UCF College of Optics and Photonics
CREOL & FPCE

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# HIGHLIGHTS

## Research on Specialized Glass Enables New Approach to Laser Design

In spite of the continuing advances in laser technology and laser applications, the golden dream of laser designers is still just beyond reach: to produce a compact laser of extreme high power with an extremely narrow spectral width and angular divergence. The basic factor limiting this development is the multimode structure of laser radiation at high levels of pumping; but this limitation is now being overcome in the work of Dr. Leonid Glebov and his colleagues.

Dr. Glebov, and his Photoinduced Processing Lab (PIP) group at CREOL (shown above) are developing photo-thermo-refractive glass (PTR) -- glass that has unique properties. These properties allow the creation of high-efficiency holographic elements which can convert multimode lasers into light sources with extremely narrow spectral width and angular divergence. PTR glass Bragg gratings are thermally-stable up to 400°C, their resistance to continuous laser radiation exceeds 10 kW/cm, and the laser-induced damage threshold is 40 J/cm$^2$ for an 8-ns-pulse width. Recent work has reduced the absorption of PTR glass in the near infrared region down to $10^{-4}$ cm$^{-1}$ and increased the diffraction efficiency to above 99%. The use of PTR Bragg gratings by a number of research groups at CREOL, and at various universities and companies in both the USA and Europe, has enabled the achievement of record values for brightness for semiconductor, fiber, and solid state lasers in a wide variety of regimes -- from CW to femtosecond pulses.

This research has been so successful that the CREOL researchers have established a spin-off company, Light Processing & Technologies, Inc., which is now doing business as OptiGrate. This privately held company is engaged in the development and fabrication of robust high efficiency volume diffractive gratings for optical beam control in high power laser systems, optical communications and processing. Optigrate was established with the goal of commercializing high-efficiency holographic elements (commonly -- volume Bragg gratings) by means of the PTR process developed at CREOL. Dr. Glebov, who co-authored the first publication on the discovery of the photo-thermo-refractive

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INSIDE:



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APRIL 18, 2008

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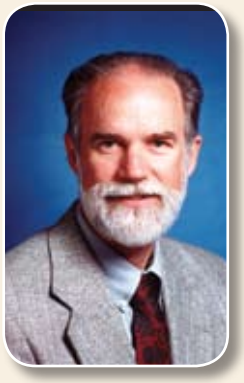

# Dean's Corner

## Eric W. Van Stryland

After our whirlwind of spring activity in the 2007 round of Florida Centers of Excellence funding, -- winning $4.5M for a new Laser Technology Institute, renaming and dedicating the institute the "Townes Laser Institute (TLI)", and hiring a Florida "21st Century Scholar" – Daniel van der Weide from the University of Wisconsin (more on Dan in the next Highlights) – we are settling down to hire the other needed faculty members for the TLI and our other initiatives. We currently have three search committees working on this (integrated photonics, quantum optics, and biophotonics) and are starting the search for laser scientists/engineers. And I can't forget the search for my replacement as Dean of the College. It is, and will continue to be, a very busy time of interviewing -- and thus eating too much at various lunches and dinners with the candidates!

As I near the end of my tenure as Dean, I am reflecting on my career here. Without a doubt, what I am proudest of is my involvement in hiring our excellent faculty. In fact, until MJ Soileau took the position of VP of Research and Commercialization, I was the chair of the standing search committee, so I have had a hand in the hiring of every faculty member at CREOL but one. This faculty has done exceedingly well as evidenced by CREOL's huge success and reputation for which the faculty is responsible. I am quite happy to rejoin them!

I would also like to say a few things about the economic development that made possible the winning of the first two rounds of Florida's Centers of Excellence program. As I have said before, the State of Florida funds higher education because of workforce development and economic development, not just for the sake of pure education. We have worked hard at CREOL to engage the optics/photonics business community. This started under MJ Soileau's tenure and has continued under mine. Several companies have spun off from CREOL research; while other companies have licensed CREOL technology. In the following paragraphs, I give a couple of recent examples, but you might also take a look at the article on tech transfer at the University of Central Florida on pages 12-13 in the October issue of OSA's Optics & Photonics News. For a great example see our cover story on Leon Glebov's CREOL research group and his spinoff company OptiGrate, which received the 2007 William Schwartz Industry Innovation Award.

In the October issue of Scientific American (p.30), you can read about the CREOL group of Shin-Tson Wu and his work with Research Scientist Hongwen Ren on adaptive lenses. Go to http://www.sciamdigital.com/index.cfm? Then click on Archive→ 2007→ October→ Liquid Zoom for a web preview. This technology, which has been licensed by Holochip Corporation, is also written up in the July issue of Photonics Spectra (p. 20). See http://www.holochip.com.

