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

Organizers:

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

Financial support:
Optical Society of America (OSA)

Sponsored by:
Photonics society

Held at Hotel Radisson, Colonia del Sacramento, Uruguay
December 6 - December 9, 2011

PROGRAM

	Tuesday – 6 December
8:30am – 8:55am	**Registration**
Chair person	
9:00am – 9:10am	Welcome
9:10am – 9:40am	**Cid de Araújo** (Univ. Federal de Pernambuco, Recife, Brazil) *Scattering lasers: from Random to Mie Lasers*
9:40am– 10:10am	**Fritz Henneberger** (Humboldt University of Berlin, Germany) *Random Semiconductor Lasers: Scattered versus Fabry-Perot Feedback*
10:10am– 10:40am	**Alexander Gaeta** (Cornell University, US) *Novel optical devices based on four-wave mixing*
10:40am – 11:00am	Coffee Break
Chair person	
11:00am – 11:30am	**Michal Lipson** (Cornell University, US) *Optomechanics in silicon nanostructures*
11:30am – 12:00am	**Eckehard Schöll** (Technische Universitat Berlin, Germany) *Nonlinear dynamics of semiconductor quantum dot lasers*
12:00am – 12:30 am	**Pascal Besnard** (Foton-Enssat, CNRS, France) *Single-frequency Quantum Dashed lasers submitted to optical injection*
12:30 pm – 2:30 pm	**Lunch**
Chair person	
2:30pm – 3:00pm	**Alejandro Hnilo** (Centro de Investigaciones en Láseres y Aplicaciones, Buenos Aires, Argentina) *Extreme value events in self-pulsing lasers*
3:00pm – 3:30pm	**Jose Rios Leite** (Universidade Federal de Pernambuco, Recife, Brazil) *Instabilities in Ring Semiconductor Lasers*
3:30pm – 4:00pm	**Lendert Gelens** (Vrije Universiteit Brussel, Belgium) *Dynamical behavior of semiconductor ring lasers*
4:00pm – 4:30pm	Coffee Break
Chair person	
4:30pm – 5:00pm	**Marcos Oriá** (Universidad Federal da Paraiba, Joao Pessoa, Brazil) *Very low rate frequency-oscillation of semiconductor lasers under orthogonal feedback*
5:00pm – 5:30pm	**Tom Gavrielides** (Air Force Research Laboratory, London, UK) *Polarization square-wave switching in orthogonally delay-coupled semiconductor lasers*
5:30pm – 6:00 pm	**Cristina Masoller** (Universitat Politecnica de Catalunya, Spain) *Rogue Waves in optically injected semiconductor lasers*

	Wednesday – 7 December
8:30am – 8:55am	**Registration**
Chair person	
9:00am – 9:30am	**Alan Shore** (Bangor University, Wales, UK) *Design and applications of electrically-injected nano-spin semiconductor lasers*
9:30am– 10:00am	**Antonio Hurtado** (University of Essex, UK) *Nonlinear Dynamics in Long-Wavelength VCSELs subject to polarised optical injection*
10:00am– 10:30am	**Sylvain Barbay** (LPN-CNRS, Marcoussis, France) *Localized states and excitability in a monolithic VCSEL with saturable absorber*
10:30am – 11:00am	Coffee Break
Chair person	
11:00am – 11:30am	**Daniel Gauthier** (Duke University, Durham, USA) *Spontaneous symmetry breaking in optical patterns generated by the interaction of light and matter waves*
11:30am – 12:00 am	**Manuel Matias** (IFISC, Universitat de les Illes Balears, Spain) *Spatially nonlocal bistable media: front propagation and localized structures*
12:00pm – 12:30 pm	**Orazio Descalzi** (Universidad de los Andes, Chile) *Noise can induce explosions for dissipative solitons*
12:00 pm – 2:30 pm	**Lunch**
Chair person	
2:30pm – 3:00pm	**Miguel Hoyuelos** (Universidad Nacional de Mar del Plata, Argentina) *Elliptically polarized transverse patterns in a cavity with electric and magnetic nonlinearities*
3:00pm – 3:30pm	**Damia Gomila** (IFISC,Universitat Illes Balears, Spain) *From the Townes soliton to Kerr-cavity solitons*
3:30pm – 4:00pm	**Marcel Clerc** (Universidad de Chile) *Front dynamics and pinning-depinning phenomenon in spatially periodic media*
4:00pm – 4:30pm	Coffee Break
Chair person	
4:30pm – 4:50pm	**Adrian Jacobo** (Max Plank Institut for the Physics of Complex Systems) *Logical operations using cavity solitons*
4:50pm – 5:10pm	**Chugo Fujihashi** (Tokyo Polytechnic University, Japan) *Stochastic Analysis of Charging and Recombination in Double-Hetero Tunnel-Junction Quantum Dot Semiconductor Laser*
5:10pm – 5:30pm	**Michal Matuszewski** (Institute of Physics, Polish Academy of Sciences) *Light Bullets in Nonlinear Curved Waveguide Arrays*
8:30 pm – 10:30 pm	**Conference Dinner (asado)**

	Thursday – 8 December
Chair person	
9:00am – 9:30am	**Ricardo Depine** (Universidad de Buenos Aires, Argentina) *Order-disorder effects in the high energy optical response of 3D photonic crystals*
9:30am– 10:00am	**Kamel Bencheikh** (LPN-CNRS, Marcoussis, France) *Slow light propagation due to nonlinear interaction in a 2D semi-conductor photonic crystal cavity*
10:00am– 10:30am	**Francesca Intonti** (Universitá degli studi di Firenze, Italy) *Optical probing and local modification of photonic crystal molecules*
10:30am – 11:00am	Coffee Break
Chair person	
11:00am – 11:30am	**Hou-Tong Chen** (Los Alamos National Laboratory, USA) *Active tuning and nonlinearity in metamaterials*
11:30am – 12:00 am	**Mario Molina** (Universidad de Chile, Santiago, Chile) *Localized modes and Fano resonances in magnetic metamaterials*
12:00pm – 12:30 pm	**Oscar Martínez** (Universidad de Buenos Aires, Argentina) *Optical fabrication beyond the diffraction limit: making it fast, easy and cheap*
12:30 pm – 2:30 pm	**Lunch**
Chair person	
2:30pm – 3:00pm	**Hernán Míguez** (Instituto de Ciencia de Materiales de Sevilla, Spain) *Porous Multilayers: Novel Multifunctional Materials for Light Absorption and Emission Control*
3:00pm – 3:30pm	**Santiago Costantino** (Université de Montréal, Canada) *Optical protein patterning, micro-engineering the cellular environment using lasers.*
3:30pm – 4:00pm	**Vasilis Apostolopoulos** (University of Southampton, UK) *Novel emitters and algorithms for THz-time domain spectrometers*
4:00pm – 4:30pm	Coffee Break
Chair person	
4:30pm – 4:50pm	**Igal Brener** (Sandia National Laboratory, US) *Interactions in 2D and 3D mid-infrared metamaterials*
4:50pm – 5:10pm	**Alejandro Giacomotti** (LPN-CNRS, Marcoussis, France) *Silicon-nitride 2D photonic crystals as substrates for fluorescence microscopy*
5:10pm – 5:30pm	**Pramod Kumar** (Indian Institute of Science Education and Research,Punjab, India.) *Phase-amplitude Coupling Factor Induced Multistability near Phase-flip Bifurcation regimes in Mutually Delay-Coupled Diode Lasers*
5:30pm – 7:00pm	**POSTER SESSION**

