SECOND ‘RIO DE LA PLATA’ WORKSHOP ON NOISE, CHAOS, AND COMPLEXITY IN LASERS AND NONLINEAR OPTICS

Organized by:

Cristina Masoller

Alejandro Hnilo

SCIENTIFIC PROGRAM AND ABSTRACTS

Colonia del Sacramento, Uruguay

December 5 - December 9, 2005

Second 'Rio de la Plata' Workshop on Noise, Chaos, and Complexity In Lasers and Nonlinear Optics

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- European Office of Aerospace Research and Development -- Air Force Office of Scientific Research (EOARD-AFOSR);
- The Abdus Salam International Centre for Theoretical Physics, Office of External Activities (ICTP);
- Optical Society of America (OSA); Office of Naval Research Global (ONR);
- Proyecto de Desarrollo de Ciencias Basicas (PEDECIBA);
- Facultad de Ciencias, Uruguay.

Second ‘Rio de la Plata’ Workshop on Noise, Chaos, and Complexity In Lasers and Nonlinear Optics

PROGRAM

Registration: Sunday December 4, 16 - 20 hs, Hotel Radisson
Monday December 5, 9 – 17 hs, Hotel Radisson

Monday, December 5

12:30 - 15:00 Lunch

Chairs: Alejandro Hnilo and Cristina Masoller

15:00 - 15:10 Opening
15:10 - 15:50 William Firth (Glasgow, UK)
Giant excess noise in misaligned lasers
15:50 - 16:30 Adrian Jacobo (Mallorca, Spain)
Optical image and data processing with cavity type-II Second Harmonic Generation

16:30 - 17:00 Coffee break

Chair: Adrian Jacobo

17:00 - 17:40 Marcelo Kovalsky (Villa Martelli, Argentina)
Dynamics of a femtosecond Ti:Sapphire laser
17:40 - 18:20 Giovanni Giusfredi (Firenze, Italy)
Intensity noise of an injection locked Titanium:Sapphire laser. Analysis of the phase-noise to amplitude-noise conversion

Tuesday, December 6

Chair: Marcel Clerc

9:00 - 9:40 Yuri Kivshar (Canberra, Australia)
Nonlinear optics and gap solitons in periodic photonic lattices

9:40 – 10:20 Eric Louvergneaux (Villeneuve dÁscq Cedex, France)
Two-dimensionnal noise-sustained structures in optics: theory and experiments
Localized patterns in one-dimensional extended systems

10:20 - 10:50 Coffee break

Chair: Marcelo Kovalsky

10:50 - 11:30 Luigi Lugiato (Como, Italy)
Cavity solitons in semiconductor microresonators

11:30 - 12:10 Marcel Clerc (Santiago, Chile)
Localized patterns in one-dimensional extended systems

12:30 - 15:00 Lunch

Chair: Marcos Oria

15:10 - 15:50 Guillaume Huyet (Cork, Ireland)
Non-linear dynamics of quantum dot semiconductor lasers

15:50 – 16:30 Paul Mandel (Bruxelles, Belgium)
Modeling quantum dot lasers

16:30 - 17:00 Coffee break

Chair: Paul Spencer

17:00-17:40 Marc Sciamanna (Metz, France)
Nonlinear polarization dynamics of VCSELs with orthogonal optical injection

17:40–18:20 Krassimir Panajotov (Brussel, Belgium)
Polarization dynamics of VCSELs with optical feedback

20: 30 Conference Dinner at Quinta Conrado
(Bus departs Radisson Hotel at 20: 30)

Wednesday, December 7

Chair: Guillaume Huyet

9:00 - 9:40	Marcos Oria (Joao Pessoa, Brazil) *Multistability in the frequency of a semiconductor laser*
9:40 - 10:20	Tom Gavrielides (New Mexico, USA) *Square wave oscillations and chaos synchronization in diode lasers with incoherent optical feedback*

10:20 - 10:50 Coffee break

Chair: Paul Mandel

10:50 - 11:30	Fritz Henneberger (Berlin, Germany) *Semiconductor lasers with integrated optical delay: A nonlinear dynamics laboratory*
11:30 - 12:10	Laurent Larger (Besancon, France) *Optoelectronic nonlinear delayed feedback oscillators in discrete and continuous time regimes*

