University of Central Florida

School of Optics / CREOL HIGHLIGHTS

Winter 2003

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Industrial Affiliates' Day

April 25, 2003

Registration form Inside!

Student Spotlight: Sergey Polyakov

by Eric Van Stryland

At the CLEO/QELS 2002 conference last year, a School of Optics/CREOL graduate student's presentation of his research on solitons earned him OSA's coveted $10,000 New Focus award. At CREOL we were delighted and proud, but not necessarily surprised: Sergey Polyakov is no stranger to awards. While an undergraduate at Moscow University, he received multiple awards for excellence. He also became interested in solitons while an undergraduate; publishing a number of theoretical papers on spatial solitons while participating in the research program of a non-linear optics pioneer: Prof. Anatoly Sukhorukov.

In 1998, while attending an ICONO conference in Moscow, Sergey met School of Optics/ CREOL Professor, George Stegeman. Professor Stegeman likes to hand pick his graduate students from the best and brightest young minds around the world; and he quickly recruited Sergey for his own research group at University of Central Florida.

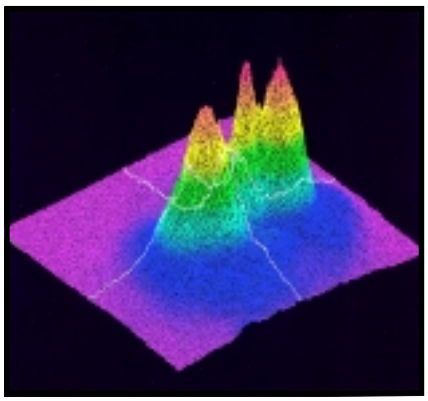
Sergey's excellent work at UCF since then has been recognized with several honors including CREOL Student of the Year, and UCF's highest award for excellence in academics, university involvement, leadership and community service, the Order of Pegasus. Sergey is a multi-faceted individual. In addition to his academic and research achievements, for example, he loves music, is an accomplished pianist and has hosted several UCF radio programs on International music.

Sergey anticipates receiving his Ph.D. early in 2003, and hopes to continue his work here in the USA. The article that follows is based on the research for which he received the New Focus Award.

Solitonic Surprises

by Sergey Polyakov

Solitons are the "darlings" of nonlinear wave science. Although they are macroscopic waveformations, they behave as quantum mechanical objects, almost as particles; forcing us to re-examine certain simple concepts of linear and nonlinear wave propagation. They are formed in nonlinear materials due to a robust balance between linear spreading effects (diffraction, dispersion) and nonlinear collapse (focusing), and do not spread (diffract) on propagation. Their optical phase has an additional component due to the strong nonlinear interaction between the optical field and matter. But this nonlinear phase shift is constant *everywhere* across the beam's intensity profile, contrary to standard nonlinear optics predictions.



3-Dimensional Soliton 'Portrait'

Optical solitons are just a sub-species of soliton families which are widespread in nature, appearing even in Bose-Einstein condensates. However, because they can be easily generated and manipulated in optics they are ideal for investigating new concepts in soliton science. *Quadratic* spatial solitons were first predicted in 1973 by Karamzin and Sukhorukov. They consist of self-trapped beams of two (or three) colors which interact via the second-order nonlinearity. Sufficient nonlinear coupling between the spectral components can be achieved by operating near phase-matching for

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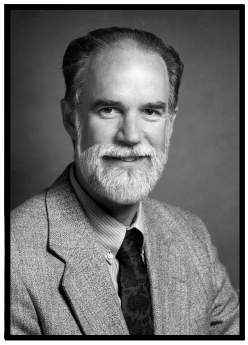
Director's Corner



Dr. Eric Van Stryland

Over a recent holiday weekend, CREOL sent out proposals worth about $50M. The bulk of this was split between a proposal to the State of Florida for creation of a Florida Photonics Center of Excellence (FPCE); and one to the National Science Foundation for an Engineering Research Center (ERC) to be headed by Peter Delfyett. The ERC would be called the Coherent Photonics Imaging Center, or C-PIC. Funding of either or both of these proposals will further our interactions with industry; and we are grateful to all of our industrial partners who helped us in these funding efforts by sending us letters and commitments of support. Now we keep our fingers crossed.

More interactions with Florida industry… Recently, a small entourage of four of us from CREOL gave presentations at Northrop Grumman in Melbourne, FL. Our affiliate DRS Optronics, also in Melbourne, hosted a Florida Photonics Cluster gathering at which I spoke, along with Congressman Weldon, M.J. Soileau and faculty from the Florida Institute of Technology. These visits, along with the many visits of individuals to CREOL (>800 last year!) are useful in letting everyone know the research we are doing and useful to us in finding potential overlaps of interest and expertise.