	Friday – 9 December
Chair person	
9:00am – 9:30am	**Martine Chevrollier** (Univ. Federal da Paraíba, João Pessoa, Brasil) *Optical study of atoms adsorption on dielectric surfaces*
9:30am– 10:00am	**Arturo Lezama** (Universidad de la República, Montevideo, Uruguay) *Generation of quantum correlated light beams in an atomic vapor*
10:00pm – 10:30 pm	**Alessandro de Sousa Villar** (Universidade de São Paulo, Brasil) *Entanglement among bright light beams: creation, structure, sudden death*
10:30am – 11:00am	Coffee Break
11:00am – 11:30am	**Roberta Zambrini** (IFISC, Universitat de les Illes Balears, Spain) *Quantum aspects of synchronization*
11:30am – 12:00 am	**Maxime Jacquot** (University of Franche-Comté, Besançon, France) *Delay electro-optic dynamics for brain inspired information processing*
12:00am – 12:30 am	**Kristof Vandoorne** (Ghent University, Belgium) *Photonic reservoir computing and information processing with coupled semiconductor optical amplifiers*
12:30pm – 12:50pm	**Mário Ferreira** (University of Aveiro, Portugal) *Nonlinear effects in optical fibers: limitations and novel possibilities*

INVITED TALKS

Vasilis Apostolopoulos (vasilis.apostolopoulos@gmail.com)

University of Southampton, UK

Novel emitters and algorithms for THz-time domain spectrometers

"Terahertz (THz) radiation can be produced by simple illumination of a semiconductor surface by an ultrafast IR laser with energy above the bandgap. The strong absorption of light near the surface creates a large carrier gradient of electron and hole pairs, which initiates a diffusion current. Because of the different mobilities electrons and holes spatially separate on a picosecond time scale. The resulting dipole radiates at THz frequencies but in a direction perpendicular to the optical illumination. This is the PhotoDember (PD) effect and was not considered to be competitive with other generation techniques because of low output power, mainly due to poor out-coupling. However, Klatt et al. in 2010 have demonstrated a lateral PD emitter which takes advantage of the dipole created by lateral diffusion currents created by metal masking. This is a novel geometry for THz generation which is compatible with time domain spectrometers and gives competitive results to photoconduction. We are presenting simulations of the effect taking into account the diffusion of carriers and the electric field and finite ele--ment modelling and analytic calculations to show how the THz emission arises. Experimental investigations confirm our simulations and we propose a new theory that explains the THz generation in this geometry and propose a novel class of emitters that can be used for integration.

Furthermore, research is included about the determination of the complex refractive index as a function of frequency in THz time domain spectrometers. A common assumption for the theoretical model in material parameter extraction is that the THz beam is a plane wave. The plane wave hypothesis is used even for focused THz beam spectrometers in order to simplify the analysis, however it results in an overestimation of the refractive index due to underestimating the optical thickness. I will present a converging beam refractive index extraction method for THz-time domain spectrometers, which uses an arbitrary frequency dependent angular profile and takes into account internal reflections"

Sylvain Barbay (sylvain.barbay@lpn.cnrs.fr), R. Braive, I. Sagnes, R. Kuszelewicz and A. Giacomotti

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

Localized states and excitability in a monolithic VCSEL with saturable absorber

We present experimental results on nonlinear localization and excitability in an original design of a Vertical Cavity Surface Emitting Laser with intracavity saturable absorber. Depending on the sample temperature, the VCSEL with saturable absorber can be locally bistable or self-pulsing at threshold. In the first case, self-localized states (laser cavity solitons) are demonstrated, excited and erased incoherently at a fast rate. We present also evidence of optical manipulation of self-pulsing states. In the second case, type III excitability is demonstrated. Excitability in a laser with saturable absorber occurs below the self-pulsing instability and is characterized by: 1) a threshold in the response to an input perturbation leading to a “all or nothing” type of response and 2) appearance of a calibrated response above threshold. We compare our experimental results to a model, including the effect of noise. At last, we present recent results obtained in arrays of micropillar cavities towards the demonstration of nonlinear wave propagation. The vertical cavity design presented here could constitute a compact platform for realization of various micro and nanophotonic semiconductor devices for applications to innovative all-optical signal-processing tasks, e.g. excitable logic-gates or reservoir computing.

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Slow light propagation due to nonlinear interaction in a 2D semi-conductor photonic crystal cavity

The phenomenon of slow light (SL) has become a topic of growing interest because it offers another level of control over light–matter interactions and potential applications such as optical buffers or phase shifters. The most efficient techniques are based on nonlinear coherent optical interactions such the coherent population oscillations (CPO) effect [1] or Electromagnetically Induced Transparency (EIT) [2]. Slowing down the light and reaching group velocities of few m/s has been demonstrated in different atomic and solid systems. Slow light propagation is also obtained through the engineering of the index of refraction in the photonic crystals [3]. The association of both effects is however still missing.

In this paper, we present our work on SL propagation in a semi-conductor-based photonic crystal (PhC) cavity. In such structure, we have associated the SL propagation induced by the CPO effect achieved in the absorbing Quantum Wells (QWs) present in the photonic crystal cavity with the dispersive properties of a nonlinear PhC cavity. We show that the cavity lifetime is enhanced thanks to the combination of two effects: CPO-based index dispersion and strong dispersion in vicinity of the nonlinear PhC cavity resonance. The PhC cavity used in our experimental investigations in based on InP semi-conductors having 4 InGaAsP/InGaAs QWs with an absorption of about 60 cm-1 at 1.57 µm. The CPO effect is achieved using the intensity modulation technique and the laser beam is coupled into the cavity using a tapered optical fibre. Using a homemade locking amplifier we were able to measure the optical delay induced in the PhC cavity. We reach group delays of about 600 ps, longer than the storage time in an empty cavity or when the CPO effect is considered on its own. These large delays show that the lifetimes of optical resonators can be enhanced by inclosing strong dispersive materials in the cavities [4]. Details on both experimental investigations and theoretical analysis will be discussed in the presentation.

[1] R.W. Boyd, M.G. Raymer, P. Narum and D.J. Harte, Phys. Rev. A 24, 411 (1981).

[2] S. E. Harris, Phys. Today 50, No. 7, 36 (1997)

[3] T. Baba, Nature photonics 2, 465 (2008).

[4] M. Soljacic, E. Lidorikis, L. V. Hau and J.D. Joannopoulos, Phys. Rev. E 71, 026602 (2005)

Pascal Besnard (pascal.besnard@enssat.fr)

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Single-frequency Quantum Dashed lasers submitted to optical Injection

Mode-locked Quantum-dashes lasers at 1.55 µm show very good performances compared to bulk ones. The first part of the talk will show some examples of how these properties can be of interest for optical communications. Some of these demonstrations use optical injection. However the multi-frequency character of mode-locked lasers is not a favorable element for a direct comparison to bulk or quantum well structures. In order to have a better understanding of the physics underlying the dynamics of such lasers, we decided to compare single frequency lasers by using DFB quantum dashes lasers. After a short review of the different phenomena that can be observed with optical injection, we show the quite different behavior of quantum dash lasers emitting at 1.55 µm when submitted to optical injection.

[1] H. L. Stover andW. H. Steier, “Locking of laser Oscillators by light injection,” Appl. Phys. Lett. 8, 91–93 (1966).

[2] S.Wieczorek,T.Simpson,B. Krauskopf et D. Lenstra,"Bifurcation transitions in an opticaly injected diode laser : Theory and experiment,"Optics communication Vol.215,pp.125-134,2003.

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[4] T. Erneux, E. A. Viktorov, B. Kelleher, D. Goulding, S. P. Hegarty, and G. Huyet, "Optically injected quantum-dot lasers", Optics Letters, Vol. 35, Issue 7, pp. 937-939 (2010).

[5] G. Huyet "Nonlinear dynamics of quantum-dot lasers", invited talk CLEO Europe 2011.