12:30 - 15:00 Lunch

Chair: Laurent Larger

15:10 - 15:50	Atsushi Uchida (Tokio, Japan) *Consistency of driven laser systems*
15:50 - 16:30	Alexander Kir'yanov (Guanajuato, Mexico) *Nonlinear dynamics of Erbium fiber lasers: external and self modulation features*

16:30 - 17:00 Coffee break

17:00 – 19:30 Poster session (continues after dinner with wine)

Thursday, December 8

Chair: Junji Ohtsubo

9:00 - 9:40 Antonio Politi (Firenze, Italy)
Partial synchronization in globally coupled oscillators
9:40 - 10:20 Ricardo Meucci (Firenze, Italy)
Control and synchronization in lasers

10:20 - 10:50 Coffee break

Chair: Atsushi Uchida

10:50 - 11:30 Rajarshi Roy (Maryland, USA)
Mutually coupled laser dynamics
11:30 - 12:10 Paul Spencer (Bangor, UK)
Optimum time-delay identification for chaos synchronisation in semiconductor lasers

12:30 - 15:00 Lunch

Chair: Maria Susana Torre

15:10 - 15:50 Claudio Mirasso (Mallorca, Spain)
Chaotic optical communications
15:5 0 - 16:30 Ingo Fischer (Brussel, Belgium)
Emission dynamics of delay-coupled semiconductor laser systems

16:30 - 17:00 Coffee break

Chair: Jia-Ming Liu

17:00 - 17:40 Jorge Tredicce (Nice, France)
Multi and single mode spatio temporal instabilities in a laser with injected signal
17:40 – 18:20 Jose R. Rios Leite (Recife, Brazil)
On the Low Frequency Fluctuations of diode lasers with optical feedback
18:20–19:00 Kevin Wegener (Arlington, VA, USA)
Doing business with AFOSR

Friday, December 9

Chair: Cristina Masoller

9:00- 9:40	Junji Ohtsubo (Hamamatsu, Japan) *Polarization dynamics and chaos synchronization in VCSELs*
9:40-10:20	Jia-Ming Liu (Los Angeles, USA) *Bidirectionally coupled synchronization scenarios of semiconductor lasers with delayed feedback*
10:20 - 10:30	Concluding remarks

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TALKS

Marcel Clerc
(Universidad de Chile, Santiago, Chile)

Localized patterns in one-dimensional extended systems

The existence, stability properties, dynamical evolution and bifurcation diagram of localized patterns and hole solutions in one-dimensional extended systems is studied from the point of view of front interactions. An adequate envelope equation is derived. This equation allows us to obtain an analytical expression for the front interaction. The effect of additive noise on a static front that connects a stable homogeneous state with an also stable but spatially periodic state and localized pattern is studied. Numerical simulations show that noise induces front propagation.

William Firth
(Department of Physics, University of Strathclyde)

Giant excess noise in misaligned lasers

The excess noise factor is calculated for a very general class of optical cavities, and is shown to have a super-exponential dependence on cavity misalignment, easily attaining values of order 10^{10}. The physical basis is shown to be transient gain associated with amplified spontaneous emission.

Ingo Fischer
(Dept. of Applied Physics and Photonics, Vrije Universiteit Brussel, Belgium)

Emission dynamics of delay-coupled semiconductor laser systems

The dynamics of coupled semiconductor lasers is of considerable interest for several applications like generation of high output power, but it is furthermore of fundamental interest in order to understand the behavior of coupled nonlinear oscillators. Only in recent years the influence of finite delays in the coupling, so far mostly neglected, has come to the focus of interest and it has been found to play an important role in various systems. In this talk we present experiments and modeling of mutually delay-coupled semiconductor lasers. We give an overview over the behavior for long coupling delays. We have found a characteristic scenario comprising delay-induced instabilities, synchronization and spontaneous symmetry breaking, leading to a splitting of roles into a leader laser and a laggard laser. Extending the configuration to three lasers exhibits that - in contrast to the two-laser case - it is possible to have isochronous synchronization of distanced lasers despite of the coupling delay. Based on the joint experimental and modeling approach we will discuss the role of delay in the coupling of semiconductor lasers and its relevance for other dynamical systems.