School of Optics faculty members and students were highlighted this year when the journal *Optics & Photonics News*, *OPN*, did a review of its impact on the field. It was rated the top optics journal in terms of citations; and George Stegeman (holder of the Cobb Family Chair at CREOL) was the 3rd most cited author. Two of the top 25 most cited papers came from CREOL, as well as THE most cited paper of 1992. More recently, when OPN published its highlights of optics in 2002, no less than seven of the articles on research had come from CREOL faculty! Our students (besides being authors on the publications) are also getting attention both in OPN. For example, they published an article about the winners of our CREOL Student of the Year Award. And when Sergey Polyakov won the New Focus prize (see our cover story!) they not only published another article, they also put a link on their website to Sergey's picture and a short description of his research. Finally, OPN published an inside front cover photo (taken at the OSA annual meeting) of the Directors of the three major optics centers : the Institute of Optics (Wayne Knox), the Optical Sciences Center (James Wyant) and the School of Optics/CREOL (that's me!) We are getting great visibility.

Other Student News… Aristide Dogariu's student Mircea Mujat has won an OSA New Focus student travel grant; and Mike Mielke, who works with Peter Delfyett, won a LEOS fellowship worth $5,000! Mike also has been selected as one of the finalists for the collegiate Inventors Competition (run by the National Inventors Hall of Fame) for work on "mode partition noise suppression in multiwavelength modelocked diode lasers," which was submittted for a patent and published in Optics Letters. CAOS held the first ever "Optics Day" (See page 5)and it was a great success.

Other Events…

This year's Annual Meeting of the Optical Society of America was held in Kissimmee. As part of this meeting we and the Florida High Technology Corridor Council co-sponsored a tour of CREOL on Sunday afternoon. Well in excess of 100 people were bused here. The students of CAOS ran the tours and again did a great job. I gave a half hour overview of the center (twice!). I can't count of the number of people who came up to me later in the week at the conference to tell me what a great tour and reception we had. They were very impressed with all the great work going on and with the students they met. I want to thank the staff and faculty for working hard to make this event a success - but I want to particularly thank the members of CAOS who took a great deal of responsibility for making this event memorable.

UCF President John Hitt held a community breakfast on Dec. 6 with a "Focus on Photonics". Our UCF Vice-President for Research, M.J. Soileau, and I shared the stage along with UCF student produced videos. Also Linda Chapin did a half hour TV show on the School of Optics/CREOL with Peter Delfyett and me along with footage from several interviews of faculty and students. This aired on Dec 15 at noon and Dec 20 at 11 pm on Channel 24. My understanding is that this will be shown at other times in the future as well.

Faculty News…

Please join me in congratulating Peter Delfyett on his 5 year appointment by the Provost as a University Distinguished Professor . As the Provost states, "in recognition of your outstanding research, teaching, and service accomplishments during your tenure at UCF". This recognition is indeed well-earned. Congratulations Peter! There was also a great article about UCF professor Dr. Delfyett in the New York Times on October 10th!

SPIE honored Distinguished Research Professor Emil Wolf at their annual meeting in San Diego, Aug. 3-6, 2003 with a special conference entitled: Tribute to Emil Wolf: Engineering Legacy of Physical Optics (AM100) He was also honored with the Esther Hoffman Beller Award at the OSA Annual meeting. (See page 5.)

Please join me in congratulating Dr. Glenn Boreman for winning the CAOS Teacher of the Year Award. He has received a "diploma" and a green laser pointer, as a token of the students' appreciation.

Dr. Shin -Tson Wu has taken over the duties of the local section of the IEEE LEOS from Nabeel Riza who has been elected to be the IEEE LEOS Vice President for 2003. Dr. Kathleen Richardson has been elected a Fellow of the Society of Glass Technology which is based in the United Kingdom. Martin Richardson received recognition at UCF for having the 100th patent. Dr. Mubarak Shah, UCF Professor of Computer Science, and one of our associate faculty members, recently became a fellow of IEEE. And we welcome Dr. Florencio "Eloy" Hernandez, as the newest member of our associate faculty (This group used to be called our "extended" or "joint appointment" faculty.) Eloy was previously with the Van Stryland/Hagan research group at CREOL and he recently accepted a faculty appointment in the UCF Dept. of Chemistry. Congratulations to all!