In an article in the June 4, 2007 issue of Business Week, startup company Raydiance, which uses Peter Delfyett's technology for ultrashort pulse lasers, mentions UCF's "state-of-the-art labs", and that "ultrafast lasers have enormous promise". They site this technology as one of the top ten 'breakthrough' technologies. Article link:

http://www.businessweek.com/magazine/content/07_23/b4037063.htm Slideshow link: http://images.businessweek.com/ss/07/05/0524_laser/index_01.htm

Another place you might check to learn about CREOL, as well as local high tech industry, is the Florida High Technology Corridor Council's website at http://www.floridahightech.com.

Finally, CREOL led all other UCF units in FY 06-07 in the most revenue earned by a unit for technology transfer related activities. "Technology transfer" is clearly one of the key elements of our effective partnerships with industry and a foundation element of our success over the years.

As part of the original Florida Photonics Center of Excellence (FPCE) proposal, we set up an endowment to fund "FPC Professorships". This endowment funds Professorships (5-year renewable terms) to reward those faculty members who best exemplify the objectives of the TDA (Technology Development Act of the State of Florida) – that is, economic development. Yes - the Professorships were awarded. They are for: Aristide Dogariu, Leon Glebov, Guifang Li, and Jannick Rolland.

I also gathered information from several faculty members to assemble an article for the June 2007 issue of Photonics Spectra on Pgs 74-78 giving a sampling of research at CREOL. On page 37 of that issue, you can find a news article on the dedication of the Townes Laser Institute. CREOL researchers have been in the news on other recent occasions as well. For example, in the July issue of Photonics Spectra, pages 85-88, Mike Bass and Martin Richardson discuss "Lasing in a Gain-Guided Index-Antiguiding fiber". On page 51 of the July/Aug issue of OPN see "UCF Dedicates Laser Institute to Townes". In the same issue on page 63 see the obituary of our friend, mentor and 'lifetime' affiliate, Arthur Guenther. Noted there are his contributions to CREOL; including his help in launching the School of Optics, which paved the way for our College. And, in the July issue of Physics Today, see on page 75 the notice of M.J. Soileau winning the Esther Hoffman Beller Medal of the OSA.

I am pleased to report significant progress in the reinvigoration of the

Continued on page 3

## COVER STORY, Continued...

phenomenon in a doped silicate glass, and recorded the first volume hologram in this material in 1989, is a company co-founder and the current President and processing. Optigrate was established with the goal of commercializing high-efficiency holographic elements (commonly -- volume Bragg gratings) by means of the PTR process developed at CREOL. Dr. Glebov, who co-authored the first publication on the discovery of the photo-thermo-refractive phenomenon in a doped silicate glass, and recorded the first volume hologram in this material in 1989, is a company co-founder and the current President and Chief Technology Officer, besides his duties at CREOL. Optigrate is located in the Research Park adjacent to the UCF campus at 3267 Progress Drive, Orlando, Florida 32826. For more information see the company website: www.optigrate.com/about.html.

OptiGrate designs and manufactures volume diffractive gratings in reflecting and transmitting geometries with efficiency exceeding 97% for commercial and defense applications; including currently funded projects for DARPA and AFOSR at the Department of Defense, for Goddard Space Flight Center and for Langley Research

*Pictured are Dr. Leon Glebov and his wife, Larissa Glebova. Larissa, a chemist, is Director of Glass Manufacturing for Optigrate. This year OptiGrate received the prestigious 2007 William C. Schwartz Innovation Award-- which recognizes the most innovative high-tech companies in Central Florida.*

Center at NASA. The basic technology of hologram recording in a photosensitive glass is protected by two issued U.S. patents (6,586,141 and 6,673,497) -- with several others pending. The company also develops and produces custom prototypes of different diffractive optical components for a number of optical and semiconductor companies.

LEONID B. GLEBOV got his Ph.D. in Physics (major in Optics) from the State Optical Institute, in Leningrad, Russia (1976). He was affiliated with this institute through 1995, holding various positions in research and scientific management. He has been at CREOL as a Research Professor since 1995. Dr. Glebov has published a book, 250+ papers in scientific journals and holds 15+ Russian and 4 US patents. He is also a member of the Organizing and Program Committees for a number of International Conferences. His primary research areas include: the optical properties of glass; photosensitive glasses for hologram recording; nonlinear phenomena, including laser-induced damage; holographic optical elements, and volume Bragg lasers.