[6] F. Lelarge, J. Renaudier, R. Brenot, A. Accard, F. van Dijk, D. Make, O. Le Gouezigou, J-G Provost, F. Poingt, J. Landreau, O. Drisse, E. Derouin, B. Rousseau, F. Pommereau, G-H Duan, "Recent Advances on InAs/InP Quantum Dash Based Semiconductor Lasers and Optical Amplifiers Operating at 1.55 µm," Selected Topics in Quantum Electronics, IEEE Journal of , vol.13, no.1, pp.111-124, Jan.-Feb. 2007.

[7] M. Costa e Silva, A. Lagrost, L. Bramerie, M. Gay, P. Besnard, M. Joindot, J. C. Simon, A. Shen, and D. Guan-Hua, "Up to 427 GHz All Optical Frequency Down-Conversion Clock Recovery Based on Quantum-Dash Fabry-Perot Mode-Locked Laser", Lightwave Technology, Journal of, vol. 29, pp. 609-615, 2011.

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Hou-Tong Chen (chenht@lanl.gov)

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Active tuning and nonlinearity in metamaterials

During the past decade electromagnetic metamaterials have realized many exotic phenomena that are difficult or impossible to occur in nature. While the passive properties in metamaterials have been widely investigated, it becomes increasingly important to achieve active tunability and nonlinearity. In this talk, I will show our experimental and theoretical results in actively and/or dynamically tunable metamaterials and devices by integrating additional semiconducting or ferroelectric materials in the metallic resonators, or choosing high temperature superconducting films to replace the metal. Additionally, enhanced nonlinearity is expected in such metamaterials. Applications for terahertz (THz) technologies will also be shown.

Martine Chevrollier (martine@otica.ufpb.br), Weliton Soares Martins, Thierry Passerat de Silans, and Marcos Oriá

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Optical study of atoms adsorption on dielectric surfaces

Understanding the basic mechanisms of atom-surface interactions is essential for many applications where atoms need to be manipulated close to surfaces as well as for controlling adsorption processes. In our pursuit of the observation of atomic bound states in the surface potential, we have proposed [1,2] a laser photo-associative technique to load cold atoms in the van der Waals potential well of a dielectric surface. It consists in exciting free cold atoms to a bound level of the excited electronic state, from where they can decay, either spontaneously or stimulated, to a bound level of the ground state. As a step toward the realization of this proposed technique, we study a laser induced adsorption technique using hot atoms, first demonstrated by Balykin and co-workers [3]. We illuminate the interface between a sapphire window and a warm cesium vapor with a laser beam close to the atomic resonance and monitor the formation of a metallic film at this interface using a set of complementary optical tools, such as reflection and transmission of an off-resonant probe laser and detection of a rich retro-fluorescence from the heated cesium atomic vapor. The film formation on the transparent sapphire surface can be further characterized through the use of the Selective Reflection (SR) technique [4]. This optical spectroscopy technique has proved to be a very sensitive probe of dielectric-metal-vapor structures [5], giving information on both the width and the refraction index of metallic films at the interface between a dielectric and an atomic vapor, as well as on long-range atom-surface interactions. Systematic measurements varying the pump laser power, the atomic density and the surface temperature evidence the simultaneous occurrence of many light-matter processes in the vapor and give a complex picture of the mechanisms leading to the accumulation of cesium atoms at the illuminated spot on the surface.

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Santiago Costantino (santiago.costantino@umontreal.ca)

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Optical protein patterning, micro-engineering the cellular environment using lasers

A myriad of signaling pathways that regulate cellular growth, migration and differentiation can be triggered by changes in the spatial distribution of biomolecules. The ability to accurately engineer the spatial organization of proteins for mimicking the in vivo cellular environments allows probing of these molecular mechanisms with unprecedented precision. These mechanisms span diverse processes, from axonal guidance, morphogene protein signaling, and leucocyte-, fungal- and bacterial-, chemoattraction, to tissue engineering and regeneration. Although technologies currently available to achieve this are becoming widespread, various technical and cost-related reasons limited their use in biomedical research. To overcome these limitations we have developed Laser Assisted Protein Adsorption by Photobleaching (LAPAP), a simple, robust and highly versatile methodology to fabricate substrate bound protein patterns. This rapid optical approach relies on photobleaching fluorophores to adsorb proteins on a cell culture substrate using commonly available reagents, and a home-made laser scanning system or a standard inverted microscope equipped with a camera port. Using LAPAP, we can simultaneously pattern up to three different proteins with optical resolution (~1μm), independently controlling their distributions and concentrations over three orders of magnitude. We can fabricate both peptide and full-protein gradients, which have been used in neuronal assays. We conceived and put together two optical setups to fabricate protein patterns, thus accelerating fabrication time by two orders of magnitude. We have succeeded to produce an overall density amplification protocol to further increase the concentration up to one order of magnitude, and we have created 3-dimensional protein patterns inside hydrogels using two-photon absorption to constrain photobleaching and protein adsorption to a femtolitter volume.

Cid B. de Araújo (cid@df.ufpe.br)

Universidade Federal de Pernambuco, Recife, Brazil

Scattering lasers: from Random to Mie Lasers

I will describe experiments performed with two types of lasers in which the feedback is provided by multiple scattering of light. Results based on down-conversion frequency and up-conversion frequency processes will be presented. An introduction on scattering lasers will be given in the first part of the talk followed by description of experiments with 3-dimensional lasers consisting of two kind of lasing systems (i - luminescent colloids containing dielectric or metallic nanoparticles; ii -dielectric powders doped with rare-earth ions); 2-dimensional lasers obtained using dye doped polymer films with metallic nanoparticles, and quasi-1 dimensional laser based on hollow optical fibers containing colloids with dyes and nanoparticles. Finally recent results obtained with Mie lasers consisting of single silica particles embedded with laser dyes will be reported.

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Order-disorder effects in the high energy optical response of 3D photonic crystals

The purpose of this talk is to discuss the different optical effects that can be observed when the wavelength of light is on the order or smaller than the lattice parameter of a three-dimensional photonic crystal made of spheres. The origin of these optical effects as well as how they are affected by the presence of different amounts of disorder will be analyzed. In particular, it will be shown that rigorous electromagnetic methods, valid for perfectly periodic structures, can be used to simulate the optical response of disordered structures and reproduce experimentally observed effects such as anomalous specular reflectance and ballistic transmittance, diffusely scattered light, and optical diffraction. Examples will be given for the case of synthetic opals made of dielectric spheres, a case for which several measured optical spectra are available.

Orazio Descalzi (odescalzi@miuandes.cl)

Universidad de los Andes, Chile

Noise can induce explosions for dissipative solitons

Spatial pattern formation in driven systems is well-known to be important for many scientific fields including chemical reactions, nonlinear optics, hydrodynamic instabilities, pattern formation in biology, etc. We demonstrate that a small amount of additive noise has a profound effect on stable spatially localized solutions of a prototype envelope equation: the cubic-quintic complex Ginzburg-Landau equation characteristic for a weakly inverted bifurcation to traveling waves in the regime of anomalous linear dispersion. We show that with increasing noise strength a chaotic state with explosions is reached via two qualitatively different routes. As intermediate states for smaller noise strength we find either a noisy state with explosions (starting from a stationary or an oscillatory spatially localized state with one frequency) or a chaotic state without explosions (starting deterministically with an oscillatory spatially localized state with two frequencies). These results on the influence of a small amount of noise reveal a qualitatively new perspective for the phenomena associated with the explosive dissipative solitons found and characterized deterministically in modelling and experiment. To test our results we suggest the performance of experiments along the lines of those reported by Cundiff et al. [1] for a solid state passively mode-locked laser.

[1] S.T. Cundiff, J.M. Soto-Crespo, N. Akhmediev, Phys. Rev. Lett. 88, 073903 (2002).