Finally, I would like to invite all of our friends, colleagues, partners, alumni, and Industrial Affiliates to spend this April 25th, 2003 attending our School of Optics/CREOL annual Affiliates Day! This year our plenary speakers will focus on the major economic impact of optics technologies. Look for the announcement and registration form in this issue or check our web site for details and updates: www.creol.ucf.edu.

Solitonic Surprises...continued

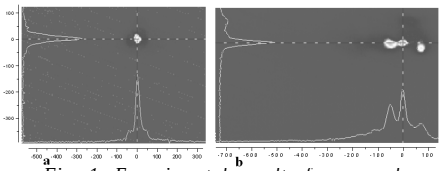


Fig. 1. Experimental results for normal incidence along the "b"-axis at 983.5 nm with the FW polarized along the "a" crystal axis and the SH along the "c" axis of a $KNbO_3$ crystal. a) generation of one soliton and b) generation of three solitons aligned primarily along the crystal's "a" axis.

second harmonic generation, i.e. the indices of refraction of a fundamental wave (FW) and second harmonic (SH) are matched.

Phase matching is usually achieved in anisotropic birefringent crystals. One of the simplest geometries is non-critical phase-match (NCPM) in which the fundamental wave and the second harmonic have orthogonal polarizations (for example in $KNbO_3$.) Figure 1a shows the output light from a crystal 7 diffraction lengths long. We observe the

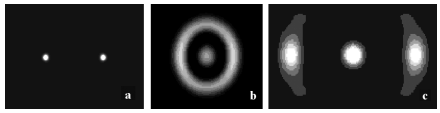


Fig. 2. (a) CW simulations of multi-soliton generation with 15 GW/cm^2 modeled for $KNbO_3$. (b) Radiation rings emitted from PPKTP (c) Coalescence of the radiation rings into solitons in PPKTP

signature of a spatial soliton when the output beam size equals the input beam size. However, as the input intensity increases we observe the generation of additional solitons along preferential spatial directions. (fig. 1b) The standard equations describing quadratic solitons in bulk materials conserve circular symmetry and fail to predict either multiple soliton formation or preferred spatial directions. A similar effect was found in periodically poled KTP (PPKTP) with parallel FW and SH polarizations.

The initial explanation in both cases is simple: Linear optics shows that the diffraction rates of the FW and SH beams are different due to frequency dispersion or crystal anisotropy, i.e. the beam cross-section spreads faster in one of the transverse dimensions leading to elliptical beams. This breaks the inherent symmetry of the generating equations and results in a preferential axis for soliton generation. Solitons are easier (lower power threshold) to generate along the more slowly diffracting axis. The inherent symmetry can also be broken by slightly asymmetric input beams, and these two effects can compete with, or complement each other.

Quadratic solitons are formed with just a FW input only so that the SH needed for these multi-color solitons must be generated on propagation into the crystal. This process is non-adiabatic, leading to two distinct scenarios for multi-soliton generation. The large oscillations in FW and SH energy which occur near the input can generate additional solitons near the axis of propagation, the case in $KNbO_3$. Or, radiation can be emitted from this turbulent region in the form of diffracting elliptical rings, which in turn coalesce into solitons away from the core region, as in PPKTP.

We performed numerical calculations for different peak intensities. Assuming perfect Gaussian beams, multiple solitons (Fig. 2a) diverge out from the core region due to the diffraction asymmetry ($KNbO_3$ case). In PPKTP (Figs 2b and 2c), a diffusing, slightly elliptical radiation ring emitted from the core region, on further propagation coalesces spontaneously (2c) into a pair of solitons. In this case, the strong FW-SH interaction "gathers" energy from

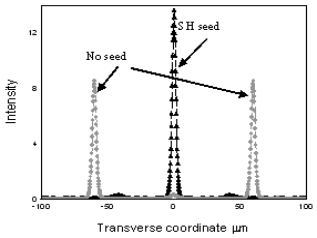


Fig. 3. CW simulations of control of multiple soliton generation by a small SH seeding beam. Nonlinear parameter corresponds to $KNbO_3$

the neighboring part of the ring to form the solitons.

We also found an optical mechanism which may be used for all-optical devices to control the switching between one and two soliton generation, . Seeding with a small fraction of SH (<1% of the FW intensity) prevents multiple soliton generation (Fig. 3).

In summary, optical soliton generation in quadratically nonlinear crystals contains fascinating new features, some of which can be used for all-optical switching.

