SIXTH 'RIO DE LA PLATA' WORKSHOP ON LASER DYNAMICS AND NONLINEAR PHOTONICS

Organizers:

Igal Brener (Sandia National Laboratories, USA)
Alejandro Giacomotti (Lab. de Photonique et Nanostructures, CNRS, France)
Cristina Masoller (Universitat Politecnica de Catalunya, Barcelona, Spain)

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Sponsored by:

Photonics society

Held at Hotel Cala di Volpe, Montevideo, Uruguay
December 9 - December 12, 2013

	Monday 9	Tuesday 10	Wednesday 11	Thursday 12
8:30-8:55	Registration	Registration	Registration	
8:55-9:00	Opening			
9:00-9:45	M. Clerc	C. de Araujo	C. Mendonça	J. Rios Leite
9:45-10:30	T. Ackermann	A. Shore	K. Lüdge	J. Tredicce
10:30-11:00	**Coffee Break**	**Coffee Break**	**Coffee Break**	**Coffee Break**
11:00-11:45	K. Bencheikh	A. Hurtado	F. Pedaci	A. Hnilo
11:45-12:30	A. Bragas	J. Javaloyes	S. Barbay	U. Bandelow
12:30-2:30	**Lunch (@ hotel)**	**Lunch (@ hotel)**	**Lunch**	**Lunch (@ hotel)**
2:30-3:15	S. Barland	B. Krauskopf	Free time	G. Genty
3:15-4:00	A. Giacomotti	J. Ohtsubo		T. Van Vaerenbergh
4:00-4:20	**Coffee Break**	**Coffee Break**	**Coffee Break**	**CLOSING**
4:20-4:50	A. Aalto	V. Odent	I. Shelyth	
4:50-5:20	C. Masoller	P. Petersen	B. Vlahovic	
5:20-5:50		**POSTERS**	E. Rosero	
5:50-6:20				
6:20-6:50				
8:30-11:00		**SOCIAL DINER (@El Milongon)**		

	Monday – December 9
8:30am – 8:55am	**Registration**
Chair person	Cristina Masoller (Universitat Politecnica de Catalunya, Spain)
8:55am – 9:00am	Welcome (A. Giacomotti, C. Masoller)
9:00am – 9:45am	**Marcel Clerc** (Santiago, Chile) *Harnessing optical vortex lattices in nematic liquid crystals*
9:45am– 10:30am	**Thorsten Ackemann** (Glasgow, UK) *Optomechanical self-organization in cold atomic gases*
10:30am – 11:00am	**Coffee Break**
Chair person	Alejandro Giacomotti (LPN-CNRS, Marcoussis, France)
11:00am – 11:45am	**Kamel Bencheikh** (Marcoussis, France) *Quantum theoretical aspects of triple photons states produced by a* $\chi(3)$ *process*
11:45am – 12:30 pm	**Andrea Bragas** (Buenos Aires, Argentina) *Nonlinear emission of polariton cavity modes in ZnO single nanocombs*
12:30 pm – 2:30 pm	**Lunch**
Chair person	Andrea Bragas (Buenos Aires, Argentina)
2:30pm – 3:15pm	**Stephane Barland** (Nice, France) *Buffering optical data with topological localized structures*
3:15pm – 4:00pm	**Alejandro Yacomotti** (Marcoussis, France) *Coupling control in photonic crystal molecules*
4:00pm – 4:20pm	**Coffee Break**
Chair person	Marcel Clerc (Santiago, Chile)
4:20pm – 4:50pm	**Antti Aalto** (Tampere, Finland) *Applications of supercontinuum sources: incoherent broadband cavity-enhanced absorption spectroscopy*
4:50pm – 5:20pm	**Cristina Masoller** (Terrassa, Spain) *Symbolic analysis of low-frequency fluctuations in semiconductor lasers with optical feedback*

	Tuesday – December 10
8:30am – 8:55am	**Registration**
Chair person	Antonio Hurtado (University of Essex, UK)
9:00am – 9:45am	**Cid B. de Araújo** (Recife, Brazil) *High-order nonlinearities in homogeneous and nanostructured systems*
9:45am– 10:30am	**Alan Shore** (Bangor, Wales, UK) *Polarization properties of VCSELs subject to optical feedback and optical injection*
10:30am – 11:00am	**Coffee Break**
Chair person	Alan Shore (Bangor, Wales, UK)
11:00am – 11:45am	**Antonio Hurtado** (University of Essex, UK) *Optical injection in 1310nm-QD DFB Lasers: analysis and applications*
11:45am – 12:30pm	**Julien Javaloyes** (*Palma de Mallorca, Spain)* *Vectorial temporal solitons with delay in VCSELs*
12:00 pm – 2:30 pm	**Lunch**
Chair person	Cid B. de Araújo (Recife, Brazil)
2:30pm – 3:15pm	**Bernd Krauskopf** (The University of Auckland, New Zealand) *Mode structure of a semiconductor laser with feedback from two external filters*
3:15pm – 4:00pm	**Junji Ohtsubo** (Shizuoka University, Japan) *Filament dynamics and synchronization in broad-area semiconductor lasers*
4:00pm – 4:20pm	**Coffee Break**
Chair person	Stephane Barland (Nice, France)
4:20pm – 4:50pm	**Vincent Odent** (Universidad de Chile) *Photoisomerization front propagation in dye doped liquid crystal submitted to a Gaussian forcing*
4:50pm – 5:20pm	**Paul Michael Petersen** (Technical University of Denmark) *New laser architecture using nonlinear frequency conversion and spectrally combined tapered diode lasers*
5:20pm – 7:00pm	**POSTER SESSION**
8:30 pm – 11:30 pm	**Conference Dinner at El Milongon (www.elmilongon.com.uy)**

