fabrication of nanoantennae for electronically controlled IR detector arrays, Eric Johnson who uses a stepper for lithography donated by Lucent for "nano-writing" diffractive optical elements onto various materials, Aristide Dogariu who studies and utilizes multiple scattering from nanoparticles, Leon Glebov who creates volumetric holograms from nanocrystal formation in glasses, Martin Richardson and Craig Siders who create ultrashort x-ray pulses to study the dynamics of nanoscale material interactions, and others. For example David Hagan and I use the nonlinearly-induced scattering of light from nanoparticles to protect sensors from damage caused by high power laser pulses. Ads for faculty in this area should come out soon and will be posted on our website.

In the area of local economic development, Optium, begun by faculty members Patrick LiKamWa and Guifang Li just opened its new 30,000 square foot facility in the Research Park next to campus. Its grand opening attracted a great deal of attention from venture capital firms from around the nation. (*See the article on Optium*.) In addition, Infinite Photonics of Warwick, RI has selected Orlando for its Grating Coupled Surface Emitting Laser (GCSEL) facility and will be moving into the Research Park. They have chosen this site in large part because of the potential interactions with the faculty, students and staff of the School of Optics/ CREOL – (*see the article on Infinite Photonics*.)

We look forward to working with both Optium and Infinite Photonics.

School of Optics/CREOL Hosts International Soliton Workshop

CREOL played host to the 3rd International Workshop on Solitons, March 22-24. This workshop is held approximately every18 months at different locations in the USA and Europe, usually in the vicinity of the OSA Topical Meeting on Nonlinear Guided Wave Phenomena, held in Clearwater Florida the following week. The workshop is a forum for addressing the latest developments in optical solitons, both spatial and temporal, and for stimulating interactions between researchers. Keynote speeches were presented by leading authorities on four specific topics, including overviews of Temporal Solitons and Communications (Akira Hasegawa), Cavity Solitons (Willie Firth), Discrete Solitons (Yaron Silberberg and Dick Slusher) and Spatial and Spatio-Temporal Solitons (Moti Segev). The participants then separated into four groups in which all individuals were given the opportunity to discuss their own, and other's work. This led to recommendations for areas that needed future development to the full meeting.

In order to stimulate interactions the participants shared meals, including an evening dinner cruise on the St. John's river. Seventy seven invited scientists from around the world participated in the meeting. Included, in addition to Americans, were participants from Australia, Japan, Taiwan, the United Kingdom, France, Germany, Belgium, Spain, Italy, Russia, the Ukraine, and Israel. Five faculty from CREOL and the Mathematics Department at UCF also attended, along with 8-10 local graduate students.

The workshop was organized by Marc Haelterman of Belgium, William Torruellas (Corvis Corp. and a former CREOL employee), and George Stegeman. The success of the workshop logistics was largely due to the work of Sarah Pimentel whose time was donated by the MURI on "Solitonic Gateless Computing".

Spray Cooling.... (cont.)

kW of heat that is produced by the diode array of our hypothetical 100 kW laser. We will not address the waste heat generated in the gain medium and the overall bulk of the chiller system required to dissipate the heat. These problems are separate issues and require different approaches as compared to handling the thermal management issues of the diode array.

To construct a diode laser array of this power level, we can consider using 100-W, 1-cm-long diode bars, at 20% duty cycle, arrayed with a 1 mm pitch (10 bars/cm). This will result in an array with an average power of 200 W/cm^2, and since a total power of 500 kW is required, the size of the array will need to be 2500 cm^2. This is an array with a dimension of 50 cm x 50 cm. This array could be broken up into several smaller arrays; however, the total heat load will not change.

To handle this large surface area array we will discuss two different thermal management techniques. The first approach utilizes a mature technology, which involves the use of conventional liquid water heat exchangers. A typical heat exchanger cools a diode array of 2 cm^2 and requires a water flow rate of approximately 4 GPM at 10ºC to maintain diodes of this power level within a desired temperature range.

This flow rate results in a pressure drop across the heat exchanger of approximately 30 psi. The large 500 kW diode array will require 1250 such heat exchangers. This will result in an overall water flow condition of 5000 GPM at 30 psi. To put this flow rate in perspective, 5000 gallons is the size of a small swimming pool and this quantity of water must be moved in one minute through the large bank of heat exchangers. A commercially available pump that will deliver 5000 GPM at 30 psi weighs 2400 lbs, is 6 ft long, 3 ft wide and requires 94,000 W (125 hp) of power to run the motor. This large and heavy pump is required to simply circulate the cooling water through the heat exchangers. This simple calculation shows that this standard cooling technique will not work when large diode arrays are scaled up from a few cm^2 to thousands of cm^2.