Tom Gavrielides
(Air Force Research Laboratory, New Mexico, USA)

Square wave oscillations and chaos synchronization in diode lasers with incoherent optical feedback

In the usual incoherent feedback model one of the polarizations has usually been neglected in simulations of rate equations. However, in recent comparisons between numerical and experimental observations, the need of a two-polarization model has become very apparent. Under specific conditions, we have experimentally found square wave oscillations of the two field intensities exhibiting a period close to two times the round trip time of the feedback. A numerical bifurcation diagram using the two-field rate equations indicates how square-wave regimes emerge. These solutions appear at a critical feedback rate after a cascade of bifurcations where sustained relaxation oscillations dominate. The rate equations consist of four delay-differential equations for the amplitude of the two orthogonal fields, the phase difference between the phases of each field, and the carrier number. By using the method of steps, it is possible to construct the square-wave solutions in the limit of large delays, and it reveals the role of the small difference between the losses of the two fields.
Additionally, we present the chaotic dynamics theoretically and experimentally in a system of unidirectionally-coupled semiconductor lasers in the incoherent feedback configuration. Experimental data in the time and frequency domain demonstrate chaos synchronization with a lag between transmitter and receiver equal to the injection time, also know as driving synchronization. The natural polarization mode of the transmitter is shown to synchronize most efficiently to the orthogonal state of the receiver which is being injected. The full two-polarization model is used for both lasers, and is in good agreement with polarization resolved experimental measurements.

J. Belfi*, I. Galli°, **Giovanni Giusfredi**°, F. Marin*
*(*Dip. di Fisica, Università di Firenze, Italy °CNR - Istituto Nazionale di Ottica Applicata, Italy)*

Intensity noise of an injection locked Titanium: Sapphire laser. Analysis of the phase-noise to amplitude-noise conversion

We describe and characterize a compact ring Titanium: Sapphire laser injection-locked to an extended-cavity semiconductor source. The laser system has a good spectral purity and allows fast scans keeping the injection-locking condition. We analyze experimentally the amplitude noise properties of the free-running and injected laser and show good agreement with a quantum-mechanical model. In spite of the sub-shot noise properties of the semiconductor source, the injected laser exhibit strong excess amplitude fluctuations. We show that this effect is due to the conversion of the strong phase noise of the semiconductor laser into amplitude noise of the injected Titanium: Sapphire.

Fritz Henneberger and Hans-Jürgen Wünsche
(Institute of Physics, Humboldt University of Berlin, Newtonstr. 15, D-12489 Berlin, Germany)

Semiconductor lasers with integrated optical delay: A nonlinear dynamics laboratory

The role of delay in nonlinear systems, arising from a finite propagation time of the coupling signals, is of central importance in many different areas of science. Multi-section DFB lasers are ideal candidates for studying delay-related phenomena as they allow to control and to tune the relevant feedback and coupling parameters in a wide range by dc currents. In this talk we review our recent work on these laser structures that has indeed uncovered a number of novel nonlinear dynamical scenarios. Among those are: regular self-pulsations due to ultra-short delayed feedback[1]; excitability at homoclinic bifurcations[2] as wells as at a boundary crisis (chaotic transients); coherence resonance close to Hopf bifurcations[3]; torus-breakup and period doubling routes to chaos; chaos control implementing the ETDF method by an external FP cavity; synchronization of delay-coupled oscillators[4].

The authors thank Bernd Sartorius, FhG Heinrich-Hertz Institute Berlin, for providing devices specifically designed for the above studies.

[1] O. Ushakov, S. Bauer, O. Brox, H.J.Wünnsche, and F. Henneberger, Phys. Rev. Lett. 92, 043902 (2004).
[2] H.J.Wünsche, O.Brox, M.Radziunas, and F.Henneberger, Phys.Rev.Lett. 88, 023901 (2002).
[3] O. Ushakov, H-J. Wünsche, F. Henneberger, I.A. Khovanov, L. Schimansky-Geier, and M. Zaks, Phys. Rev. Lett.

[4] H-J. Wünsche, S. Bauer, J. Kreissl, O. Ushakov, N. Korneyev, F. Henneberger, E. Wille, H. Erzgräber, M. Peil, W. Elsässer, I. Fischer, Phys. Rev. Lett.