	Wednesday – December 11
Chair person	Bernd Krauskopf (The University of Auckland, New Zealand)
9:00am – 9:45am	**Cleber Mendonça** (São Carlos, Brazil) *Femtosecond pulses in nonlinear optics: multi-photon absorption and pulse shaping*
9:45am– 10:30am	**Kathy Lüdge** (Berlin, Germany) *Optical instabilities in quantum-dot lasers: what makes them different to quantum-well lasers*
10:30am – 11:00am	Coffee Break
Chair person	Cleber Mendonça (São Carlos, Brazil)
11:00am – 11:45am	**Francesco Pedaci** (Montpellier, France) *Excitability in optical torque tweezers*
11:45am – 12:30pm	**Sylvain Barbay** (Marcoussis, France) *Self-pulsing and fast excitable response in micropillar and nano-lasers with saturable absorber*
12:30 pm – 2:30 pm	**Lunch**
4:00pm – 4:20pm	**Coffee Break**
Chair person	Kathy Lüdge (Berlin, Germany)
4:20pm – 4:50pm	**Ivan Shelykh** (Nanyang Technological University, Singapore) *Nonlinear polarization phenomena in semiconductor microcavities*
4:50pm – 5:20pm	**Branislav Vlahovic** (North Carolina Central University, Durham, USA) *Femtosecond pulsed laser fabrication of nanostructures for biochemical detector utilization*
5:20pm – 5:50pm	**Edison Rosero** (Recife, Brazil) *Pulsing dynamics in a semiconductor laser with an external ring cavity configuration*

	Thursday – December 12
Chair person	Sylvain Barbay (Marcoussis, France)
9:00am – 9:45am	**José Rios Leite** (Recife, Brazil) *Nonlinear dynamics in a ring diode laser*
10:45am – 10:30 am	**Jorge Tredicce** (UNC-Nouvelle Caledonie) *How a crisis produces an extreme event*
10:30am – 11:00am	**Coffee Break**
Chair person	Jorge Tredicce (UNC-Nouvelle Caledonie)
11:00am – 11:45am	**Alejandro Hnilo** (Buenos Aires, Argentina) *Optical rogue waves in the solid state laser with a saturable absorber*
11:45am – 12:30pm	**Uwe Bandelow** (Berlin, Germany) *Solitons on a background, rogue waves, and classical soliton solutions of the Sasa-Satsuma equation*
12:00 pm – 2:30 pm	**Lunch**
Chair person	Alejandro Hnilo (Buenos Aires, Argentina)
2:30pm – 3:15pm	**Goery Genty** (Tampere, Finland) *From nonlinear instabilities to rogue waves in optics*
3:15pm – 4:00pm	**Thomas Van Vaerenbergh** (Ghent University, Belgium) *Towards integrated optical spiking neural networks: delaying spikes on chip*
	CLOSING

INVITED TALKS

Thorsten Ackemann[1] (thorsten.ackemann@strath.ac.uk), E. Tesio[1], G. Labeyrie[2], G. R. M. Robb[1], P. M. Gomes[1], A. Arnold[1], W. J. Firth[1], G.-L. Oppo[1], R. Kaiser[2]

1 SUPA and Department of Physics, University of Strathclyde, Glasgow G4 0NG, UK

2 Institut Non Linéaire de Nice, UMR 6618, 1361 Route des Lucioles, F-06560 Valbonne, France

Optomechanical self-organization in cold atomic gases

We discuss the formation of optomechanical structures from the interaction between linear dielectric scatterers and a light field via dipole forces without the need for optical nonlinearities. The experiment uses a high density sample of Rb atoms in a single mirror feedback geometry. We observe hexagonal structures in the light field and a complementary honeycomb pattern in the atomic density. Different theoretical approaches are discussed assuming either viscous damping of the atomic velocity or not. The interplay between electronic and optomechanical nonlinearities is analyzed. A prediction for dissipative light – matter density solitons is given. The investigations demonstrate novel prospects for the manipulation of matter in a pattern forming system in which quantum effects should be accessible.

Uwe Bandelow (uwe.Bandelow@wias-berlin.de)

Weierstrass Institute (WIAS), Berlin, Germany

Solitons on a background, rogue waves, and classical soliton solutions of the Sasa-Satsuma equation

Short pulse propagation in optical fibres in lowest order approximation can be described by the nonlinear Schrödinger equation (NLS), which provides a good description for propagation of signals with relatively narrow spectrum. However, for shorter pulses, when the spectrum widens, it has to be supplemented with additional terms that describe higher-order effects taking place in the fibre. In the case of arbitrary coefficients, solutions can be found only numerically. For analytic solutions, the coefficients have to be related in a special way. One of the several integrable cases is the Sasa-Satsuma equation. Soliton solutions have been presented already in the original version by Sasa and Satsuma, and in the work by Mihalache et al. Heteroclinic connections have been presented later by Wright III. We will consider the most general case of a soliton on a background solution [1]. The solution has rich structure and admits several limiting cases that are important for applications. Among them are rogue waves and classical solitons. The zero background limit contains, as particular cases, previously known soliton solutions [1].

[1] U. Bandelow and N. Akhemdiev, "*Solitons on a background, rogue waves, and classical soliton solutions of Sasa-Satsuma equation*", J. of Optics, 15(6):064006/1–064006/10, 2013.

Sylvain Barbay (sylvain.barbay@lpn.cnrs.fr)

Laboratoire de Photonique et de Nanostructures, CNRS-UPR20, Marcoussis, France

Self-pulsing and fast excitable response in micropillar and nano-lasers with saturable absorber

We present recent experimental and theoretical results on the nonlinear dynamics of semiconductor micro and nano-lasers. First, fast excitable, neuron-like, dynamics is experimentally evidenced in a micropillar laser with intracavity saturable absorber with fast response times in the 200ps range. We study also the refractory time in this system and show the existence of a relative refractory period, analogue to what is found in neurons. Second, we propose a scheme for achieving self-pulsing in nanolasers based on asymmetrically coupled cavities and study theoretically its implementation in a photonic-crystal based system. Short pulses with duration as short as 35ps with multi-GHz repetition rates are found, as well as a region giving rise to a chaotic dynamics. We also predict a parameter region where the self-pulsing bifurcation can lead to ultra-fast excitable dynamics in such a nanolaser.