More recent technology involves the use of micro-channels that are etched into metal or silicon. These micro-channels are small passageways (100 μm by 100 μm) contained within the substrate that the diode bars are mounted onto. This technology is very effective in the acquisition of heat. The coolant flow rate is thus lower and is only limited by the allowable temperature rise within the diode array. However, since the micro-channels are very small, a large pressure head will be required to move the coolant, resulting in a large overall hydrodynamic power requirement. Also, typical micro-channel designs will have 20 to 50 passageways per diode bar. The hypothetical 500 kW diode array (in this example) is 2500 cm^2, with 10 bars/cm^2 for a total of 25,000 bars. With an average of 30 micro-channels per bar, a total of 750,000 channels will be needed. To ensure that all the emitters are at the same temperature, each of these 750,000 channels will need to have the same flow rate of water. It is very difficult to maintain an even flow distribution across such a large number of separate channels. Both the cold water heat exchanger and the micro-channel cooler approaches are used in many diode laser arrays in operation today. However, it is very likely that when these arrays are scaled to the 500 kW power level, and the cooling systems are scaled up to match, the supporting devices (pumps, chillers, etc.) will be much larger than mobile platforms can handle.

It is clear that the only technique to remove a large amount of waste heat with a low coolant flow rate is through a phase-change process. This is because the latent heat of vaporization is much larger than the sensible heat over a few degrees temperature increase (the temperature rise being limited by the strict requirement of temperature uniformity over the diode array).

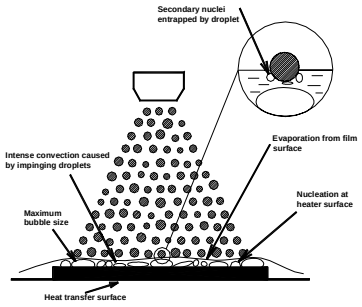

Figure 2. Spray Cooling Heat Transfer Mechanisms

Both pool boiling and spray cooling are two-phase heat transfer methods that can remove large amounts of heat from a surface at relatively low surface superheats. The surface superheat is defined as the difference between the surface temperature and the liquid saturation temperature. Pool boiling refers to a boiling process that takes place in a submerged environment where bubbles grow from heated vapor trapped in cavities on the surface. For pool boiling with water, the maximum heat flux, or critical heat flux (CHF), is known to be about 100 W/cm^2 [1]. This heat flux limit occurs when the rate of vapor generation is too fast for the vapor to break through the liquid layer and escape from the surface, resulting in vapor blanketing at the heated surface. An effective way to avoid this vapor blanketing is to reduce the liquid barrier by maintaining a thin liquid film. On the other hand, it is critical to make sure there is adequate liquid supply as phase change occurs at the surface. The particular form of two-phase cooling that we address here is spray cooling in which a dense spray of liquid droplets is deposited on a surface through an atomizer/nozzle (see Figure 2). The

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Spray Cooling.... (cont.)

spray droplets not only keep the surface wet, but also help remove the vapor bubbles by puncturing them. Spray cooling CHF can reach beyond 1000 W/cm^2 for water [2]. Spray cooling is capable of removing at least ten times more heat flux than pool boiling at the same superheat, and also exhibits a much higher heat transfer coefficient. A compilation of results comparing spray cooling to pool boiling can be seen below in Figure 3.

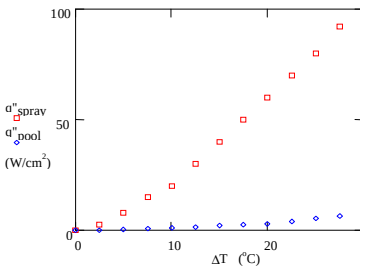

Figure 3. Spray Cooling vs. Pool Boiling

The use of spray cooling allows all the diodes in an array to be cooled in parallel to a common temperature. This results in diode laser arrays in which all the diodes emit the same wavelength. Utilization of spray cooling also makes possible smaller, lightweight, high-power diode laser arrays that can operate at lower temperatures than are otherwise possible. With lower temperature operation one gains the added benefits of higher efficiency and longer laser life.

Under AFRL, BMDO and Army sponsorship, CREOL and Rini Technologies Inc. (RTI) are developing and demonstrating the spray cooling technique for cooling diode laser arrays. Spray cooling can transfer the same amount of heat as conventional cooling systems but with a greatly reduced input of fluid and pressure. Test data were obtained for a heat load of 400 W over a 2-cm^2 area, a heat flux similar to the example given above. Figure 4 contains a comparison of the coolant flow rates for a standard convection cooling system, a micro-channel cooler and a spray cooling system for a 400-W diode array.