Guillaume Huyet
(Tyndall National Institute & Physics Department, University College Cork, Ireland)

Dynamics of quantum dot semiconductor lasers

Quantum dot semiconductor materials present many interesting advantages as they may allow the incorporation of two-level atoms into compact semiconductor materials. In particular, this should lead to the realization of semiconductor lasers operating with a low line-width enhancement factor. The aim of this talk is to present the latest results obtained with quantum dot semiconductor lasers. In particular, we will show that these devices do not necessarily have a low line-width enhancement factor but can insensitive to optical feedback due to the strong damping rate of the relaxation oscillations. Such characteristics are also illustrated by analysing the behaviour of these lasers under optical injections where various instabilities are described.

Adrian Jacobo

(IMEDEA, Palma de Mallorca, Spain)

Optical image and data processing with cavity type-II Second Harmonic Generation

We show the possibilities of type-II intracavity Second Harmonic Generation as a way to perform all-optical parallel processing of images [1].
To do image processing operations we pump the crystal at two orthogonal polarizations at fundamental frequency, the *y*-polarized pump is a homogeneous wave and the *x*-polarized pump has a spatial dependence that represents the image to be processed.
Depending on the relative intensities between the two pumps, different operations can be done. If the intensity of the homogeneous pump is greater than the intensity of the *x*-polarized pump we obtain at the output of the system the same image but at second harmonic frequency and in the *y*-polarization.

Also the inverted image appears in the *y*-polarization at fundamental frequency. If the intensity of the homogeneous field is lower than the *x*-polarized field in some regions of the image this regions appear enhanced in the *x*-polarized fundamental field at the output of the system, and in the second harmonic we obtain the contour of the image. Furthermore the system shows noise filtering properties.
We show that injecting two images simultaneously it is possible to perform logical operations such as "AND" and "XOR".
Finally we analyze the effect of using cavities with spherical mirrors, and the case when the cavity is nonresonant at the second harmonic frequency [2].

1. P. Scotto, P. Colet, and M. San Miguel, Opt. Lett. 28, 1695 (2003).
2. A. Jacobo, P. Colet, P. Scotto and M. San Miguel, Appl. Phys. B, accepted.

Alexander Kir'yanov

(Centro de Investigaciones en Optica, Guanajuato, Mexico)

Nonlinear dynamics of Erbium fiber lasers: external and self modulation features

The results of recent studies performed in the Centro de Investigaciones en Optica (Leon, Mexico) in the field of diode-pumped Erbium fiber lasers (EFL) engineering are presented. The main attention is paid to an inspection of pulsed regimes of the EFL, which have been realized applying various passive and active Q-switching methods: (i)
The use of a saturable absorber (Co^{2+}:ZnSe crystal) inside the EFL cavity. In this case the EFL transits to the passive Q-switching (PQS) regime due to the nonlinear behavior of the transmission coefficient of Co^{2+}:ZnSe under the action of intra-cavity radiation; (ii)
The technique that exploits the self-action effects inside the erbium active fiber, which lead to establishing of the self-Q-switching (SQS) regime in the laser cavity. The governing nonlinearities allowing a transition of the EFL to pulsing in this case are the resonant and thermal ones - the excited-state absorption in the system of erbium ions and nonlinear thermo-lensing in the active fiber core; (iii) The direct (active) modulation of power of the pumping diode laser or cavity-loss.
Some accompanying nonlinear phenomena, which appear in the EFL dynamics in these last cases (e.g., the generation of multiple attractors and transition to chaos in the laser), are inspected as well.
For all the methods, are thoroughly provided the descriptions of experimental setups and data as well as theoretical models for the corresponding EFL systems.

The developed methods and obtained results are compared with the alternative ones known from the literature on pulsed EFLs. Notice that short pulses (of the nanosecond and sub-microsecond range) on the wavelength 1.5 μm generated by the EFL at Q-switching as well as some nonlinear dynamics features of the EFL are of a great interest for the contemporary needs of optical fiber communications, sensing, amplifying, etc.