Stephane Barland (stephane.barland@inln.cnrs.fr)

Institut Non-Lineaire de Nice, Valbonne, France

Buffering optical data with topological localized structures

Optical localized states are often proposed as information units, which can be used either to store data (especially when localization occurs in the dimension transverse to propagation) or to buffer it (when light is localized along the propagation direction). Optical localized states along the propagation dimension have been observed in systems with phase symmetry such as mode-locked lasers with saturable absorber and more recently in phase locked systems, in which case they received the name of temporal cavity solitons. In this contribution, we will present experimental and numerical results based on an optical excitable system with delayed feedback. Based on the analogy between space and delay terms, we present an experimental demonstration of the buffering of optical data with topological temporal localized states.

Kamel Bencheikh (kamel.bencheikh@lpn.cnrs.fr)

Laboratoire de Photonique et de Nanostructures LPN – CNRS, Marcoussis, France

Quantum theoretical aspects of triple photons states produced by a $\chi^{(3)}$ process

I consider the generation of triple photons where a pump field incident on a nonlinear material gives birth simultaneously to three photons. During this process that is governed by the third order electric susceptibility $c^{(3)}$, three photons, with the energies $\hbar w_1$, $\hbar w_2$ and $\hbar w_3$, are created from the splitting of a pump photon at $\hbar w_0$. Quantum mechanically, triple photons generation (TPG) is the most direct way to produce pure quantum states of light whose statistics go beyond the usual Gaussian statistics associated with coherent sources and optical parametric twin-photon generators. The simultaneous birth of three photons is indeed at the origin of intrinsic three-body quantum properties such as three-particle Greenberger-Horne-Zeilinger (GHZ) quantum entanglement. It also leads to Wigner functions presenting quantum interferences and negativities. In the presentation, I will describe the triple photons generation process and will detail some of the quantum aspects of the photon triplets.

Andrea V. Bragas (bragas@df.uba.ar)[1], Maria Gabriela Capeluto[1], Gustavo Grinblat[1], Monica Tirado[2] and David Mario Comedi [2]

1 Universidad de Buenos Aires, Argentina

2 Universidad Nacional de Tucumán, Argentina

Nonlinear emission of polariton cavity modes in ZnO single nanocombs

Tunable second harmonic (SH) polaritons have been efficiently generated in ZnO nanocombs, when the material is excited close to half of the semiconductor band-gap energy. The nonlinear signal couples to the nanocavity modes, and, as a result, Fabry-Pérot resonances with Q factors of about 500 are detected. Due to the low effective volume of the confined modes, matter-light interaction is very much enhanced. This effect lowers the velocity of the SH polariton in the material by 50 times, and increases the SH confinement inside the nanocavity due to this higher refractive index. We also show that the SH phase-matching condition is achieved through LO-phonon mediation. Finally, birefringence of the crystal produces a strong SH intensity dependence on the input polarization, with a high polarization contrast, which could be used as a mechanism for light switching at the nanoscale.

Marcel Clerc (marcelclerc@gmail.com)

Departamento de Física, Facultad de Ciencias Físicas y Matemáticas. Universidad de Chile

Harnessing optical vortex lattices in nematic liquid crystals

By creating self-induced vortexlike defects in the nematic liquid crystal layer of a light valve, we demonstrate the realization of programable lattices of optical vortices with arbitrary distribution in space. On each lattice site, every matter vortex acts as a photonic spin-to-orbital momentum coupler and an array of circularly polarized input beams is converted into an output array of vortex beams with topological charges consistent with the matter lattice. The vortex arrangements are explained on the basis of light-induced matter defects of both signs and consistent topological rules.

Cid B. de Araújo (cid@df.ufpe.br)

Universidade Federal de Pernambuco, Recife, Brazil

High-order nonlinearities in homogeneous and nanostructured systems

High-order nonlinearities (HON) play important role in many photonic systems. Although in some cases HON may cause problems, their contributions are important and desired in many cases. For instance, HON prevents catastrophic self-focusing, enables formation of stable multi-dimensional solitons, and their influence explains aspects of filamentation. It is also of large interest the exploitation of HON in quantum information and for improvement of high-precision measurements.

In this talk I will report on the observation of HON in liquid CS_2 and in colloids consisting of silver nanoparticles suspended in CS_2 (or acetone). Robust (2+1)D soliton propagation and management of the nonlinear refractive index of the colloid will be presented. Varying the volume fraction, *f*, occupied by the nanoparticles it was measured the effective fifth-order refractive index, $n_4 \propto \mathrm{Re}\,\chi_{eff}^{(5)}$, under conditions such that the effective third-order refractive index, $n_2 \propto \mathrm{Re}\,\chi_{eff}^{(3)}$, was suppressed. Therefore, an interesting composite presenting $n_4 = +3.2 \times 10^{-25}\ \mathrm{cm}^4/\mathrm{W}^2$ and $n_2 = 0$ was obtained for $f = 1.6 \times 10^{-5}$. The seventh-order susceptibility, $\chi_{eff}^{(7)}$, could also be controlled in a large range of values and the results were understood with basis on contributions of the constituents of the colloid. The experiments demonstrate a procedure for nonlinearity management with possible applications in soliton physics, optical communications and stability control of systems.

Goery Genty (goery.genty@tut.fi)

Tampere University Technology, Tampere, Finland

From nonlinear instabilities to rogue waves in optics

Alejandro Hnilo (ahnilo@citefa.gov.ar)

Centro de Investigaciones en Láseres y Aplicaciones, Buenos Aires, Argentina

Optical rogue waves in the solid state laser with a saturable absorber

We study the features of the optical rogue waves (ORWs) observed in an all-solid-state (diode-pumped, Cr:YAG+Nd:YVO4) passively-Q-switched laser, which is a system of wide practical interest. The extreme events appear during the chaotic and hyper-chaotic regimes of this laser, in one of two forms: 1) as isolated pulses of extraordinary intensity ("intensity ORW", I-ORW), or: 2) as an exceptionally long time between pulses ("time ORW"). These two types of ORW are not correlated in general (i.e., an I-ORW is not preceded or followed by a T-ORW). The standard theoretical description of this laser system (three-level rate equations for a single mode of the field and a two-level system for the absorber) is not able to predict these phenomena, not even the mere existence of ORW. Faced with the problem of improving the theoretical description, we find that ORW are observed mainly if the Fresnel number of the laser cavity and the embedding dimension of the attractor reconstructed from the experimental time series are high, and the laser spot profile presents a spatially complex structure. These results suggest that the spatial effects are an essential ingredient in the formation of ORW in this type of lasers.