Recently Dr. Glebov was made a Fellow of the Optical Society of America. The citation reads: for the discovery of photo-thermal refractive glass as a new medium for recording high-efficiency volume holographic gratings and pioneering studies of photo-ionization physics of pure and doped glasses..

## DEAN'S CORNER
continued from page 2

Florida Photonics Cluster (FPC). The FPC, originally started as the Florida Electro-Optics Industry Association (FEOIA) by Bill Schwartz, has begun building its membership (currently 18 companies, 5 university organizations, and 2 economic development organizations) under the leadership of the FPC President, Alex Fong of Optronic Laboratories and their Acting Executive Director, our own Jim Pearson. The FPC has organized several cluster groupings at SPIE exhibitions, sponsored a webinar, co-hosted a seminar by Dr. Martin Stickley, developed an informative website, and is planning a number of other activities to help support and build the industry in Florida.

Peter Delfyett suggested we add an "Alumni Corner" to Highlights, so it seems appropriate to begin with one of his former students:

See the article on CREOL alumnus Michael Mielke in this issue.

We are also pleased to have had two major conferences of our professional societies held recently in Orlando: The Laser Institute of America (LIA) recently hosted the 26th International Congress on Applications of Lasers & Electro-Optics (ICALEO) at the Hilton in Walt Disney World Resort. See http://www.icaleo.org. The Congress included a new nano-manufacturing conference to discuss the future of optical and laser-related nanotechnologies. The second recent conference was IEEE's Lasers and Electro-Optics Society (LEOS 2007) annual meeting, held in Orlando Oct. 21-25 at the Wyndham Palace Resort & Spa, Lake Buena Vista. Both LEOS and LIA scheduled tours of CREOL during their meetings; and these were very well attended. Look for further items of interest in the Faculty and Student News section.

# Research Focus: Peter Delfyett

## Interband Injection Locking

Injection locking of semiconductor lasers has been considered an effective technique to control lasers, both in frequency and time domains. Reducing mode partition noise, narrowing the linewidth, reducing the relaxation oscillations and synchronizing many lasers to a single master laser using small injection powers have been demonstrated by injection locking techniques.

Clock recovery using injection locking techniques such as sub-harmonic, fundamental or harmonic optical pulse injection has been demonstrated and studied using quantum well (QW) and quantum dot (QD) mode-locked lasers. The use of QD based mode-locked lasers as a clock recovery source is now an attractive choice for high speed all-optical clock recovery due to its superior characteristics, such as low noise and fast gain recovery, as well as its broad spectrum (~ 100nm) which originates from the ground state (GS) and an excited state (ES) transitions.

Until now, clock recovery using injection locking techniques has been achieved only by sharing the same spectral band between the master and slave lasers under injection locked conditions. Recent research by Professor Delfyett and Ji-Myung Kim, performed as a part of the DARPA University Research Photonics Program's Center for Optoelectronic Nanostructured Semicondutor Technologies (CONSRT), has shown experimentally that injection locking between a master and a slave laser is possible when a master and a slave laser oscillate via different states, e.g., using either ground state (GS) or excited state (ES) transition. This interband injection locking will overcome the physical consideration of sharing the same spectral band between a master and slave laser for injection locking. As a result, one master laser can control different slave lasers whose finite lasing spectral band does not overlap with that of the master laser.

For interband injection locking, two grating coupled quantum dot external lasers (master and slave) were constructed so each laser operated with a nominal pulse repetition frequency of 4GHz. Hybrid mode-locking and passive mode-locking is performed on the master laser and the slave laser, respectively. Fig. 1 shows the interband injection locking setup. Pulse trains generated from the master laser oscillating on the opposite transition (GS or ES) with respect to the slave laser (ES or GS) is injected into a saturable absorber of the slave laser.

The injection power level is controlled by a neutral density filter. The partially reflected output of the interband injected slave laser is passed through a band pass filter and then is amplified through a QD semiconductor optical amplifier (SOA). Because the band pass filter allows the spectral band of the slave laser to pass, only the spectral band of the interband injected slave laser is detected and analyzed.

The interband injection locking experiment has been done by considering two cases. In the first case, the pulses from ES transition of master laser are injected to the slave laser oscillating via the GS transition. The second case examined pulses generated from the master laser via the GS transition injected to the slave laser running via the ES transition. The lasing band operation on the GS or ES transition is achieved through a grating (900ln/mm) which is externally coupled to QD curved 2-section device in the Littrow configuration.