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Spontaneous symmetry breaking in optical patterns generated by the interaction of light and matter waves

We observe the creation of transverse optical spatial patterns when laser beams interact with a gas of cold rubidium atoms trapped in a highly asymmetric magneto-optic trap. The instability arises from parametric self-oscillation due to an extremely large fifth-order nonlinear optical process that is due to the simultaneous action of Sisyphus cooling and atom bunching, allowing pattern formation at ultra-low powers. We observe that the pattern undergoes a spontaneous symmetry breaking in that the azimuthal orientation of the pattern wanders in time. We also find that this pattern can be pinned using an exceedingly weak control beam.

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Dynamical behavior of semiconductor ring lasers

Semiconductor Ring Lasers (SRLs) are a modern class of semiconductor lasers whose active cavity is characterized by a circular geometry. SRLs have attracted attention for two main reasons. On the one hand, SRLs are promising components in photonic integrated circuits due to their potential in applications such as all-optical memories and data processing. On the other hand, SRLs are prototypes for the large class of Z2 symmetric systems encountered in a wide number of physical systems.

This talk addresses the stochastic and nonlinear dynamical behavior of single-longitudinal and single transverse mode SRLs, putting emphasis on the experimentally observable effects that are a consequence of the ring symmetry and that can be theoretically addressed in a device-independent way by investigating the invariant manifolds of the system.

We show how to experimentally control the internal parameters of the SRL such as the mode coupling and how to break the ring symmetry in a controllable and reversible way. In particular, we discuss mode hopping between multiple stable attractors present in the system [1,2]. We also demonstrate excitability in a single SRL [3] and pulse excitations in coupled SRLs [4]. This suggests that SRLs are possible candidates for scalable optical excitable units, which could be in principle integrated on chip with densities exceeding 100000/cm2. Such optical neural networks are attractive because of the high degree of parallelism that can be achieved and the large optical bandwidth allowing for very fast processing. Finally, we study the SRL subjected to feedback exhibiting e.g. square-wave oscillations.

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From the Townes soliton to Kerr-cavity solitons

Conservative and dissipative solitons are in some ways very different: the former are exact solutions of integrable systems, the latter no; conservative solitons appear as one parameter families, dissipative solitons are unique once parameters are fixed, and so on. In some optical systems, however, dissipative solitons are intimately linked to their conservative counterparts. This is the case, for instance, of dissipative solitons in a self-focusing Kerr cavity, also known as Kerr cavity solitons (KCS). A Kerr cavity can be modeled by the Lugiato-Lefever equation (LLE), describing the dynamics of the electric field inside the cavity in the paraxial and mean field approximation. This equation is a prototypical model displaying spontaneous pattern formation. In the limit of large detunings the LLE can be reduced, however, to the conservative nonlinear Schroedinger equation (NLSE). In the LLE, KCS can be formed both in cavities with one and two transverse dimensions. In the 2D case, KCS exhibit a rich variety of dynamical regimes only possible in driven dissipative systems, including oscillations and excitability. In this paper we will show that, as a matter of fact, all this behavior emerge from the properties of the Townes soliton of the conservative 2D NLSE. In particular, in the 2D case, we demonstrate by continuation methods that KCS emerge from the Townes soliton, and that this one sits exactly at a codimension-2 Takens-Bogdanov point. When considering dissipation and driving as unfolding parameters, one can explain the different dynamical regimes observed in the dissipative case, namely, stationary, oscillatory, and excitable cavity solitons, as a consequence of the properties of the cavity solitons in the conservative limit.

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Random Semiconductor Lasers: Scattered versus Fabry-Perot Feedback

As a result of growth imperfections, (Zn,Cd)O/ZnO quantum well structures exhibit random laser action. Fabrication of micro-resonators allows us to study and to compare directly cavity and scattered feedback. Our experimental and theoretical analysis shows that (i) pure random lasing requires generally a larger gain than in the standard Fabry-Perot regime, (ii) the presence of Mie scatteres in the semiconductor-based cavity does not increase substantially the lasing threshold, and (iii) the random feedback creates a subtle modal gain distribution that might be of particular importance for the dynamical properties, both with and without Fabry-Perot cavity.

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Extreme value events in self-pulsing lasers

Events with an extreme amplitude value, appearing rarely but still with a frequency much larger than expected from a Gaussian distribution, were originally reported in oceanic science, where they received the name of “rogue” or “freak” waves. Few years ago, an analogous phenomenon, i.e., the sporadic occurrence of pulses of light of extraordinary intensity, was found in a system based on a micro-structured optical fiber pumped by an ultrashort pulse laser near the threshold of super-continuum generation. The conditions for the formation of these sometimes called “optical rogue waves” have been revealed from experiments on optical setups. Recently, they have been observed in a VCSEL with a CW signal injected from a master laser oscillator. Numerical simulations indicate that they should exist in mode-locked fiber lasers. We report experimental and theoretical evidence of their existence in two types of self-pulsing lasers of widespread use, both belonging to the “laser with a saturable absorber” scenario (whose equations are similar to the Bénard-Rayleigh problem with a solute). One is the

Kerr-lens-mode-locked Ti:Sapphire laser (“fast” saturable absorber case, pulses of fs duration at a repetition rate of 80 MHz). The other one is the diode-pumped, Nd+Cr:YAG passively Q-switched laser (“slow” saturable absorber case, pulses of ns duration at a repetition rate of 10 KHz). Extreme value events are observed in some (not all) of the chaotic regimes of both systems. A previously well-tested theoretical model, based on a five variables iterative map, describes the observations for the former case. The usual description in terms of rate equations apparently fails to predict rogue events for the latter, implying that this description must be improved, possibly by including the oscillation of several transversal modes.

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Elliptically polarized transverse patterns in a cavity with electric and magnetic nonlinearities

We analyze the evolution equations of electric and magnetic field amplitudes in a ring cavity with flat mirrors, where the degree of freedom of light polarization is taken into account. The cavity is filled with a positive or negative refraction index material (NRM) with third order Kerr-like electric and magnetic nonlinearities (magnetic nonlinearities can be relevant for NRM). We present an overview of the possible patterns and instabilities for different values of the parameters (detuning, nonlinear parameter, light polarization and sign of diffraction). We also present a method for the analysis of eigenvalues that allows the derivation of some exact and general results. The method allows us to find Turing-Turing codimension 2 (where two different wavenumbers destabilize simultaneously) and a Turing-Hopf-Turing codimension 3 instability. It is shown that for a given input intensity there cannot be more than three unstable tongues.

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Nonlinear Dynamics in Long-Wavelength VCSELs subject to polarised optical injection

We present our recent work analysing the effects of polarised optical injection in Long-Wavelength Vertical-Cavity Surface Emitting Lasers (LW-VCSELs) emitting at the important telecom wavelength of 1550nm. The properties of the polarisation switching and bistability that can be induced in these devices when subject to orthogonally-polarised optical injection will be discussed in detail. Additionally, we will review our analyses of the injection locking properties of these devices when subject to different polarised injection. Furthermore, we have also identified a rich variety of different nonlinear dynamics outside the stable locking range when these devices are subject to different polarised optical injection. These include regions of periodic dynamics (such as limit cycle and period doubling) and chaos. Experimental and numerically calculated stability maps plotting the regions of nonlinear dynamics will be presented showing very good overall agreement between theory and experiments. This rich variety of nonlinear effects observed in LW-VCSELs operating at 1550nm offers exciting prospects for novel practical uses of these devices in present and future optical networks.

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Optical probing and local modification of photonic crystal molecules

Recent theoretical advances in cavity quantum electrodynamics (QED) have indicated that arrays of coupled nonlinear cavities may be candidates for exploring quantum many-body phenomena of light [1]. Within this framework, a fascinating implementation has lead to the proposal of an optical analogue of the Josephson interferometer consisting of two coherently laser driven linear optical cavities connected through a central cavity with a single-photon non linearity [2]. More complex architectures, such as bidemensional arrays of optical cavities show phase transition from Mott insulator to superfluid during the decreasing of nonlinearity regime [3].