Antonio Hurtado (ahurt@essex.ac.uk)

Department of Computing and Electronic Systems, University of Essex, U.K:

Optical injection in 1310nm-QD DFB Lasers: analysis and applications

We review our work with 1310nm Quantum Dot (QD) Distributed-Feedback (DFB) lasers. We report experimentally on the effects induced in such devices when subject to external optical injection. These include two-wavelength switching, bistability, nonlinear dynamics and dual-mode lasing inducing. We will also discuss the practical applications of optically-injected QD DFB lasers for Ultra-High Frequency applications, including the generation of microwave, millimeter-wave and THz signals. Continuous tunable microwave signals with frequencies ranging from below 1 GHz to over 40 GHz are generated by means of the period-1 dynamics induced in the QD DFB laser under external optical injection into the device's lasing mode. A novel technique is also reported for the generation of higher frequency signals in the millimeter-wave and THz ranges. This technique is based on the dual-mode lasing arising in the QD laser under single-beam optical injection into one of its subsidiary Fabry-Perot modes. Tunability of the generated millimeter-wave and THz signals from 117 GHz to 954 GHz is demonstrated. The simplicity of the experimental configuration used and the variety of responses observed offer promise for novel uses of QD lasers as Ultra-High Frequency sources for Radio-over-Fiber applications and future mobile communication networks.

Julien Javaloyes (julien.javaloyes@uib.es)

Universitat de les Illes Balears, Palma de Mallorca, Spain

Vectorial temporal solitons with delay in VCSELs

We show that Vertical-Cavity Surface-Emitting Lasers can emit light in the form of temporal dissipative solitons when placed into an external cavity. These solitons exploit the vectorial nature of the electromagnetic field, and arise as polarization slips in which the emission orientation performs a cycle while the intensity remains almost constant and can be interpreted as dark-bright soliton. The large temporal aspect-ratio of the cavity enables the experimental observation of independent solitons coexisting with bounded states of soliton molecules within the same round-trip. While the formers evolve independently as evidenced by their uncorrelated random walks, the latter evolve as rigid bodies.

Bernd Krauskopf[1] (b.krauskopf@auckland.ac.nz), Poitr Slowinski[2], and Sebastian Wieczorek[3]

1 The University of Auckland, New Zealand

2 University of Warwick, U.K:

3 University of Exeter, U.K.

Mode structure of a semiconductor laser with feedback from two external filters

We investigate the solution structure and stability of a semiconductor laser receiving time-delayed and frequency-filtered optical feedback (FOF) from two external filters. This system is referred to as the 2FOF laser, and it has been used as pump laser in optical telecommunication and as light source in sensor applications. The 2FOF laser is modeled by rate equation in the form of delay differential equations.

Our analysis of the 2FOF laser focuses its the basic solutions, known as external filtered modes (EFMs), which correspond to laser output with steady amplitude and frequency. We consider the EFM-surface in the space of steady frequency, the corresponding steady population inversion, and the feedback phase difference. The EFM-surface emerges as the natural object for the study of the 2FOF laser, and we classify its possible types in dependence on the two detunings of the filter, for different but fixed values of the filter width and the two delay times. Moreover, we consider how the stability regions of EFMs are related to the type of the EFM-surface. From a viewpoint of practical interests, we find various bands and islands of stability on the EFM-surface that may be accessible experimentally.

Kathy Lüdge (kathy.luedge@tu-berlin.de)

Institute of Theoretical Physics, Technische Universität Berlin, Germany

Optical instabilities in quantum-dot lasers: what makes them different to quantum-well lasers

Semiconductor lasers are very important to opto-electronics, which has applications in many aspects of our daily lives and whose development represents the forefront of quantum electronics and quantum optics research. Especially nano-structured lasers like quantum-dot (QD) lasers, which emit light in the telecommunication wavelength range, offer a variety of advantages in applications over conventional quantum-well (QW) lasers, and on the same time exhibit very interesting dynamics, e.g., when under the influence of optical perturbations. In fact, in contrast to quantum-well devices, their dynamics is strongly influenced by the charge-carrier scattering between bound QD states and off-resonant reservoir states. This additional degree of freedom leads to an amplitude phase coupling that cannot be described by a constant α-factor.

Instead, an additional dynamic equation is needed to describe temporal changes not only in the gain but also in the refractive index of the device.

Based on a microscopic modelling approach, we present a simplified QD laser model that is able to correctly cover the dynamics under optical perturbations and on the same time can easily be implemented into bifurcation tools. Further, we report on the electrical modulation properties of QD lasers. We find that the interplay between the different carrier relaxation timescales strongly nonlinearly affects the laser output under electrical modulation, which underlines the importance of implementing a reasonable material model for the QD laser.

Cleber R. Mendonça (crmendon@ifsc.usp.br)

Instituto de Física de São Carlos, Universidade de São Paulo, São Carlos, SP, Brazil

Femtosecond pulses in nonlinear optics: multi-photon absorption and pulse shaping

Nonlinear optics has received a great deal of attention due to its potential for the development of new technologies, as well as for the understanding of fundamental aspects of light-matter interaction. This area has been driven by the development of femtosecond laser pulses, which present short duration and, consequently, high peak power and broad spectral band. In the last few years, nonlinear optical processes in organic compounds have been extensively studied, leading to methods for fine-tuning the optical nonlinearities, which has motivated applications in various technological areas. This was a seminal idea for manipulating materials structure and achieving higher nonlinear responses. In this talk, we will present results on the use of fs-laser to study the relationship between molecular structure and the multi-photon absorption process in organic materials. The obtained multi-photon absorption spectra were modeled using the sum-over-states approach. To further understand the measured optical nonlinearities, we carried out theoretical calculations using semi-empirical methods as well as the quadratic response function formalism within the density functional theory framework. In the second part of this talk, results on the use of pulse shaping methods to control light-matter interaction will be presented. By modulating the spectral phase of fs-pulses we are able to control different optical processes, from gold nanoparticles production to the exciton emission in semiconductors. Such control is carried out by interfering on the spectral phase profile of the pulse, and consequently on its temporal profile, using either known function as phase masks (open loop configuration) or by applying artificial intelligence algorithm, such as the genetic algorithm, a heuristic search that mimics the natural process of evolution (closed loop strategy). Therefore, this talk should cover aspects of relevance for the generation of new technologies as well as of interest from the standpoint of fundamental physics.