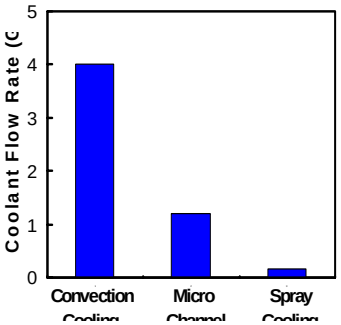

Figure 4. Coolant Flow Rate

To keep the surface temperature at lower temperatures, spray cooling can be used at lower system pressures and with a wide variety of fluids. These fluids can be forced to boil at varying temperatures by changing the system pressure. Therefore, the combination of fluid and pressure will determine the temperature of the diodes. Figure 5 illustrates the cooling rates and operating temperatures for three different operating conditions. The highest heat flux data shown here should not be taken as the critical heat flux due to limitations with the experiments. The CHF value for water is generally 1000 W/cm^2 (even at lower pressures) and ammonia is expected to be around 600 W/cm^2.

Let us now turn our attention back to the example of the hypothetical 500-kW diode laser array. If spray cooling were used as the cooling technique, what would be the size and weight savings from the large and massive pump and coolant that is required to circulate chilled water through conventional heat exchangers?

The spray performance shown in Figure 4 results in a total fluid flow rate of 400 GPM to cool the 2500 cm^2 diode array. A commercially available pump that will produce this flow condition weighs 310 lbs, is 22" long, 12" wide and draws 7000 W (about 10 hp) of power; a considerable reduction in size and weight. The above calculations were performed assuming that the laser is cooled continuously and that it may be run for an indefinite period of time. Continuous operation will require a massive chiller unit to dump the heat load to the ambient.

CREOL and RTI are developing a second method of spray cooling that will further reduce the coolant flow rate by at least a factor of five from the values already outlined above. It also has the potential to be implemented with no moving parts using a simple plumbing and control system. This new technique will also not require the operation of a chiller unit, but will allow for low temperature operation. CREOL and RTI are exploring the implementation of this second spray technique to more closely match the performance requirements of high power laser weapons.

Figure 5. Cooling Performance of Water

References

1. Carey, Van P., Liquid-Vapor Phase-Change Phenomena, Hemisphere Publishing Corporation, New York, 1992.

2. Chow, L. C., Sehmbey M. S. and Pais M. R., "High Heat Flux Spray Cooling," Annual Review of Heat Transfer, Vol. 8, Chapter 6, pp. 291-318, 1997.

CREOL develops 4 micron laser for U.S. Air Force

Hans Jenssen and Rita Peterson

Rita Peterson

Laser sources in the 3-5 micron region have been of interest to the Air Force for infrared countermeasures and eyesafe lidar, as well as having commercial applications in such areas as remote sensing and environmental agent detection. Many of these uses require good beam quality, high average power, high efficiency, and a compact, reliable and rugged package. Nonlinear frequency conversion techniques and semiconductor lasers can access this spectral region, but often cannot satisfy the other system constraints. As an alternative, we are developing a room-temperature, all-solid-state source lasing directly at 4 microns.

Our approach employs BaY_2F_8 doped with Ho^{3+} (Ho:BYF), and resonantly pumped by a pulsed Cr:LiSAF laser tuned to the Ho absorption peak at 890 nm. Figure 6 shows a boule of Ho:BYF fresh from the furnace. Resonant pumping of rare-earth-doped solid state lasers, sometimes referred to as linear down-conversion, is an established means of obtaining high-efficiency,

Figure 6 BYF boule

high energy sources [1,2,3,]. Figure 7 shows the relevant 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 µsec vs. 5 msec), leading to two significant laser design constraints: 1) a

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Research Experiences for Undergraduate Students (REU)

by Susan Hill

The School of Optics/CREOL successfully recruited students, nationwide, to be a part of our summer program of research and training in optics and lasers. This summer both a domestic and an international program were offered. Both REU programs are funded jointly by the National Science Foundation and the School of Optics/CREOL. The students that participated in the domestic program at the School of Optics received a $3,900 stipend and either a housing allowance or campus accommodations. This summer, there were 10 students from the U.S. and five from France participating in the domestic REU program. The program included coursework on the basic principles of optics, laser and optical materials, and seminars presented by our faculty. Donald Jones, a UCF philosophy professor, led weekly classes in ethics. Industrial visits were also included. We visited Audio Visual Imagineering, CIRENT/AGERE and Crystal Photonics, Inc. ZYGO Corporation presented a 2-day lecture and lab demonstration on equipment in Dr. Jim Harvey's and

2001 REU Students

Dr. Kathleen Richardson's labs. The program concluded with a poster session in which the students presented their research results. David Hagan, Kathleen Richardson and Peter Delfyett are organizers for the domestic program.