First, the pulse train from the master laser operating on the ES transition is injected to the saturable absorber of the slave laser oscillating on the GS transition. The bias current of 134mA to the gain section, a reverse bias of 0V and an RF power of 15dBm to the saturable absorber section enables the master laser to be hybridly mode-locked via the ES transition. The slave laser is passively mode-locked via the GS transition by applying a reverse bias of 5.7V to the saturable absorber and a bias current of 37mA to the gain section. Fig. 2 shows the RF spectrum of the slave laser before and after the ES optical pulse injection. Upon ES optical pulse injection to the slave laser, the slave laser was locked to the master laser, and the phase and amplitude noise were significantly reduced. Fig.3 shows the locking bandwidth of the interband injected slave laser, where the maximum locking bandwidth of 500KHz is measured with an estimated 1mW injection power.

In the second experiment, a GS optical pulse train from the master laser is injected to the saturable absorber of the slave laser running on the ES transition. A bias current of 75mA to the gain section, a reverse bias of 0V and RF power of 15dBm to the saturable absorber section are applied to the hybridly mode-locked GS master laser. For the operation of the slave laser via the ES transition, a bias current of 115mA and a reverse bias of 1.5V are applied to the gain and the saturable absorber section, respectively.

The RF spectrum in Fig. 4 shows a reduction of timing jitter and amplitude noise after GS optical pulse injection to the slave laser oscillating via the ES transition. This implies a locking of the interband injected slave laser. A large locking bandwidth of 6MHz is achieved as shown in Fig. 5. It should be noted that interband injection locking in this configuration is not achieved at the same cavity frequency but at the higher cavity frequency. The details of this exciting behavior will be described in a subsequent publication.

In conclusion, we showed experimentally that the slave laser oscillating via GS or ES transition is locked through injection of optical pulses generated via different transition bands, i.e. ES or GS transition. This interband optical pulse injection locking is achieved by interplay between the gain and absorption dynamics within the slave laser. These results represent to our knowledge the first observation of interband injection locking in mode-locked semiconductor lasers.

*----Dr. Peter Delfyett (delfyett @creol.ucf.edu) and Jimyung Kim---*

# of Quantum Dot Mode-locked Semiconductor Lasers

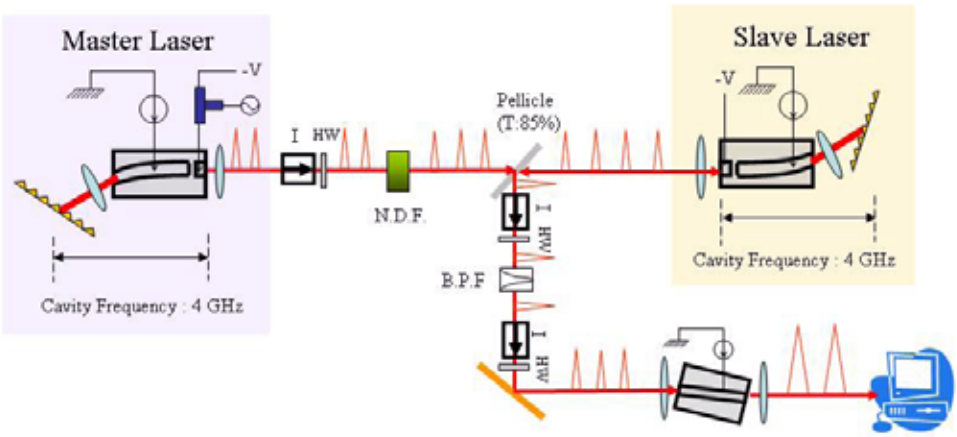


**Figure 1. Experimental Setup**

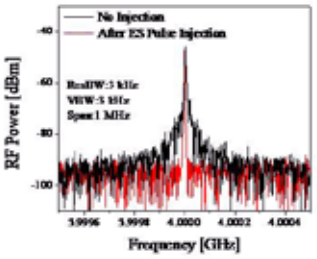


Figure 2.

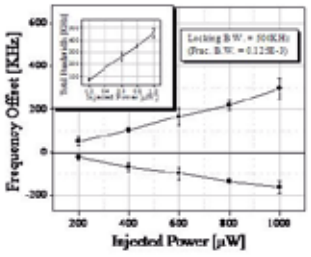


Figure 3.

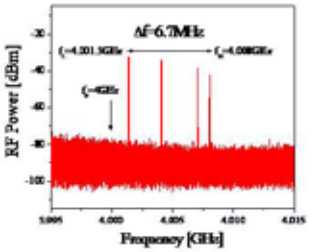


Figure 4.