Junji Ohtsubo (tajohts@ipc.shizuoka.ac.jp)

Shizuoka University, Japan

Filament dynamics and synchronization in broad-area semiconductor lasers

High-power semiconductors laser are promising light sources for various industrial applications. One of the technologies for high-power semiconductor lasers is a broad-area structure of the active region whose stripe width is as much as ~100 μm, which is about twenty times or more larger than those for ordinary narrow-stripe edge-emitting semiconductor lasers. Different from narrow-stripe edge-emitting semiconductor lasers, broad-area semiconductor lasers are unstable light sources owing to the spatial dependence of the oscillations along the stripe width even in solitary oscillation. They are capable of emitting high optical powers, while they have rather poor beam quality owing to instabilities caused by microscopic dynamics [1].

One of the instabilities observed in the dynamics of broad-area semiconductor lasers is filamentation. This gives rise to irregular local pulsating oscillations with a time period on the order of picoseconds. Since the spatial size of these bright spots is on the order of several microns, broad-area semiconductor lasers exhibit fast spatio-temporal fluctuations. The presence of filamentation greatly deteriorates the beam quality of the laser. In the meantime, the dynamics of semiconductor lasers are strongly affected by optical feedback and optical injection. In this talk, I will discuss the filament dynamics of broad-area semiconductor lasers under optical feedback or optical injection, and give some examples of controls of the beam profile. Also filament synchronization between two broad-area semiconductor lasers is presented.

[1] J. Ohtsubo, *Semiconductor Lasers: Stability, Instability and Chaos*. Springer-Verlag, Berlin, 2013.

Francesco Pedaci (francesco.pedaci@cbs.cnrs.fr)

Centre de BiochimieStructurale, Montpellier, France

Excitability in optical torque tweezers

The possibility to directly manipulate microscopic objects with focused laser beams has opened many new possibilities in biophysics. Using microscopic handles, optical tweezers allow to apply and measure forces directly to single molecules, probing mechanical properties of DNA, RNA or protein motors, with nanometer and pico-Newton resolution.

The optical torque wrench is an extension of optical tweezers towards the control and measurement of angle and torque of the trapped particle. It has the potential to unravel new and fast dynamical processes in biological systems where rotation is relevant. Examples include the coiling of the DNA double helix, or the fast spinning of flagella in bacteria.

The angular dynamics of the trapped particle in the optical torque wrench is governed by a periodic tilted potential, and by a simple bifurcation that leads to excitability. We have experimentally shown and characterized this excitable dynamics, which links this technique to many other non-linear systems. Based on excitability, we proposed a method to locally detect single perturbation events acting on the trapped particle, with tunable sensitivity and high signal to noise ratio.

Such knowledge is important to efficiently employ the technique in studying biophysical systems at the single molecule level. I will describe preliminary results obtained in manipulating and measuring the torque developed by a single bacterial flagellar motor, a powerful nanometer-scale rotary protein motor.

José R. Rios Leite[1] (rios@df.ufpe.br), J. R. Tredicce[2], *W. Barbosa*[1] *and Edison Rosero*[1]

1. Departamento de Física, Universidade Federal de Pernambuco, 50670-901, Recife, Brazil

2. Universite de Nice-Sophia-Antibes-INLN, Valbonne, France and Universite de la Nouvelle Caledonie, Noumea, Nouvelle Caledonie

Nonlinear dynamics in a ring diode laser

The dynamics of a semiconductor laser including external ring cavity will be presented with emphasis on comparison of experimental results and various simplified models. In addition to the periodic and chaotic dynamics that has been observed experimentally in the diode system we shall discuss novel properties of the equations that can be extended to other types of ring laser.

K. Alan Shore (K.A.Shore@bangor.ac.uk), A. A. Qader , Y. Hong

Bangor University, School of Electronic Engineering, Bangor, Wales, UK

Polarization properties of VCSELs subject to optical feedback and Optical Injection

The presentation will describe experimental work which illustrates novel features of VCSELs subject to external optical interrogation. Attention will be given to (i) the effects of circularly polarized optical feedback; (ii) the role of the suppressed mode in VCSEL switching and (iii) polarization switching and hysteresis in optically injected VCSELs. Some attention may also be given to properties of nano-lasers.

Jorge Tredicce (Jorge.Tredicce@inln.cnrs.fr)

UNC-Nouvelle Caledonie

How a crisis produces an extreme event

We show that extremely high intensity pulses can be produced by laser systems [1] as a result of a dynamical bifurcation corresponding to an external crisis of a chaotic attractor. We discuss also about predictability, control and influence of noise on those extreme events.

[1] J. Zamora-Munt, B. Garbin, S. Barland, M. Giudici, J. R. Rios Leite, C. Masoller, and J. R. Tredicce, "*Rogue waves in optically injected lasers: origin, predictability, and suppression*", Phys. Rev. A 87, 035802 (2013).

T. Van Vaerenbergh (thomas.vanvaerenbergh@intec.ugent.be) and P. Bienstman

Ghent University, Belgium

Towards integrated optical spiking neural networks: delaying spikes on chip

To emulate Spiking Neural Networks (SNN) on an integrated photonic chip, one needs both excitable optical components, to mimic the spiking neurons, and delay lines acting as the connections that transfer the pulses between those neurons. Such an optical connection needs to have a delay in the order of magnitude of the internal timescale of the neuron. Consequently, when using passive Silicon-On-Insulator microrings as the basic excitable unit, those delay lines should have > 60 ns delays, which is infeasible to obtain with standard integrated delay line approaches. In this talk, we present in simulation a photonic neural circuit achieving a > 200 ns spike delay. This paves the way towards fully integrated optical SNNs.