The students that participated in the international program (in France) received a $3,800 stipend; $700 for travel and accommodations were provided by the host institution. A two-day workshop was held at the Institut d'Optique in Orsay, France. The three students and their advisors from France attended along with several students from France that participated in the domestic program at the School of Optics/CREOL in the summer of 2000. The international program is a new and exciting program. Five students from France are chosen to participate in the domestic REU program at the School of Optics/CREOL and five students are chosen from the U.S. to participate in the international REU program held in France. While spending the summer in France, the U.S. students had an opportunity to learn more about the French culture and language and work with some of the most prestigious professors in France. At present, there are five institutions in France that are involved with the program. Kathleen Richardson organizes the international program.

Our web site is www.creol.ucf.edu or if you would like information mailed to you please contact us at 407-823-6800.

Dr. Kathleen Richardson teaching Optical Materials Class.

CREOL develops 4 micron laser...(cont.)

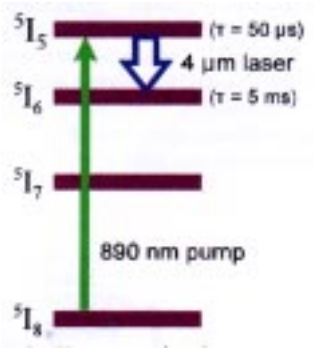

Figure 7. HO Energy Levels

pump pulse on the order of 50 µsec for efficient lasing, a good match for the Cr:LiSAF laser, and 2) an upper limit on repetition rate to allow for emptying of the lower laser level.

The upper laser level lifetime can be maximized by judicious choice of host crystal. The longer the lasing wavelength, the more easily the laser transition will be bridged by multiphonon relaxation. A host crystal with low phonon energies will therefore result in less nonradiative relaxation, a longer upper laser level lifetime, and a greater chance of successful lasing. Our research has focused on fluorides since they have lower phonon energies than other hosts such as oxides, and on BYF in particular where the Ho $^5I_5$ lifetime is 50 µsec as compared with 20 µsec in the better-known host crystal $YLiF_4$ (YLF) [4].

The benefits of BYF come at the expense of its monoclinic structure. In a monoclinic crystal the three crystallographic axes, denoted a, b, and c, are not orthogonal, and differ from the principal axes of the refractive index tensor, denoted x, y, and z, although the b and y axes coincide in BYF because of symmetry constraints. As a result, both absorption and emission are strongly anisotropic, with maxima which may not coincide with any of the principal axes, and moreover which differ for each transition. Determining the direction of maximum absorption or emission is generally impractical, and it is better simply to choose a convenient orthogonal set of axes to measure spectra for polarization along each axis, and to orient laser samples based on the results. A thorough discussion of principal axes in monoclinic crystals is found in [5].

Figure 8. Absorption in 10% Ho:BYF.

Figure 8 shows absorption of Ho:BYF in the 890 nm pumping region. Absorption is strongest along the [001] direction, and weakest along the a-axis. Based on these data, laser samples were fabricated for propagation along a, with pump polarization along either b or [001]. This orientation is convenient since BYF grows well along the a-axis, simplifying the cutting of samples with sufficient length.

In laser experiments to date, using crystals doped with 10% and 20% Ho and cut in various orientations, a maximum output pulse energy of 30 mJ was obtained, and a slope efficiency of 14% with repetition rates up to 5 Hz. In our initial experiments, the high reflector was coated onto the input face of the laser crystal. Laser threshold was low, less than 10 mJ of pump energy, but the HR coatings on the crystals were prone to damage, caused at least in part by focusing of the pump, hot spots in the pump, and nonuniformity of the coatings. Damage evaluation of uncoated Ho:BYF crystal indicates that the material is quite robust, surviving power densities in excess of 50 kW/cm^2 before cracking internally, with the polished incident surface still unmarred.

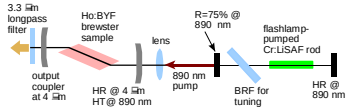

Figure 9. Ho:BYF Brewster cavity laser.

To avoid coating damage and to facilitate scaling to higher output energies the laser resonator was modified to use a Brewster-cut laser crystal, and to position the pump waist well away from coated surfaces. This configuration is shown in Figure 9. Initial experiments with the Brewster resonator show it to perform as well as the original design, and without the problem of damage. Lasing was characterized for samples doped with 10% and 20% Ho, with the 20% samples consistently providing more output, likely because of greater pump absorption. Samples cut for polarization parallel to b and parallel to the [001] direction performed equally well. The lasing wavelength was seen to depend on both polarization and outcoupler reflectivity, with measured values from 3883 nm to 3942 nm, raising the attractive possibility of tuning the output from this laser.