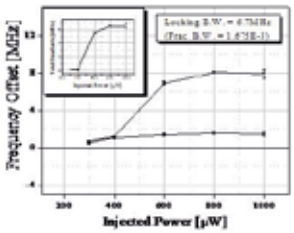


Figure 5.




## CREOL Fall Picnic 2007

# CREOL NEWS

**FACULTY NEWS:**
Dr. **Eric Van Stryland** elected IEEE Fellow: The Board of Directors of the Institute of Electrical and Electronic Engineers (IEEE) at its meeting on 18 November 2007, elevated Dr. Eric Van Stryland to the grade of IEEE Fellow, effective 1 January 2008, with the following citation: "for contributions to nonlinear optics and the development of Kramers-Kronig relations to ultrafast nonlinearities".

Dr. **MJ Soileau**, Vice- President for Research and Commercialization, has been elected a Fellow of the American Association for the Advancement of Sciences (AAAS) for his "distinguished research contributions and leadership in the field of lasers and optical engineering." The AAAS Council selects a small group of scientists as fellows each year to recognize those who work toward advancing science applications that are deemed scientifically or socially distinguished. Dr. Soileau will be formally recognized at the AAAS Annual Meeting in Boston in February 2008.

"**Demetri Christodoulides, Aristide Dogariu**, and their colleagues at the University of Central Florida in Orlando have come up with a new family of non-diffracting waveforms that have another, even stranger property: they appear to curve. The Airy waveform was described theoretically nearly 30 years ago as a surprising solution to the quantum equation for a free particle, a problem with a mathematical analogy in optics." Ref: http://focus.aps.org/story/v20/st19 .

The annual UCF Office of Research and Commercialization (OFC) picnic and awards presentation was held recently. CREOL and our faculty received the following awards:
The OFC "Cash Cow Award": for the most revenue earned by a unit for technology transfer related activities went to CREOL.
The OFC "Millionaire's Club": for faculty receiving $1M +of new funding, was received by: **Martin Richardson**, CREOL – 5,198,928
**Eric Van Stryland**, CREOL – 2,775,768
**David Hagen**, CREOL – 1,362,961
**Pieter Kik**, CREOL – 971,307.

**STUDENT NEWS:**
**Tobias Schmid** won the Top Award for the Use of LightTools in the Optical Research Associates Optical System Design Competition 2007. Tobias's project on the design of Grazing Incidence Mirror Collectors for EUV Lithography was motivated by his research with Dr. **Martin Richardson** and his class project in the Optical System Design Class OSE 6265 taught by Dr. **Rolland**.
.
**Jon Harben** is one of the recipients of the NASA 2007 Fellowships awards, renewable for up to 3 years. The ODALab under the direction of Prof. Jannick Rolland accepted the NASA invitation to develop new instrumentation for Lunar Landings. The goal of the project is to collect physical measurements of the lunar soil properties upon landing. Jon Harben is a first year PhD student who joined the project after completing his Masters Degree at CREOL and his accomplishments under that project won him this award. Mohammed Salem, a senior PhD student at CREOL, is also a key contributor in this program.

## ALUMNI PROFILES

**Alumnus:** Mike Mielke, Ph.D. (Optics, 2003, Peter Delfyett)
**Lives In:** Bennett Valley (near Santa Rosa), CA
**Currently Reading:** Wikipedia
**Newest Hobby:** Biking the trails in Annadel State Park
**Occupation:** Director of Science & Technology
**Employer:** Raydiance, Inc. It has grown substantially from our small first office in the UCF Technology Incubator to the 54 person (and growing) organization we are today. The Raydiance sites in Central Florida and the San Francisco Bay Area house a revolution in the making. We are building powerful ultra-short pulse lasers that are as easy to use as a personal computer.
**Favorite CREOL Memories:** The great camaraderie and international culture are truly wonderful at CREOL. This group of intensely smart and successful individuals has no trouble stepping forward for dizzy-bat relay races at the Fall picnic.
**Quote:** A word is worth only a milli-picture.

## Summer 2007 Graduates

**Wang Kuen Lee, Ph.D.**

**Masters Degrees:**

Kaia Buhl
Curtis Rosenow
Kelly McKirahan
Ivan Vivanco
Troy Anderson
Hubert Seigneur
Dimitrios Mandridis
Ibrahim Ozdur
Amy Thompson
Oleksander Savchyn
David Shelton
David Haefner

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