The building blocks of all these theoretical proposals are pairs of optical resonators, also denominated photonic molecules, where photon tunneling produces delocalized light states. In order to create proper quantum optics devices a fundamental requirement is the design and control of adjacent nanocavity modes at the target wavelengths, within an accuracy which is not directly obtainable due to the fabrication tolerances. The compensation of the fluctuations related to the structural disorder and more generally the control of the resonance wavelength of each resonator within the array and also of the tunnelling coefficient between adjacent nanocavities is of the utmost relevance in the roadmap toward quantum photonic devices.

In this presentation I will show different approaches aimed to probe and to locally modify photonic crystal molecules. Scanning near-field optical microscopy (SNOM) will be exploited to give experimental evidence of the spatial delocalization of coupled-cavity optical modes by imaging the electromagnetic local density of states [4], while far-field measurements of the angular emission pattern of quantum dots embedded in the system allow probing the mode symmetry of photonic molecules [5]. Beside the optical characterization, I will also present different post-growth techniques able to locally change the refractive index around the photonic molecules by means of liquid infiltration [6] and laser induced oxidation [7]. In this way it is possible to compensate the fabrication induced disorder, always present in real device, and to fine tune the coupling condition between the modes of the two photonic crystal nanocavities forming the photonic molecule. Clear mode anticrossing, with transition from localized to delocalized states [8], and molecular hybridization are observed [9]. Finally, the possibility to access single photonic molecule is also applied for changing, in a controlled way, the coupling strength of the coupled photonic system.

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Delay electro-optic dynamics for brain inspired information processing

The talk will report on the first experimental photonic demonstration of a neuromorphic computational unit, on the basis of a recently proposed brain-inspired paradigm typically referred as Echo State Network, Liquid State Machine, or also Reservoir Computing in the neuronal computing literature. This paradigm, intrinsically differing from the Turing machines, makes use of the computational power offered by high dimensional transient motions developed by complex nonlinear dynamical systems, when the latter are excited by the information to be processed. The originality of the proposed photonic implementation is to exploit the dynamical complexity of delay dynamics, instead of that provided by spatially extended networks of dynamical nodes (as typically proposed in the existing literature). Complex delay dynamics are indeed well known in photonics with many different practical implementations. Our results have been obtained via a hybrid optoelectronic architecture, which has been successfully used in the past in the framework of optical chaos communications. We will report on two practical implementations involving whether wavelength or intensity dynamics subject to a single nonlinear delayed feedback, or even a multiple delayed one with randomly defined weights for each delay. The computed output consists in a simple linear separation of the transient trajectory in the complex phase space, according to a separation determined from a preliminary learning phase. (Since the computational power is mainly originating from the nonlinear transient properties of the complex dynamics, it might better to refer to it as nonlinear transient computer (NTC) instead of ESN LSM or RC, at least from the nonlinear dynamics community viewpoint.) We will discuss about the different proposed NTC "topologies" performed by a nonlinear single delay dynamics or multiple delay dynamics, in a lowpass or bandpass feedback configuration. The computational performance is successfully evaluated on a benchmark test, a spoken digit recognition task, with which state of the art performances are achieved.

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Generation of quantum correlated light beams in an atomic vapor

The production of separate light beam possessing non-classical correlations is an essential ingredient for the realisation of quantum information networks. We have shown that by single passage through a resonant atomic vapor cell, two orthogonal polarization components of a laser beam acquire quantum correlations resulting in the squeezing of the relative intensity fluctuations. We discuss the conditions for the production and detection of such polarization squeezing and discuss applications.

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Optomechanics in silicon nanostructures

Optomechanical cavities enable control of the cavity length by the manipulation of the mechanical degrees of freedom, using the optical forces provided by photons circulating inside the optical microcavities. We have demonstrated that the use of optical forces can provide tuning of a microcavity resonance over the full telecom C or L-band using only mW of laser power. We have recently also dmeosntrated the capability fo synchronization between different optomechanical cavities using solely optical radiation. On the nanoscale, synchronization has been shown to occur in spin-torque systems and driven nano-electromechanical resonators. These systems are all based on coupling through physical contact which limit the applicability and topology of future oscillator networks. We show that two micromechanical oscillators synchronize without coupling through any physical medium, but only through optical radiation field in vacuum, using the concept of optomechanics. These results may open a practical route for building large oscillator networks (scaling) that is of fundamental importance for micromechanical neurocomputation, pattern recognition and the study of system dynamics in which individual oscillators can be addressed individually. In addition the low loss nature of the optically mediated coupling could be explored to realize long range synchronization.

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Optical fabrication beyond the diffraction limit: making it fast, easy and cheap

A nanopatterning scheme is presented by which the structure height can be controlled in the tens of nanometers range and the lateral resolution is a factor at least 3 times better than the point spread function of the writing beam. The method relies on the initiation of the polymerization mediated by a very inefficient energy transfer from a fluorescent dye molecule after single photon absorption. Very low power laser diodes are used. The mechanism has the following distinctive steps: the dye adsorbs at the substrate surface with a higher concentration than in the bulk, and upon illumination it triggers the polymerization and isolated islands develop that merge into a uniform structure (percolation) and subsequently grows until the illumination is interrupted. This percolation mechanism has a threshold that introduces the needed nonlinearity for the fabrication of structures beyond the diffraction limit.

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Spatially nonlocal bistable media: front propagation and localized structures

In the recent years considerable effort has been devoted to the study of evolution equations of extended systems in which the spatial interaction includes a nonlocal contribution, in the form of an integral over an spatial domain. Nonlocal interaction terms can appear in Physics and other fields when long-range interaction terms are considered, and also as the result of using approximations in reaction-diffusion descriptions and also due to density-dependent effects in biological and ecological systems.

We have studied spatially nonlocal effects on a prototypical spatially extended system representing the evolution of a real field in 1-D with two equivalent states connected by monotonic fronts (or kinks): a nonlocal Ginzburg-Landau equation. For attractive interactions we find an enhancement of the interaction. The relative velocity between two fronts decays exponentially with separation, as for the local case, and a nonlocal interaction increases the interaction range. In both cases the asymptotic result is coarsening, i.e., the mutual annihilation of all kink-antikink pairs. The effect of a spatially nonlocal interaction is more dramatic (and so, interesting) in the case that the interaction is repulsive (or inhibitory). In this case one finds that the velocity becomes zero at regular intervals of the distance between two fronts. At these positions the fronts are locked, leading to the formation of localized structures, stabilized by tail interaction. This is a new effect created by the nonlocal interaction that makes the tails oscillatory, not possible in the local case (the fronts are monotonic).

In conclusion, nonlocal interactions are common in nonlinear optics, biology, chemistry, and other fields of science, and they can have a constructive role by enhancing the propagation of information between distant parts of the system, and also allowing the system to exhibit new dynamical regimes. They also offer a route to create localized structures, potentially useful for information storage and processing, in a class of systems for which local interactions lead exclusively to coarsening.

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Porous Multilayers: Novel Multifunctional Materials for Light Absorption and Emission Control

In recent times, several synthetic pathways have been developed to create multilayered materials of diverse composition that combine accessible porosity and optical properties of structural origin, i.e., not related to absorption. These materials posses a refractive index that varies periodically along one direction, which give rise to optical interference effects characteristic of Bragg stacks or one-dimensional photonic crystals (1DPC). The technological potential of such porous optical materials has recently been demonstrated in various fields such as biological and chemical sensing, photovoltaics, or radiation shielding. In all cases, improved performance is achieved as a result of the added functionality porosity brings on. Also, they offer the possibility to study fundamental light absorption and emission phenomena in nanomaterials and compounds that could not be integrated in photonic structures before, as well as to develop environmentally responsive coatings with them. In this talk, a unified picture of this emerging field will be provided.