A key feature of the Ho:BYF laser is that it operates without any cryogenics. In fact, so far we have operated it without any real thermal management - the crystal simply sits on an aluminum mount. In spite of the promising results obtained, the effects of this neglect have been apparent; pulse energy falls off rapidly with each successive pulse, reaching a steady-state value that can be barely half that of the first pulse even at repetition rates of only a few Hz. Scaling to higher output energies and repetition rates will clearly require effective heat removal. Upcoming research will address this issue, as well as making improvements in the cavity design to increase output energy, and continuing the systematic study of concentration and sample orientation to include samples doped with 15% and 30% Ho.

Development of the four micron laser is conducted in collaboration with, and with support from AC Materials in Winter Park. FL,

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The School of Optics/CREOL Seeks Photonics Faculty

The University of Central Florida (UCF) in Orlando, Florida is making a major expansion into the burgeoning field of Photonics and is seeking leaders and team players to help form a faculty research and education workforce for the photonics revolution of the 21st century. UCF, with 34,000 students, is seeking multiple scientist/engineer educators to help lead the School of Optics/CREOL's activities in photonics education and research. This major new initiative will significantly expand our five member faculty team in photonics and optical communications and seek faculty at Asst./Assoc./Full professor levels including PREP (Provost Research Enhancement Program) positions designed for senior research faculty. Desired areas of research include: semiconductor devices, MEMS, optical networking, and systems design. A combination of Industrial and/or Academic experience will be considered in filling one or more of these positions.

The School of Optics/CREOL was established in 1987 as the State University System's Center of Excellence in research and education in optical sciences and engineering. The School has attained national and international prominence for scholarship in optics research and education. Its mission is to provide the highest quality education and scholarly fundamental and applied research in optics, and support the development of high technology based industries. The School has 24 academic faculty members and 100 graduate students. Fifteen faculty members are Fellows of one or more of the leading optics, physics and electronics societies and our graduates are in great demand. Current expertise in optoelectronics, lightwave technology, nonlinear optics, diffractive optics, IR systems, glass science, ultrafast technology, etc. complements this new thrust in optical telecommunications. Other areas of research include FEL technology, X-ray sources, materials processing (AMPAC, another UCF center, includes a major materials characterization facility), virtual reality, 2 and 3-D displays, optical system design, etc.

The School is housed in a state-of-the-art 83,000-sq. ft. building dedicated to optics research and education and equipped with over $35 million of state-of-the-art equipment. Total annual expenditures exceed $9 million, of which $3 million is university base funding. The School of Optics plays a key partnership role with government agencies, and with national and Central Florida industries, including workforce development and economic development in partnership with the Florida High-Tech Corridor Council and the Florida Electro-Optics Industry Association (FEOIA). Additional information is available at http://www.creol.ucf.edu.

Applications, with a curriculum vitae, and a list of three references should be sent to Chair of the Photonics Search Committee, School of Optics/CREOL, University of Central Florida, 4000 Central Florida Blvd, Orlando, FL 32816-2700. E-mail inquiries can be directed to photonics@creol.ucf.edu. These positions are available immediately.

UCF is an affirmative action employer. Women and minorities are encouraged to apply. As an agency of the State of Florida, UCF makes all application materials, including transcripts, available for public review upon request.

Optium Moves into New Headquarters in The Research Park

Optium moved into their new headquarters in the Central Florida Research Park last month. The co-founders are two of our faculty, Guifang Li and Patrick Li Kam Wa. Leaders of several capital venture firms from Boston to Silicon Valley came to tour Optium's new 30,000-square-foot facility. M.J. Soileau, UCF's VP for Research stated, "I doubt that there has ever been so much venture money in one room anywhere in Florida." Including a $35 million deal announced last month, Optium has raised about $50 million in venture cash since November. The company expects to grow from 40 to almost 150 by year's end. The company is led by Paul Suchoski, a former executive of JDS Uniphase, and now a member of the School of Optics/CREOL Board of Visitors. Its makes next-generation optical signal-processing components for fiber networks for customers such as Nortel, Alcatel, and Lucent Technologies. UCF has a licensing agreement to help commercialize the technology. "I hope this marks the beginning of many partnerships with the great companies and organizations that Optium has brought to our region," Soileau said.

Schwartz Fellowship Fund

The Schwartz Fellowship Fund has been created in honor of Bill Schwartz for all he did to help CREOL, and the laser and optics industry in Central Florida. Income from it will support student fellowships. Dr. Van Stryland would be happy to discuss a donation with you at 407-823-6834.