CONTRIBUTED TALKS

Antti Aalto[1](antti.2.aalto@tut.fi), Goëry Genty[1], Juha Toivonen[1] and Toni Laurila[2]

1 Department of Physics, Tampere University of Technology, Tampere, Finland

2 Centre for Metrology and Acreditation, Espoo, Finland

Applications of supercontinuum sources: incoherent broadband cavity-enhanced absorption spectroscopy

We study experimentally the application of supercontinuum (SC) sources in incoherent broadband cavity enhanced absorption spectroscopy (IBB-CEAS). By carefully tailoring the SC spectrum to match the high reflectivity bandwidth of the mirrors, an unprecedented spectral brightness can be achieved at wavelengths where the effective absorption path length exceeds 40 km, making the fiber-based SC an ideal match for the simple and robust IBB-CEAS technique. We demonstrate the potential of SC sources in broadband measurement of weak overtone transitions of carbon dioxide and methane and compare its performances with that of typical superluminescent diode (SLD) source..

Cristina Masoller (cristina.masoller@upc.edu)

Departament de Física i Enginyeria Nuclear, Universitat Politècnica de Catalunya, Spain

Symbolic analysis of low-frequency fluctuations in semiconductor lasers with optical feedback

I will discuss a method of nonlinear time-series analysis that allows inferring signatures of determinism in the sequence of intensity dropouts emitted by a semiconductor laser with optical feedback in the low-frequency fluctuations (LFFs) regime. The method uses symbolic ordinal analysis to classify the inter-dropout-intervals (IDIs) in two categories that display statistically significant different features, one being consistent with waiting times in a resting state until noise triggers a dropout, and the other, with dropouts occurring during the return to the resting state, which have a clear deterministic component [1]. The method can be used for the analysis of real-world data where signatures of high-dimensional deterministic dynamics can be obscured by the presence of noise. The method is computationally simple to implement and the data requirements can be adapted for the analysis of small and large data sets.

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Vincent Odent (vodent@ing.uchile.cl)

Universidad de Chile

Photoisomerization front propagation in dye doped liquid crystal submitted to a Gaussian forcing

Lately photoresponse of materials has become a very attractive research subject. It offers ways to develop many applications without using an electrical power supply [1]. Many studies have shown a particular interest on the photoisomerization transition (between an anisotropic state and an isotropic state) which is used like an optical switching [2]. However these studies consider a homogeneous optical forcing [2, 3], while the optical external forcing is a laser beam with a Gaussian spatial profile. They have also showed that the temperature is an important factor for this transition. We propose to study experimentally the front propagation in 2D submitted to a Gaussian profile corresponding to a photoisomerization. We will also compare also the front propagation with the spatio-temporal temperature evolution induced by the laser beam in the medium. The setup is composed by a dye doped liquid crystal illuminated by a

laser beam. The optical signal is recorded by a CDD camera. A polarizer is disposed in front of it to optimize the contrast between two states. In order to record the temperature evolution, a thermal camera is placed at a certain angle near the liquid crystal sample. We determine experimentally that the transition is a first order with a hysteresis cycle. A bistable system submitted to a Gaussian forcing in 1D was studied theoretically by [4]. They demonstrate the front temporal evolution corresponds to hyperbolic tangent. In the first place, to verify that the front propagation dynamics in 2D follows the trajectory predicted by the theory, we detect the circle radius in the time (the front position). The experimental result is in a very good agreement with the analytical trajectory. Later, we study experimentally and numerically the final front position with different laser intensities. The numerical simulations show a good quantitative correspondence with the analytical prediction and the experimental work also show a good qualitative correspondence with the analytical prediction. Finally, we follow, in real time, the front propagation and the spatio-temporal evolution of the temperature in the dye doped liquid crystal. We show that there is a perfect correlation between the front and temperature propagations.

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Paul Michael Petersen (pape@fotonik.dtu.dk)

DTU Fotonik, Technical University of Denmark

New laser architecture using nonlinear frequency conversion and spectrally combined tapered diode lasers

In this work we propose an efficient concept increasing the power of diode laser systems in the visible spectral range. In comparison with second harmonic generation of single emitters, we show that spectral beam combining with subsequent sum-frequency generation enhances the available power significantly. Combining two 1060 nm distributed Bragg reflector tapered diode lasers (M24σ £ 5.2), we achieve a 2.5-3.2 fold increase of green light with a maximum power of 3.9 Watts in a diffraction-limited beam (M24σ £ 1.3). Without any further stabilization the obtained power stability is within ± 2.6 %. The electro-optical and nonlinear conversion efficiencies at maximum performance are 5.7 % and 2.6 %/W, respectively. These results increase the application potential of green diode laser systems, for example, within the biomedical field. In order to enhance the power even further, our proposed concept can be expanded combining multiple diode lasers.

Edison Rosero (ediroser@googlemail.com), José R. Rios Leite

Departamento de Fisica, Universidade Federal de Pernambuco, 50670-901 Recife, PE, Brazil.

Pulsing dynamics in a semiconductor laser with an external ring cavity configuration

We experimentally studied a novel configuration for a semiconductor laser included in a ring cavity with the semiconductor chip as amplifier medium and cavity end mirror. With pump current below and near the solitary threshold, the counter propagating modes were observed to be locked in frequency. Just above this threshold, bidirectional instabilities appear with chaotic power drops, typical of the Low Frequency Fluctuations that occur in Fabry-Perot diode laser with feedback. Tilted alignment of the external cavity along with appropriate pump current, changed the nature of the pulsed instability of cavity modes, indicating a sensitive dependence on the geometry of the modes within the active junction region. A theoretical model for the pulsed dynamics, using rate equations, was also done an compared well with the observations. The model included the effects of saturated absorption due to the junction regions that do not attain the amplifying condition, but are visited by the light beam created under external cavity operation.

Ivan A. Shelykh (shelykh@hi.is)

Science Institute, University of Iceland and Division of Physics and Applied Physics, Nanyang Technological University, Singapore

Nonlinear polarization phenomena in semiconductor microcavities

A quantum microcavity consists of a pair of dielectric Bragg mirrors with one or several quantum wells embedded at the positions where the electric field amplitude of the standing electromagnetic wave) reaches its maximums. In the strong coupling regime the elementary excitations in these systems are cavity polaritons, which are linear combinations of cavity photons and quantum well (QW) excitons.