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Localized modes and Fano resonances in magnetic metamaterials

We study localized modes and the scattering of magneto-inductive plane waves by internal (external) capacitive (inductive) defects coupled to a one-dimensional magnetic metamaterial modeled as a split-ring resonator array. We examine a number of simple defect configurations where the localized mode can be found in closed form, and where Fano resonances occur, and study the behavior of the transmission coefficient as a function of the controllable external parameters. We find that for embedded capacitive defects, the addition of a small amount of coupling to second neighbors, is necessary for the occurrence of Fano resonance. For external inductive defects, Fano resonances are commonplace, and they can be tuned by changing the relative orientation/distance between the defect and the SSR array.

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Very low rate frequency-oscillation of semiconductor lasers under orthogonal feedback

Optical feedback with orthogonal polarization may not change (or change very little) the intensity of semiconductor lasers working far from the threshold current. Nevertheless, it has been shown that the emission frequency of these devices varies linearly with the power of the orthogonal field sent back into the laser-diode cavity. A rich behavior of the laser frequency may be obtained if one modulates the injected power with a spectral filter [1,2]. In order to determine how universal is such a frequency response to orthogonal feedback, we have examined many different laser diodes and observed that the efficiency of frequency tuning depends on the geometrical coupling of the feedback power into the laser cavity. I.e., the laser response depends on the effective power back into the cavity and is therefore related to the confinement factor [3] of each laser. We also report on our measurements exploring orthogonal filtered feedback to induce frequency oscillations in the emission of a monomode, Fabry-Pérot-type, AlGaAs laser. We used the spatial resolution of a 1800 lines/mm diffraction grating to modulate the power sent back to the laser. As a result we measured modulation depths up to hundreds of MHz/mW for laser frequency oscillating at rates of hundreds of Hz. This very slow rate of the frequency oscillation is determined by the thermal nature of the spectral response of semiconductor lasers to re-injection of orthogonal power [4]. We expect such frequency oscillations to be useful in future studies of multi-laser systems. Coupling lasers by way of orthogonal feedback allows cross-connections at constant injection levels.

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Dynamics in a Ring Diode Laser

We shall describe experiments on the dynamics of a semiconductor diode laser operating with an external optical ring cavity. The cavity had a 3 m round trip length and was composed by three mirrors adjustable for characterization of the emission modes. 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 laser with feedback. Tilted alignment of the external cavity along with appropriate pump current changed the nature of the pulsed instability of higher order cavity modes. Up to 2 GHz frequency composition of the pulsed instabilities were characterized. Optical spectra and radio frequency spectra of pulsed power time series were obtained and compare with theoretical models. A model for ring cavity stability, predicting the expected optical frequency composition of the pulses was solved numerically. Comparison was made between the experimental observations and the calculation for the fundamental longitudinal and the first transverse accepted modes of the cavity. A theoretical model for the pulsed dynamics, using rate equations, was also done and 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 beam created under external cavity operation.

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Nonlinear dynamics of semiconductor quantum dot lasers

Self-organized semiconductor quantum-dot (QD) lasers are quantitatively modeled using nonlinear rate equations with microscopically calculated carrier-carrier scattering processes between the carrier reservoir and ground and excited state confined QD levels [1]. This microscopic approach yields the capture and relaxation lifetimes of electrons and holes, and allows one to separately treat the internal dynamics of each species inside each confined QD level. Small and large signal response and turn-on dynamics of the QD laser are investigated as a function of temperature, reservoir doping and band structure. We find that p-doping leads to an increased damping of the relaxation oscillations while n-doping does the opposite. Analytic relations between the microscopically obtained carrier lifetimes and the device performance, e.g. modulation bandwidth, are discussed by means of asymptotic methods.

The complex dynamics and bifurcation scenarios of a QD laser subjected to delayed optical feedback are also investigated. It is shown that the feedback tolerance of a laser depends on the damping of its relaxation oscillations [2]. We show that it is possible to optimize the feedback tolerance of QD lasers by tuning the carrier scattering rates between QD and reservoir, e.g. by modifying the band structure or by doping the reservoir.

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Design and applications of electrically-injected nano-spin semiconductor lasers

A tutorial overview will be presented of opportunities for the development of a novel class of miniaturized semiconductor lasers having wide applications potential. Attention will be given to the design and fabrication challenges which must be met in order to exploit the capabilities of electrically-injected nano-spin semiconductor lasers. Firstly the context for the development of electrically-injected metal-clad nano-spin semiconductor lasers will be presented and secondly an indication will be given of the design and fabrication challenges to be faced in their implementation.

The practical realization of such devices would seemingly represent the first application of the combined capabilities of three key technologies: plasmonics, spintronics and nano-technology.

Rather subtle wave-guiding effects arise in plasmonic lasers including the opportunity to significantly enhance the optical confinement factor. Exploitation of spintronic effects can enable reductions of up to 50 % in the lasing threshold current. The utilization of nano-cavities gives access to Purcell- enhanced spontaneous emission for laser threshold reduction and, potentially, threshold-less lasing.

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Entanglement among bright light beams: creation, structure, sudden death

Quantum systems are said to be entangled when the most complete description for it allowed by quantum mechanics cannot be decomposed into individual descriptions for each one of them: Insisting in such a separable description will always imply loss of information, and will not account for all observed physical phenomena.

There are many ways in which physical systems can be entangled, especially when at least three of them are involved. The structure of entanglement refers to the way quantum correlations are shared by many parties.

We investigate quantum entanglement among three beams of light, produced by a source of quantum light called "optical parametric oscillator". We aim to understand how entanglement is distributed among the light beams, and how its properties can be used to harness multipartite entanglement. A formal description in terms of field modes reveals the complex structure behind the quantum correlations, offering new insights to better understand this fascinating non-classical effect.

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Photonic reservoir computing and information processing with coupled semiconductor optical amplifiers

Reservoir computing is a decade old framework from the field of machine learning to use and train recurrent neural networks and it splits the network in a reservoir that does the 'computation' and a simple readout function. This technique has been among the state-of-the-art for a broad class of classification and recognition problems such as time series prediction, speech recognition and robot control. However, so far implementations have been mainly software based, while a hardware implementation offers the promise of being low-power and fast. Despite essential differences between classical software implementation and a network of semiconductor optical amplifiers, we will show that photonic reservoirs can achieve an even better performance on a benchmark isolated digit recognition task, if the interconnection delay is optimized and the phase can be controlled. In this paper we will discuss the essential parameters needed to create an optimal photonic reservoir designed for a certain task.

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Quantum aspects of synchronization

We consider coupled quantum harmonic oscillators and show how synchronization depends on the presence of one common or separate thermal environments. We then explore connections between synchronous dynamics and quantum correlations such as discord and mutual information.

CONTRIBUTED TALKS

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Interactions in 2D and 3D mid-infrared metamaterials

Metamaterials (MM) provide for new ways of manipulating light and achieving complex functionality due to the ability to control the spatial distribution of the permittivity and permeability. This full functionality usually requires complex 3D assemblies of subwavelength resonators that are very difficult to implement at optical frequencies. In this talk I will give an overview of our activities related to 2D and 3D metamaterials in the infrared, using both metallic and non-metallic (dielectric) approaches. Also, I will present recent results on the strong coupling between Metamaterials and other dipolar excitations, such as phonons, free carriers and intersubband transitions. Some of these effects can be further exploited for active control of Metamaterials and provide new photonic devices in the infrared.