An Outstanding Affiliates Day Meeting

Annually, the School of Optics /CREOL invites its Affiliates and other members of the laser/optics and photonics industry to visit CREOL and catch up with all that is going on. Our recent Industrial Affiliates' Day, held on April 6, 2001, was one of our best. This year, we focused on photonics and managed to garner a fine array of invited speakers to give about 200 attendees an excellent overview of the past, present and future in this exciting area. During our morning plenary session they got to hear Richard Slusher of Lucent Technologies on "Quantum and Nonlinear Limits for Optical Communications: They're closer than you think!", Arpad Bergh of the Optoelectronics Industry and Development Association (OIDA) on "The Optics and Photonics Industry", Milton Chang of New Focus on "Entrepreneurship in Optics and Photonics" and David Honey of the Defense Advanced Research Projects Agency on "Future Directions in Photonics." UCF Vice President for Research, M.J. Soileau, also gave a very interesting presentation on "Florida's Push Towards a Knowledge-Based Economy."

After the morning session, we all returned to CREOL for a delicious lunch, generously provided by one of our sponsors for the day's activities: Digital Lightwave, Inc. of Clearwater, Florida. Digital Lightwave was also one of the thirteen exhibitors brightening our lobby with colorful and informative displays that day. (By the way, we would like to again thank all of Affiliate Day 2001's participants and sponsors for helping us put on a good show. Check out some photos and the full list of sponsors elsewhere in this issue.)

Milton Chang with Brant Gray from Applied Photonics

After lunch, Dr. Eric Van Stryland, our Interim Director, presented awards to graduate students Jeremy Ellis (Litton Fellowship), Irina Puscasu (Student of the Year) and Ferenc Szipocs (Charles Gramm Travel Award) before giving his annual overview of our current research activities. Five excellent student presentations followed his overview: Christopher Depriest on "High Quality Optical Sampling Streams from a Semiconductor Diode Ring Laser", Mohammed Al-Mumin on "Self-Pulsating DFB Lasers for Broadband Wireless Networks", Gabriel Popescu on "Low-Coherence Dynamic Light Scattering for Particulate Systems", Laurent Vaissie on "Side-Polished Fibers for Integrated Micro-Optics Applications", and Irina Puscasu on "Transmission and Enhanced Absorption of Frequency-Selective Surfaces in the Infrared."

During the rest of that afternoon, attendees talked with exhibitors or strolled along the balcony viewing the twenty-one Poster Presentations and chatting with their student presenters. Many of them also toured our research facilities and/or saw one of the many fascinating optics demonstrations presented by our principal research groups, before returning to the Lobby for the wine and cheese reception. The day wasn't over for some. It was a beautiful Spring evening for a stroll across campus to the annual dinner meeting of our School of Optics/CREOL Board of Visitors.

By all accounts, it was an excellent day for everyone. We were delighted to see over 90 visitors from outside of UCF. They came from as far away as Turkey and Paris and represented over 50 companies. Please look for the snapshots of some of our visitors, students, and faculty on the following pages.

David Hagan checking out Claudia Mujat's poster.

Sponsors of Industrial Affiliates Day 2001

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EDC of Mid-Florida
Florida Electro-Optics Industry Asso.
Melles Griot, Inc.
Noah Industries, Inc.
Optical Research Associates
OptXCon, Inc.
Orlando Venture Capital, Inc
Photonics Spectra
Tutle International Tech Marketing
Zygo Corporation
Zygo TeraAutomation

An Outstanding Affiliates Day Meeting

Richart Slusher, Martin Stickley and M. J. Soileau.

Balcony Poster Displays

Afternoon Reception

V.P. for Research, M. J. Soileau, and Bruce Soileau of Analog Modules.

Faculty members Aristide Dogariu and Glenn Boreman with Kathleen Stepan, from Digital Lightwave, Inc..

Roger Flannigan, Brant Gray, and Brian Hoekstra of Applied Optics.

Digitial Lightwave, Inc. Exhibit

Melles Griot Exhibit

FEOIA Exhibit

Attendees chat with exhibitors.

CREOL Lobby

Amanda Lomanaco of LIA Marketing

The School of Optics/CREOL Seeks Nano-Photonics Faculty

The University of Central Florida (UCF) in Orlando is making a major expansion into the burgeoning field of nanoscience and technology. As part of this program, the School of Optics/CREOL (Center for Research and Education in Optics and Lasers) will be adding tenure/tenure track faculty in the nano-photonics area. We are interested in looking at qualified individuals in this broadly defined research field involving nano devices/materials/structures in optics. UCF, with 34,000 students in Orlando, seeks faculty at Asst/Assoc/Full professor levels including PREP (Provost Research Enhancement Program) positions designed for senior research faculty.

The School of Optics/CREOL was established in 1987 as the State University System's Center of Excellence in research and education in optical sciences and engineering. The School has 25 academic faculty members and 100 graduate students. The School is housed in a state-of-the-art 83,000-sq. ft. building dedicated to optics research and education and equipped with over $35 million of state-of-the-art equipment. Additional information on the School is available at www.creol.ucf.edu.