The interplay between polariton spin and many-body interactions makes the spin dynamics of microcavity polaritons extremely rich and leads to a variety of promising effects, which will be considered in the presentation. We will consider the polarization of cavity polaritons and introduce the concept of the polariton pseudospin, which is a simple but useful representation of polarization. We discuss the physical mechanisms that provide various effective magnetic fields, which can lead to changes of the pseudospin. In particular, we will analyze the stability of polariton gases under nearly resonant continuous wave (cw) pumping and show how the polarization multistability and hysteresis of the polarization as a function of external pumping develop. These effects are shown to give rise to polarized pattern formation and also allow applications ranging from optical memory devices to optical circuits. Finally, we will discuss the perspectives and unresolved problems in the field and summarize the main features of the spin and polarization dependent dynamics of exciton-polaritons.

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Branislav Vlahovic (vlahovic@nccu.edu)

North Carolina Central University, Durham NC 27707, USA

Femtosecond pulsed laser fabrication of nanostructures for biochemical detector utilization

Discussed will be femtosecond pulsed laser deposition, multi-photon absorption and deposition parameters, laser fluence, pulse duration and shape, beam wavelength, and backing gas pressure for rapid synthesis of a wide range of semiconductor QDs and NW, to establish composition – property relationships. Experimental systems available at NCCU include ultrafast pulsed laser and pulsed electron deposition that are enhanced with pulsed free electron laser deposition at nearby Duke FEL facility. We produce group IV (SixGe1-x), III-V (InAs, InxGa1-xAs, GaAsxSb1-x) and chalcopyrite (CuInSe2, CuInTe2, ZnSiAs2 and ZnSiSb2) QDs and NWs by ultrafast pulsed beam techniques from bulk targets. Formed are size controlled QDs, with size dispersions matching those exhibited by conventionally grown QDs, that can be deposited at low temperatures on substrates free of lattice mismatching constraints. QDs sizes range from the strong quantum confinement regime (< 5 nm) to QDs with lateral sizes similar to conventional strain induced growth QDs. Discussed will be properties of produced nanostructures, their application in biochemical detectors, and processes important for detectors selectivity and sensitivity, interaction of light and nanostructures, and charge tunneling between nanostructures.

A. M. Yacomotti (alejandro.giacomotti@lpn.cnrs.fr), S. Haddadi and J. A. Levenson

Laboratoire de Photonique et de Nanostructures –Marcoussis, France

Coupling Control in Photonic Crystal Molecules

We experimentally show that the mode splitting in two-evanescently coupled Photonic Crystal L3 cavities (three holes missing in the underlying triangular lattice) can be controlled through barrier engineering. The "potential barrier" is formed by the air-holes in between the two cavities. By changing the hole radius of the central row in the barrier up to ~30%, the frequency splitting can be strongly reduced. Moreover, the sign of the splitting can be reversed in such a way that the fundamental mode can be either the symmetric or the anti-symmetric one without altering neither the cavity geometry nor the inter-cavity distance.

POSTERS

Alfredo Campos Mejía (alfredo@cio.mx)

Centro de Investigaciones en Óptica, León Guanajuato, México

Noise-induced on–off intermittency in mutually coupled semiconductor lasers

Intermittent switches between low-frequency fluctuations and steady-state emission are experimentally observed in two bidirectionally coupled semiconductor lasers subject to common Gaussian noise applied to the laser pump currents. The time series analysis reveals power-law scalings typical for on–off intermittency near its onset, with critical exponents of −1 for the mean turbulent length versus noise intensity and for probability distribution of laminar phases versus the laminar length. The same power-law scaling is found by the power spectrum analysis for the signal-to-noise ratio versus the noise intensity.

Leandro Junges (leandrojunges@gmail.com)

Universidade Federal do Rio Grande do Sul (UFRGS) Porto Alegre - Brazil

Dynamical characterization of semiconductor lasers subjected to delayed feedback

We present a numerical investigation to characterize the dynamics of semiconductor lasers subject to delayed optical feedback from an external cavity, according to the Lang-Kobayashi model [1]. We analyze the system behavior under the variation of two key control parameters: the delay time and the pump current. The individual increasing of the delay time have shown a periodic sequence of transitions between different regimes of operation, such as CW, Regular Pulse Packages (RPPs), quasiperiodic and aperiodic oscillations. These transitions have shown to be closely related to the creation of new External Cavity Modes (ECMs). Same regimes of operation were observed for the increasing of the pump current, but different sequences of transitions were seen for different values of the constant delay time. The trajectories of the solution in phase space, among the respective ECMs, were studied for all the observed regimes. Phase diagrams were constructed considering the joint variation of the control parameters, differentiating the regions where each regime can be found. A complex distribution of periodic and aperiodic phases was observed, unveiling the real extension of the phases where the mentioned regimes can be achieved.

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Cristina Masoller[1] (cristina.masoller@upc.edu), Jose A. Reinoso[2] and Jordi Zamora-Munt[3]

1 Departament de Fisica i Enginyeria Nuclear, Universitat Politecnica de Catalunya, Spain

2 Universidad Nacional de Educación a Distancia, Madrid, España

3 Instituto de Física Interdisciplinar de Sistemas Complejos (CSIC-UIB), Palma de Mallorca, España

Extreme intensity pulses in a semiconductor laser with a short external cavity

We present a numerical study of the pulses displayed by a semiconductor laser with optical feedback in the short cavity regime, such that the external cavity round trip time is smaller than the laser relaxation oscillation period. For certain parameters there are occasional pulses, which are high enough to be considered extreme events [1]. We characterize the bifurcation scenario that gives rise to such extreme pulses and study the influence of noise. We demonstrate intermittency when the extreme pulses appear and hysteresis when the attractor that sustains these pulses is destroyed. We also show that this scenario is robust under the inclusion of noise. The superposition of several extreme pulses in phase space generates a narrow curve well before the extreme pulse occurs, which allows predicting the extreme pulses; similar predictability has been found for rogue waves in continuous-wave optically injected lasers [2]. Since semiconductor lasers with integrated short external cavities are nowadays widely used in many applications that require single-mode, narrow line-width emission, our results can be relevant for avoiding extreme intensity pulses in these devices, which might originate due to uncontrolled small variations in the feedback parameters.