FREE REGISTRATION

Industrial Affiliates' Day

Fax this form to 407-823-6966 **or use our Online Registration Form** at: www.creol.ucf.edu/affiliates/aform.htm

INDUSTRIAL AFFILIATES' DAY 2003 **Friday April 25, 2003 8:30 AM to 6:00 PM**

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Novel All Optical Displays

by Michael Bass, Professor Emeritus, School of Optics/CREOL

This is a case of a phenomenon in search of an opportunity, or how fundamental research can lead to fascinating practical applications. In the early 1990s we were studying the spectroscopy of rare earth doped crystals that might serve as laser media. As part of that work we examined the process of up-conversion in which a material would absorb two near infrared photons and be excited to a state that could emit visible light. Such a process might have yielded a crystal laser in the visible range, pumped by near infrared diode lasers. Needless to say it didn't. However, we knew how to make a lot of visible light from infrared light.

If we could make visible light, could we make a display in which near infrared light excited visible emission? After all, near infrared diode lasers were getting to be quite efficient and their cost was coming down. The problems would be: generating red, green and blue visible light; the up conversion efficiency of each; and how to prepare the materials for use in displays. Our approach to the materials issue was to consider particles of some of the visible light emitting up converters dispersed in a passive host or binder of perhaps a polymer or a sol gel. Some of our most efficient up converters were fluoride crystals doped with both ytterbium, Yb, and one other rare earth dopant, either erbium, Er, holmium, Ho or thulium, Tm. The Yb ions absorbed light near 970 nm and transferred that energy to the co-dopant in sequential steps. The result being that the co-dopant gets excited to emit visible light. We have used this concept to demonstrate very efficient red, green and blue emitters using Yb,Er:YF_3, Yb,Er:$NaYF_4$ and Yb,Tm:$LiYF_4$, respectively. In fact the efficiencies in lumens per watt of incident pump power are 26.4, 7.0, and 2.6 % making them very attractive for display use. Just consider that our displays can be so bright that they can be easily viewed in the mid day sun of central Florida. If the particles are placed in a host having the same index of refraction, we can make transparent displays as well.

Figure 1 Examples of our red, green and blue emitters using up-conversion in rare earth doped fluoride crystals excited by diode laser light near 976 nm for the red and green and 959 nm for the blue. The red emitter is in a polymer containing a green absorbing dye that absorbs some unwanted green emission from this material.

When particles of these emitters are placed in a specially prepared version of polymethyl methacrylate (PMMA) (many thanks to Prof. Kevin Belfield) they enable very stable and efficient 2D displays to be made. When the focused beam of a near infrared diode laser source is scanned over a surface of our particles in this polymer, a very bright, very sharp image is generated as shown in Fig. 1 for each of our emitters (see the web site http://bass.creol.ucf.edu/2D/2D_display.htm to see videos of this display at work).

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School of Optics/CREOL

Industrial Affiliates' Day
Friday, April 25, 2003

University of Central Florida
Student Union, Cape Florida Ballroom

Optics Technologies - - Economic Impact

Lithography **Dan Herr, Semiconductor Research Institute**
Biophotonics **Tom Baer, Arcturus**
Additional Speakers to be announced

Plus: Exhibits, Poster Papers, and Lab Tours

Esther Hoffman Beller Award Presented to Professor Emil Wolf

The Optical Society of America presented the Esther Hoffman Beller Medal to Professor Emil Wolf (Provost's Distinguished Research Professor of Optics at the School of Optics/CREOL) for his numerous outstanding contributions as an educator, but especially for the influence of his books which have been educating optical scientists and engineers for more than forty years.

The prestigious Esther Hoffman Beller Award is presented for outstanding contributions to optical science and engineering education. Consideration is given to outstanding teaching and/or original work in optics education that enhances the understanding of optics. The scope of the award is international. This award was endowed by a bequest from the estate of Esther Hoffman Beller presented to OSA in 1992.

Professor Wolf co-authored Principles of Optics with Max Born and Optical Coherence and Quantum Optics with Leonard Mandel. He is also the editor of Progress in Optics. Professor Wolf is the recipient of numerous awards including seven honorary degrees. His is an honorary member of OSA. In 1978 he served as OSA President.