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NONLINEAR EFFECTS IN OPTICAL FIBERS: LIMITATIONS AND NOVEL POSSIBILITIES

Nonlinear effects in optical fibers impose different limitations on the communications link, and an understanding of such effects is almost a prerequisite for actual lightwave-system designers. On the other hand, they offer a variety of possibilities for all-optical signal processing, amplification and regeneration. The nonlinear effects are enhanced dramatically and new phenomena are observed in the so called photonic crystal fibers. In this paper we review the effects – both detrimental and potentially beneficial – of optical nonlinearities in conventional and in photonic crystal fibers.

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Stochastic Analysis of Charging and Recombination in Double-Hetero Tunnel-Junction Quantum Dot Semiconductor Laser

The double-hetero tunnel-junction quantum dot semiconductor laser model is presented in this paper to analyze a charging process by tunneling to isolated quantum a dot in an active area. The double-hetero tunnel junction structure including a low band gap quantum dot prevents tunneling transitions of electrons and holes to p and n type sides and enhances the recombination in the dots, while a high band gap quantum dot can be used for an electron or hole current selectable transistor. A photon contained in a laser output is produced by a recombination of an electron and a hole in the quantum dot. Although the output contains many photon quanta, each charging of the electron and hole is discreet process, and the recombination is occurred in a probability manner. The laser output analysis is based on the stochastic process analysis appropriate to the treatment of the problem. The analytical solution for the probability to the charging number is given, and numerical calculations of the output characteristics are presented.

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Logical operations using cavity solitons

Optical computing, via photons instead of electrons, has long appealed researchers as a way of achieving ultrafast performance. Photons travel faster than electrons and do not radiate energy, even at fast frequencies. Despite the constant advances and miniaturization of conventional electronics, optical computing remains as an alternative to overcome the heat generation and bandwidth limitations of conventional electronics. Many of the systems studied in optical computing applications imply light propagation, for example in optical correlators, already commercially used in optical processing applications, or using spatial solitons to create all-optical logic gates. Dissipative solitons (DS), also known as cavity solitons, have been suggested as a potentially useful strategy for information storage that is especially attractive after DS have been shown in semiconductor lasers, a very compact and widespread technology. Within this approach a DS describes a bit of information. Here we will take this idea a step further and discuss the potential of DS for carrying out computations, not merely information storage, benefiting from the excitability property exhibited by some DS. In particular, we will consider DS in an optical cavity filled with a self-focusing Kerr medium, and we will show how three basic logic gates can be designed using these structures, namely the AND, OR and NOT gates.

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Phase-amplitude Coupling Factor Induced Multistability near Phase-flip Bifurcation regimes in Mutually Delay-Coupled Diode Lasers

Delay-coupled diode lasers system have shown plethora of collective fascinating complex dynamical instabilities in the output intensity by several ways and the dynamics displayed by system vary dramatically depending on setup and system parameter chosen. Dynamical maps are more appropriate way to display the global view of dynamics because very diverse time scales involved in the dynamics. We have manually produced the map by carefully observation of the sustained temporal behavior to show the different dynamical regimes and notify the parameters where dynamical changes occur. The complex dynamics is investigated as a function of coupledcavity time delay τ and the optical injection strength η. The synchronized dynamics of 'in-phase locking' and 'out-of-phase locking' are observed in a wide range of parameters. Shifting of different phase-correlated dynamics, such as phase-flip bifurcation [2], is observed and analyzed when η is varied for a particular τ. We show that the phase flip transition does not occur abruptly at a particular value of coupling strength. Instead we find a coupling strength region around the phase flip transition where the co-existence of multi-attractors occurs. The existence of multiple attractors near the regime of phase flip bifurcation has raised the issue of whether the noise plays a crucial role or not. We also study the effect of the phase-amplitude coupling factor [1] [2] on the dynamics in the amplitude death regime. We show that the phase flip transition occurs abruptly from in-phase amplitude death to anti-phase amplitude death but the transition does not occur abruptly from anti-phase to inphase. In this letter, we wish to provides fundamental insight into the underlying physics of the system and present a detailed description of amplitude death and existence of multiple amplitude death islands [2],

which are crucial considerations for redesign the device or improve the processing, or simply exploit the dynamical performance of a diode lasers stabilization applications. We emphasize on the enlargement of anti-phase amplitude death islands in which the coupled lasers mutually stay in ultimate stable states. Our Numerical analysis is based on the observation that the cross-correlation and time-shifted correlation measure unveils the signature of coexistence of multiple attractors and enhancement of stability within anti-phase amplitude-death islands.

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Rogue Waves in optically injected semiconductor lasers

Rare and irregular extreme events can occur in many different systems in nature. A typical example is rogue waves observed in the oceans, where waves higher than 30 meters are more or less common phenomena. This fact is in contradiction with Gaussian models often used to describe fluctuations of the wave height in the sea [1,2]. Scientist interest on extremely high waves increased substantially during the last decade not only in oceanographic studies but also in other systems such as capillary waves [3] and optical waves [4-7]. Both, from theoretical and experimental point of view there are several questions still remaining unsolved. The physical mechanisms that originate them, the way they develop, the probability for them to occur, the type of system able to generate such extreme events, and the connections between extreme events in systems which are apparently completely different, are being the subjects of intensive research. The understanding of the generation of rare extreme events it is interesting for itself, but also can allow to identify mechanisms to control or suppress the occurrence of such events. In this way, the investigation of the phenomenon in a controllable experimental setup is very important from a practical point of view and offers a great possibility to shade new light in this subject.

In this work we investigate, both theoretically and experimentally, the appearance of rare giant pulses or rogue waves in a semiconductor laser subject to optical injection. We perform a detailed experimental characterization of the parameter region where rogue waves appear, and compare the experimental observations with numerical results from the simplest rate-equation model. It is shown that the sporadic large intensity events can be understood as a result of a deterministic nonlinear process [8]. By changing the pump current of our injected laser, several dynamical scenarios were identified. Rogue waves were detected inside a chaotic region, for certain levels of bias current. Their typical experimental manifestation occurs in the laser power time series, where sporadic large intensity pulses are observed. To investigate the rarity of the large pulse events, and to confirm the rogue wave character according a certain definition, histograms for the laser intensity were measured.. The analysis of the theoretical model allows a discussion of the mechanisms associated with the appearance of rogue waves. Extensive numerical simulations were performed to characterize the phase diagram of the system and parameter regions where rogue waves occur. The role of noise in the system is investigated and its influence to induce or inhibit rogue waves is discussed.

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Light Bullets in Nonlinear Curved Waveguide Arrays

We predict that stable spatio-temporal solitons can exist in arrays of periodically curved optical waveguides. We combine approximate variational methods and direct numerical simulations to describe two-dimensional light bullets in one-dimensional arrays with harmonic in-plane bending profile, and three-dimensional bullets in square lattices with helical bending profile. We show that light bullets can freely move across the arrays with optimized bending, and this mobility property is a distinguishing characteristic compared to previously considered discrete light bullets which were trapped to a specific lattice location. These results suggest new possibilities for flexible spatio-temporal manipulation of optical pulses.

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ELECTROMAGNETICALLY-INDUCED CROSS FOCUSING IN A FOUR-LEVEL ATOMIC MEDIUM

We investigate theoretically the cross focusing between two weak fields mediated by a four level atomic sample under the condition of electromagnetically induced transparency (EIT) [1]. The transverse intensity profile of a signal field leads to a spatially-varying index of refraction profile which is experienced by a resonant probe beam. This spatial variation of the index of refraction induces a lens in the medium, focusing or defocusing the probe field depending on the signal field detuning. We show that strong focusing/defocusing of the probe field can occur even when at low signal intensities (below line saturation level) due to the giant Kerr nonlinearity exhibited by the atoms under EIT [1]. By tailoring the signal intensity profile, different phase profiles can be imprinted in the atomic medium, thus controlling its focusing properties. We study the cases of gaussian, quadratic (spherical lens) and modulo-2□ quadratic (Fresnel lens) phase profiles and how the focusing depends on the excitation parameters (signal detuning, intensity, and optical depth of the atomic sample).