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Huber Nieto-Chaupis (hnieto@physik.hu-berlin.de)

Universidad Nacional de Ingeniería, Lima Perú

Nonlinear classical Compton Backscattering with twisted fields.

In this poster, inspired on the prospects for producing high energy twisted photons, which are photon states containing orbital angular momentum (OAM), the classical intensity spectrum obtained from the interaction between electron and twisted field, is computationally simulated.

Specifically, we have paid attention to the theory of Nonlinear Classical Compton Backscattering (NCCB) by providing an interesting theoretical description of the interaction between MeV photons and GeV electrons. In fact, NCCB has revealed at the past, that the dynamics of the scattered photon appears to be compatible with the ones obtained from Quantum Electrodynamics. Our resulting spectrum agrees well the obtained one from studies given at the past, where the classical model is capable to reproduce simple Compton Scattering with a 0.01 TW photon and a 50 GeV electron. Indeed, in this paper we also show the interesting variations on the spectrum morphology as consequence of the coupling of the OAM state and the electron kinematics along the linear and nonlinear regions of interaction.

In addition, these results might be of importance to produce another family of bright and tunable x rays which would improve the analysis and characterization of compounds and materials at the range of MeV photon energy.

Vincent Odent (vodent@ing.uchile.cl)

Universidad de Chile

Statistical analysis of spatial frequency supercontinuum in pattern forming feedback systems

The dynamics of highly nonlinear regime in physics is very complex and the underlying physical processes are still under investigation [1,2]. In the spatiotemporal optical systems, highly nonlinear regimes are characterized by the spatiotemporal chaos and supercontinuum, and their transition from the weakly nonlinear to highly nonlinear dynamics remains an open field of research [3]. We report on generation of spectral supercontinua in a one-dimensional transverse Kerr slice medium, subject to an optical feedback. We show that these supercontinua are closely related to generation of abnormally high intensity peaks in the transverse patterns that disappear as fast as they appear. The associated highly nonlinear regime [4] is far above the threshold for the Turing instability (spatial modulational instability), where stationary rolls are observed. We investigate this spatiotemporal chaotic regime using a statistical approach in terms of probability density functions (PDFs) of the pattern intensity maxima. We find that statistical distribution of these maxima is well described by the generalized gamma distribution, characterized by three parameters. These parameters are used as quantitative indicators to characterize the transition from the weakly to the highly nonlinear dynamical regime. Most interestingly, we discover that the generalized gamma PDF reduces to the gamma PDF with the shape parameter equal to 3/2 for the spatiotemporal chaotic regime very high above the Turing threshold. It should be noted that in terms of the probability density function for the peak amplitudes (instead of intensities) this corresponds to the Rayleigh distribution which was observed for the statistics of the oceanic waves. This behavior of the PDF can be an indicator of the universality of the spatiotemporal chaotic regime and calls for similar investigations in other types of dynamical systems manifesting chaos.

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Vincent Odent (vodent@ing.uchile.cl)

Universidad de Chile

Front pinning induced by spatial inhomogeneous forcing in a Pérot-Fabry Kerr cavity with negative diffraction

In a bistable system, the front dynamics connecting two states is a problem concerning many domains of physics [1, 2]. In this system, under a parameter breaking symmetry, the front propagates, except at the Maxwell point. To observe front locking behavior, a spatial periodic forcing has been proposed [3]. In optics, usually we work with Gaussian laser beam which presents inhomogeneous spatial profile, so a natural question arises: Is the dynamics of fronts in optical system affected by an inhomogeneous spatial profile? In the present work, we study front pinning phenomena due to a Gaussian optical forcing. The final pattern is a localized state bounded by two pinned fronts. We develop an analytical model of front dynamics subjected to spatial forcing from the imperfect pitchfork equation [4]. Under a parabolic forcing approximation, we obtain an analytical expression of the front core trajectory. The analytical study is verified by numerical simulations of this model with parabolic and Gaussian forcing. In this latter case, the numerical simulations show a transitory regime where the front propagation velocity slowly decreases until reach a pinned state. We carried out experiments in a one-dimensional Perot-Fabry passive Kerr cavity submitted to negative diffraction with a 4f lens arrangement. The Kerr medium is a nematic liquid crystal thin film. The spatial forcing comes from the Gaussian profile of the laser beam and cylindrical lenses, which generate one-dimensional Gaussian beam. Fronts are generated using cavity under negative diffraction feedback. This last feature is achieved via 4f lens arrangement that allows obtaining negative optical cavity length and consequently negative diffraction [5]. Under these conditions, experimental fronts are pinned after a nonlinear transitory propagating regime, showing a good agreement with the theory. The final state is a spatial localized structure. Numerical simulations of the Kerr cavity dynamics are consistent with the core trajectory analytical expression.

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M. S. Torre[1](marita@exa.unicen.edu.ar;), Matias F. Salvide[1], and Cristina Masoller[2]

1 Instituto de Física "Arroyo Seco", CIFICEN –CONICET -UNCPBA, Tandil, Argentina

2 Departament de Fisica i Enginyeria Nuclear, Universitat Politecnica de Catalunya, Spain

Numerical implementation of a stochastic logic gate based on a VCSEL with tunable optical injection

We study the dynamics of a vertical-cavity surface-emitting laser (VCSEL) with continuous-wave orthogonal optical injection from a tunable laser. We use the dynamical properties of polarization bistability and the interplay with internal or external noise to demonstrate numerically a reliable stochastic logic gate [1]. With adequate noise strength the laser output polarization is the correct logic response to two logic inputs encoded in the wavelength of the injected light [2]. We present a detailed analysis of the reliability of the VCSEL-based stochastic logic gate in terms of the laser parameters and of the orthogonal injection parameters. We show that this configuration using orthogonal injection works more than ten times faster than the opto-electronic implementation proposed in [3] (where the login inputs are encoded in a three-level modulation of the laser current), and is as fast as the all-optical one proposed in [4] (where the login inputs are encoded in a three-level modulation of the optical injected power), with the advantage of being simpler to implement, as it requires constant injection power.

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