Applications, with a curriculum vitae, and a list of three references should be sent to Chair of the Nano-Photonics Search Committee, School of Optics/CREOL, University of Central Florida, 4000 Central Florida Blvd, Orlando, FL 32816-2700. E-mail inquiries can be directed to nanophotonics@creol.ucf.edu. These positions are available immediately.

UCF is an affirmative action employer. Women and minorities are encouraged to apply. As an agency of the State of Florida, UCF makes all application materials, including transcripts, available for public review upon request.

Industry, Students and Pizza!

Recently, we had had several of our "Industry, Students and Pizza Days" – an event in which industry comes to CREOL and briefs students during lunch time on the 'who/what/where/how' of their company, and while doing so, the students (and faculty too!) are devouring pizza provided by the company. It seems to be an excellent way to get the attention of the busy students and for the company to get their message across about why students should come to work for them. The most recent company to do this was Edmond Industrial Optics of Barrington, N.J. Greg Hollows gave an overview of the company and its products to a hungry audience. Prior to their visit was PSI, Incorporated of North Andover, Massachusetts, plus their newly formed spin-off, Confluent Photonics, also of Massachusetts. Dr. Bob Weiss gave an overview of PSI's business and activities, and David Hardwick, the new CEO of Confluent, did so for his company. By all accounts, it was a very successful event – for the price of about $200 worth of pizza, PSI and Confluent made a number of promising contacts with students, and hired a away one of our visiting research scientists. Both companies got to know the CREOL faculty and our activities better. While PSI is an Affiliate, your company does not have to be an Affiliate to do this, we encourage prospective Affilates to visit also.

School of Optics/CREOL
Highlights

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School of Optics/CREOL
P. O. Box 162700
Orlando, Fl 32816-2700
(407) 823-6800
FAX (407) 823-6880
http://www.creol.ucf.edu

Faculty News

Dr. Peter Delfyett served as the Guest Editor for the March 2001 issue of Optics & Photonics News (OPN) that focused on fiber-optic communications. Included were articles on the early days of lightwave systems, undersea cable networks, the role of semiconductor optical amplifiers, optical metrology for WDM, optical code-division multiplexing, WDM terabit technologies, and lightwave machines for optical networks. Peter was also the Guest Editor for the first issue of OPN Trends, a supplement to OPN News. Featured was - you guessed it! – Fiber Optics. Peter was also invited to address Florida's Economic Development Corporation in Boca Raton in May. The EDC, a public/private partnership specializing in providing strategic business development services to emerging technology companies, sponsors a 'Showcase' – a series of seminars on technology and science. Peter spoke on the recent revolution in communications using fiber optics.

Brian Thompson of the University of Rochester wrote a fine review for OPN (March 2001) of the Handbook of Optics, 2nd Edition, volumes III and IV, edited by **Drs. Michael Bass** and **Eric Van Stryland** of CREOL and Jay M. Enoch and William Wolfe. He commented that "the OSA and the editors are to be commended for producing this four-volume set. It is an extremely important addition to our literature…..This one linear foot of shelf space goes a long way toward defining our field of optical science and engineering and helping to counter the fragmentation of our discipline".

Drs. Eric Van Stryland and **David Hagan** were co-recipients of a 2001 R&D 100 Award for a "Tandem-Configured Solid-State Optical Limiter". The other co-recipients were from Los Alamos National Laboratory. The R&D 100 awards are given annually by Photonics Spectra magazine. This award helps to recognize the years of work by Eric and Dave (and many others at CREOL) on developing a widely applicable optical device for limiting to safe levels the peak laser irradiance that can enter the pupil of the eye.

Dr. George Stegeman, in conjunction with Lluis Torner of the Universitat Politecnica de Catalunya in Barcelona, Spain, has written an article in the June 2001 OPN for the non-specialist laser physicist on 'Multicolor Solitons' in the hopes of convincing others that these are real and that commercial applications might not be far off. George is also the PI on a Multidisciplinary University Research Initiative on solitons, a review of which was held at CREOL in March 2001. A report on this meeting is found on page 2 of this issue of Highlights.

The Breault Research Organization in Arizona has created a new product, the OpticsReport. It is issued quarterly. Issue 3 of volume 1 addresses the future for Augmented Reality Displays (ARDs) – devices that combine what the user sees in the real world with computer-generated images. This issue features the work of **Dr. Jannick Rolland** and her group at CREOL. They are miniaturizing the optics and developing ARDs with fully integrated eye tracking, that creates high-fidelity, augmented realities as a new tool for physicians.

Two students, Ed and Charlene Sarver, in the geometrical optics class last fall and the lens design class this spring taught by **Dr. Jannick Rolland**, applied for and won the Optical Research Associates' annual competition for lens design. Their submission, "New CODE V Macro: Pentaprism with Roof", won them a $4000 prize. This will be announced at the SPIE Annual Meeting in August. Congratulations to the students and to Jannick for her role in encouraging and guiding their submission.