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Time-delayed second-order electronic circuit synchronization

Synchronization is a phenomenon that happens in natural systems (biological, chemical and physical) as well as in artificially interacting systems (computers, web, urban traffic, logistical systems...). Synchronization has been studied in the past several years in real and idealized systems, looking for universalities in chaotic behavior [1]. Lasers and electronic circuits are particularly convenient systems to search for such universal chaotic behaviors. A second-order oscillator with external pumping presents chaotic behavior [2] and two of such circuits can be synchronized. We modified this circuit by suppressing the external pumping and introducing a time delay. We observed that a single circuit exhibits chaotic behavior and synchronization between two identical circuits in a master-slave configuration was achieved. No particular effort was made to match the electronic components. The observations are in very good agreement with numerical simulations that we performed using the dde23 solver [3]. We analyzed various parameters that lead the system from total desynchronization to complete synchronization, validating such nonlinear systems for future studies of isochronal and lag synchronization.

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Optical Phase Coherent Amplitude Death in Mutually Delay-Coupled Diode Lasers System

Amplitude death [3] is one of the collective fascinating phenomena, where coupled lasers drive each other to a fixed point and stop the oscillatory dynamics. This coupling induced stabilization is known to occur via either change the stability of unstable fixed points to the stable one which are already exists in the absence of coupling or the new stationary state that can be entirely created by the coupling. So the routes by which the two coupled lasers reach their stable states of optical phase and amplitude in the presence of finite-delayed interaction remain poorly understood because of very diverse time scales involved in the dynamics. Laser field fluctuations usually trigger a diffusion of phase because electric field fluctuations very fast in comparison to intensity fluctuations then the two lasers cannot be locked or synchronize in optical phase, and their relative optical phase drifts indefinitely in time. So here we address the question,` Can we really probe the optical phase dynamics and thereby lock in the amplitude death regimes. Optical phase locking can occur in two lasers where time delay between them is small in comparison to coherence time but the long time delayed coupling can be useful for application where two distant lasers require a well defined relative phase. The termination of optical phase diffusion with ultimate amplitude death of intensity fluctuations of the dynamics may lead to efficient coherent combining where the coupled output power exceeds what is impossible from single diode lasers. We have used two lasers are mutually coupled via two optical path with two longer different time delays (compared to the coherence time) in order to achieve robust zero lag optical phase synchronized amplitude death without any self-feedback or relay unit. So the coupling signal arrives long after the optical phase memory is lost. In order to get synchronization between these two lasers(L1 &L2) situated at a distance τ, a L1 need information not only on the time delayed signal of L2 but also on its time delayed state. Suppose L2 acts as like a mirror, the light transmitted by L1 returns to itself after time 2τ. Thus , if we add an additional light signal with delay 2 τ, namely L1(t-2τ) and L2(t-2τ) and they may be able to synchronize. In the context of such system, we wish to provides fundamental insight into the underlying physics of the system and present a detailed description of optical phase synchronized amplitude death and existence of multiple amplitude death islands [2], which are crucial considerations for redesign the device or improve the processing, or simply exploit the dynamical performance of a diode lasers stabilization applications. The optical phase dynamics is investigated as a function of coupled-cavity time delay □ and the optical injection strength □. The synchronized dynamics of 'inphase locking' and 'out-of-phase locking' are observed in a wide range of parameters. Shifting of different phase-correlated dynamics, such as phase-flip bifurcation [1], is observed and analyzed when □ is varied for a particular □. We emphasize on the enlargement of anti-phase amplitude death islands in which the coupled lasers mutually stay in ultimate stable phase-locked states. In the gap regimes the relative optical phase is not stationary; However, it remain bounded. This means that the average frequency of the coupled lasers are locked without phase locking. Our Numerical analysis is based on the observation that the cross-correlation and timeshifted correlation measure unveils the signature of enhancement of robust phase locking stability at a particular ratio of delay times within anti-phase amplitude-death islands. In order to probe the coherence between field and intensity dynamics we also measure the average and instantaneous fringe visibility on slow and fast time scales to find a regime where amplitude death takes place coherently with optical phase .

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Pattern formation in ring cavities outside paraxial approximation

Theoretical and numerical studies about pattern formation in nonlinear optical media, such as ring cavities filled with Kerr media, are usually developed under the paraxial approximation. In doing so, fields along the propagation direction of the wave are neglected. Also, almost parallel wavectors are assumed.

Those approximations make sense, for instance when we work with plane waves or Gaussian beams with broad waist. Nowadays, many scientific reports in optics are related to localized beams or sources, where wavevectors may point, towards a great range of directions.

In this communication, we develop an evolution equation for electromagnetic waves in Kerr media, which takes into account wavevectors that may have big transverse components, and We analize their effect. We also study how the fields pointing towards the propagation direction may modify pattern formation. A comparison with other evolution equations like the Nonlinear Schrödinger Equation is also made.

Finally, we use the propagation equations to numerically simulate fields inside a ring cavity. Pattern formation and existence of localized structures in those cases is analyzed. The use of very narrow pulses in wide cavities, which may be the case if cavities are used for memory storage, is also modeled.

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Decoherence control in quantum eraser via ghost imaging

A controlled decoherence mechanism of double-slit quantum eraser on a quantum ghost imaging scheme using entangled photon pairs is studied. We consider a two-photon state, produced by spontaneous parametric down-conversion process in a maximally entangled polarization state, then we consider a birefringent double slit illuminated by one of the down-converted photons that couples the polarization with the transversal momentum of these photons while the other photon acts as a which-path marker. We show how the present quantum eraser takes advantage of ghost imaging since the complete wich-path information of a photon is transferred to its distant entangled twin through a ghost image, and how the transition from wave-like to particle-like behavior of the signal photons crossing the double slit is a function of the decoherence parameter.

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Temporal and spatial detection limits of ghost imaging with a double slit in one-dimensional motion

Ghost imaging is a technique by which a high resolution camera produces, by a statistical process, the image of an object located in a place where the camera cannot itself see. A pseudo-thermal source and a beam-splitter are used, which produces a pair of time varying twin speckle pattern beams, one of these beams, called reference beam, passes without alteration and is detected by a bucket detector, the other one, called test beam, is incident on a translucent sample and is detected by a CCD camera just behind the sample. We study

dynamic parameters in an experiment using a double slit in one-dimensional motion transversely to the direction of propagation of the test beam, playing the role of the sample in typical experiments of ghost imaging. We also determine how those parameters are related with the coherence properties of the source and how they influence the spatial and temporal limits of detection of ghost imaging.

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Orthogonal feedback induced frequency shift in diode lasers: experiments and theory

We report experimental and numerical investigations concerning semiconductor lasers under polarization-rotated feedback. We experimentally observe that for some semiconductor lasers the TM mode (typically hundreds of times less intense than the TE main mode) does lase even in the absence of TM feedback and we monitor how the TE and TM emissions evolve with the increase of the TM feedback strength. The emission of a semiconductor laser subject to polarization-rotated optical feedback is known to experience a frequency shift proportional to the optical power fed back into the laser [1]. We aim to investigate what affects the sensibility of the frequency of semiconductor lasers to polarization-rotated feedback. Experimentally, we measured the proportionality coefficient (β) between frequency shift and feedback power for different laser models and characterized how it varies with injection current, temperature and the TE/TM power ratio without feedback. Theoretically, we made numerical calculations using a rate equation model, which describes the time evolution of the two field transversal components and of the carrier density [2]. Our results show a critical dependence of the β coefficient with the gain self- and cross-saturation of both modes and the relations between these saturation coefficients. Numerical simulations obtained with the model are compared with the experimental results.

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