CAOS' Optics Day 2002

by Mircea Mujat, past president
CREOL Association of Students

On September 10th, last fall, the CREOL Association of Optics Students, CAOS, invited all UCF Students to attend Optics Day at the School of Optics/CREOL. CAOS combines the Student Chapters of the OSA, SPIE and IEEE-LEOS in an effort to focus the student activities related to optics and lasers at the School of Optics/CREOL. This powerful combination of efforts of the three student chapters results in a large variety of student activities. Through our outreach programs, we also offer a modest contribution in helping the non-scientific community to understand the importance of science, and optics in particular, in our daily life. CAOS tried to share some of these activities with the entire UCF campus during Optics Day 2002.

Ferenc Szipocs explains optics demo project.

The purpose of this event, initiated and organized by CAOS, and sponsored by SGA, was to promote the discipline of Optics among UCF students. The schedule included oral presentations in CREOL's Conference rooms and practical demonstration of display projects.

Optics Day 2002 started with presentations on current research by School of Optics/CREOL faculty. Dr. Eric Van Stryland, presented an Overview of the School. Dr. Mike Bass and Dr. Peter Delfyett included in their presentations examples from their laboratories and their experience on why it is exciting to do research and graduate studies in Optics--and how people make real money out of it. Dr. Delfyett made a presentation on the basics of lasers, and Dr. Bass described the current research on 2D and 3D displays (see page 4). also made a short presentation on CAOS activities.

Mike Mielke explains a laser project to UCF undergrads.

Another highlight of Optics Day 2002 was the use of display projects intended for demonstrating fundamental optical phenomena, emphasizing both the physics and practical applications. They provided an attractive, entertaining and, most importantly, educational demonstration of the research conducted at the School of Optics/CREOL. Many of our graduate students were also available to explain these projects, and discuss their research with UCF students.

Our attempt to entice the UCF student body to visit us as we increase awareness of the opportunities and challenges that optics, and science in general, have to offer seems to have been successful, since about 100 UCF students visited CREOL for Optics Day 2002. A short video about this event was featured on WNSC on Channel 21 and Time Warner Cable channel 98.

Novel All Optical Displays....continued

By pixelating our materials into red, green and blue matrices, a full color display can be prepared. We are currently working with colleagues at the Philips Co. in Holland to demonstrate such a display, and consider making a product based on it. Its advantages as an emissive display compared to a traditional cathode ray tube (CRT) display would be that an all optical display requires: no high voltage, no heavy, lead glass faced vacuum tube, and produces no ionizing radiation. Also, since it involves optical excitation, the beam path can be folded and the device can be made significantly thinner than a CRT display of the same area. It is also possible with our efficient emitters that such as display will demand less power than a comparable CRT display.

Through contact with NEOS Co. in Melbourne, FL we are considering how to apply our 2D display materials to the rotating spiral they use in a 3D display. They currently use very expensive and low power visible lasers to write images in 3D on a rotating spiral surface. Except for the fact that it can only be seen when your eyes are dark adapted, the rotating spiral 3D display works. Since our emitters are much brighter than the scattered light from a low power visible laser, and since the near infrared diode lasers we would use are much cheaper than any visible laser, we are planning work with NEOS to "bring the rotating spiral 3D display out of the dark." This would provide, in the relatively short term, a working 3D display for applications testing and human factors studies.

This research connects several School of Optics people in interesting ways. Hans Jenssen of the School of Optics, and his wife Arlette Casanho, through her company, AC Materials in Orlando, have collaborated with us on developing the optimized up-converting crystals. Alexandra Rapaport first came to CREOL as a 6 month intern from Marseilles. She returned to carry out Ph.D. studies in Physics (the School of Optics did not exist back then) working with me on problems of spectroscopy and lifetime dynamics. As she was finishing, the possibility of working on the new display concepts came up and she stayed as a Post Doc and Research Scientist. Janet Milliez came as an intern from Paris for 6 months and returned to seek her Ph.D. in Optics on the subject of these novel displays. Ferenc Szipocs came to the School of Optics to work on 3D displays and received his masters degree last summer. We have a close collaboration with Prof. Mike Canva of the University of Paris – Orsay, formerly a post-doc at the School of Optics, on exploring the use of sol-gels as passive hosts for the 2D displays and maybe to host the dyes for 3D displays. Al Ducharme, who received his Ph.D. at the School of Optics and is now with the UCF Engineering Technology department (see page 3), provided great help in making absolute measurements of the emitter efficiencies. Jason Eichenholz, another School of Optics Ph.D. recipient, helped to set up the demonstrations seen in the web site.

We gratefully acknowledge the sponsorship of this work by the U. S. Army Research Office.

School of Optics/CREOL
Highlights

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Updates

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