Dr. Jannick Rolland won the UCF Centers and Institutes Researcher of the Year Award for 2001. Congratulations again to Jannick!

Dr. Nabeel Riza, Professor of Optics and Electrical Engineering Chaired the SPIE Optics in Computing & Processing Working Group's recently concluded Special Panel on "Optical Technologies for Wireless Communications" at the SPIE Annual Meeting, San Diego, August 1, 2001. The distinguished panelists included Prof. S. Fainman (UC-San Diego), P. MacManamon (Scientist, Wright Labs-US Air Force), S. Mecherle (CTO, fSona), E. Korevaar (CTO, Optical Access), and H. Willebrand (CTO, LightPointe).

Dr. Guifang Li has received notification from the National Science Foundation that the major proposal for Integrative Graduate Education and Research Training (IGERT) submitted by UCF in January will be funded. Co-PIs include Dr. Mostaga Bassiouni of Computer Science, and Drs. Peter Delfyett, Patrick LiKamWa, and Jim Moharam of CREOL. The program will support graduate students in Optical Communications and Networking and will involve students and faculty from the Departments/Schools of Mathematics, Statistics, Optics, Physics, Materials Science, Electrical Engineering & Computer Science, and Education. Congratulations to the IGERT team!!

CREOL develops 4 micron laser...(cont.)

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CREOL Student News

Recently the CREOL IEEE/ LEOS Student Chapter sent a letter to Dr. Philip J. Anthony, President of IEEE/LEOS, with a suggestion concerning how membership in LEOS might be increased: if a person is already a member of another technical society, that person can be made an Affilliate Member of LEOS without paying IEEE and LEOS dues for up to one year. The suggestion was adopted by LEOS and will certainly attract many CREOL students from disciplines other than electrical engineering as new 'Affiliate Members' of LEOS. This applies to any member of another society – not just student members. The CREOL Student Chapter was recognized and praised by Dr. Anthony in a recent issue of the IEEE/LEOS Newsletter for putting forth this suggestion.

CREOL has instituted a 'Student of the Year' award. This was based on their total performance, that is in the class room and also on their research. This year there were three finalists: Irina Puscasu in Dr. Boreman's group, Gabriel Popescu in Dr. Dogariu's group, and Sergey Polyakov in Dr. Stegeman's group. They each gave an oral presentation on their work. The final decision by the faculty was a tough one, but ultimately the winner was Irina Puscasu. Congratulations to Irina and also to Gabriel and Sergey for their fine work!

CREOL Graduates

The following CREOL Graduate Research Assistants have recently achieved educational milestones:

First Name	Last Name	Advisor	Program	Degree
Spring 2001				
Jennifer	Evans	Delfyett	Optics	MS
Camilo	Lopez	Silfvast	Optics	MS
Kevin	Zollinger	Bass	Optics	MS
Erdem	Ultanir	Stegeman	Optics	MS
Zahid	Yaqoob	Riza	Optics	MS
Steve	Dunn	Moharam	EE	PhD
Summer 2001				
Raluca	Negres	Hagan/ Van Stryland	PHY	PHD
Iulian	Codreanu	Boreman	Optics	MS
Arnaud	Zoubir	M. Richardson	Optics	MS
Laurent	Vaissie	Johnson	Optics	MS
Ferenc	Szipocs	Bass	Optics	MS
Adela	Apostol	Dogariu	Optics	MS
Bojan	Resan	Delfyett	Optics	MS
Te-Yuan	Chung	Bass/Chow	Optics	MS
Robert	Iwanow	Stegeman	Optics	MS
Waleed	Mohammed	Johnson	Optics	MS
Donald	Jacob	Moharam	Optics	PHD
Mohammed	Al-Mumin	Li	OSE	PHD
Ma'an	AL-Ani	M. Richardson	PHY	PHD
Susan	Machinski	K. Richardson	MMAE	MS
Roman	Malendevich	Stegeman	PHY	PHD

Books, Book Chapters, Patents

Book Chapter:

G. Boreman, "Basic Wave Optics," in Handbook of Optical Engineering, Marcel Dekker, 2001.

Books:

G. Boreman, Modulation Transfer Function in Optical and Electro-Optical Systems, SPIE Press, 110 pp., 2001.

Patents:

M. Bass, "A Methode of Producing an Array of Diode Lasers so that they are Coherent with Each Other," Submitted 6/02/01.

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D. K. Sengupta, N. R. Quick, and A. Kar, "Laser Conversion of Electrical Properties for Silicon Carbide Device Applications," J. Laser Applications., 2001, Vol. 13, pp. 26-31.

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