Yuri Kivshar
(Nonlinear Physics Centre, Research School for Physical Sciences and Engineering, Australian National University)

Nonlinear optics and gap solitons in periodic photonic lattices

I will describe the recent advances in the study of nonlinear optics effects in periodical media such as photonic crystals and optical lattices. First, I will introduce a general concept of photonic crystals as dielectric materials with periodically varying refractive index, Floquet-Bloch eigenmodes, and bandgap spectrum, also discussing their potential use in all-optical photonic devices. I will also overview our recent experiments on one- and two-dimensional optically-induced photonic lattices created by light in photorefractive nonlinear crystals which may serve as a simple test bed for observing many fundamental effects in periodic structures such as Bloch oscillations and Zener tunneling, optical gap solitons and discrete vortices, tunable positive and negative refraction, selective Bloch wave excitation and mode coupling, etc.

Marcelo Kovalsky
(Centro de Investigaciones en Láseres y Aplicaciones, Argentina)

Dynamics of a femtosecond Ti:Sapphire laser

The Ti:Sapphire laser is the most widely used source of femtosecond pulses. However, and in spite of its applications in many fields of science, several of its dynamical properties remain poorly known. This presentation is a resume of an exhaustive study of the dynamics of the Kerr - lens mode locked Ti:Sapphire laser. On the one hand, a theoretical model based on iterative maps is developed. The observed modes of operation are naturally obtained from a description based on an iterative map of five pulse variables, beam size, curvature, pulse duration, chirp and energy. The stability regions for each mode are obtained as well as its characteristic behaviors. On the other hand, the structurally stable properties of the system are experimentally found, observing a good agreement between the experiment and the model.

It is experimentally shown that pulse to pulse instabilities in the output of the laser are usual and they can affect some of the pulse variables and not others. A simple way to detect and eliminate the instabilities is described. Experimental time series of the two pulsed model are obtained. From this series the chaotic low dimensional deterministic behavior is confirmed and the route to chaos in each case is established. The same attractors are obtained from the simulated series. As an application of the model, an algorithm of control of chaos that allows reach shorter pulse duration, close to 10 fs, is presented.

Laurent Larger
(University of Franche-Comte, Optics dept., Besancon, France)

Optoelectronic nonlinear delayed feedback oscillators in discrete and continuous time regimes

An original optoelectronic delayed feedback oscillator is reported. The well-known optoelectronic implementation of the Ikeda architecture is modified through the used of a periodic pulsed laser as the seeding coherent light source. We show experimentally how this configuration allow a discrete time dynamical process, depending on the relative scaling between the delay, the physical response time of the oscillator, and the seeding laser pulse period. A different explanation than the well-known adiabatic approximation (also called singular limit map) is given for a smooth, and dimension preserving, transition from continuous time behavior to discrete time ones.

Jia-Ming Liu
(Electrical Engineering Department, University of California, Los Angeles, USA)

Bidirectionally coupled synchronization scenarios of semiconductor lasers with delayed feedback

General synchronization scenarios of bidirectionally coupled oscillators with delayed feedback are studied with all possible conditions. Four generic configurations are identified, with one of them reduced unidirectional coupling but the other three represent bidirectional coupling. Necessary conditions of synchronization for all scenarios are analyzed. Experimental work on anticipated and retarded synchronization of bidirectionally coupled semiconductor lasers with optoelectronic feedback are carried out. These two types of synchronization are found to arise from a predictable relation between feedback/coupling delay times under particular feedback/coupling strength combinations. A comparison between the experimental results and the theoretical predictions is given. The experimental results generally agree with the theoretical predictions.

Eric Louvergneaux, G. Agez, P. Glorieux, C. Szwaj, and M. Taki (*Université des Sciences et Technologies de Lille, Villeneuve dÁscq Cedex, France)*

Two-dimensional noise-sustained structures in optics: theory and experiments

In a previous study we have evidenced that the presence of a transverse displacement in a one dimensional (1D) optical system leads to convective instability patterns. Here, we present the effects of strong translational transverse displacement effects on pattern formation in a two-dimensional (2D) noisy optical system. These non-local interactions give rise to a large domain of convective instability resulting in *2D noise-sustained structures*. The various types of "basic patterns" are investigated and their associated thresholds and properties are analytically derived. Corresponding typical 2D experimental noise-sustained patterns are evidenced in an optical feedback system, in complete agreement with theory. Surprisingly enough, purely noise-sustained structures are found to be stationary in contrast with the commonly widespread situation where convection leads to propagating patterns. Experimental stationary noise-sustained superlattices will also be presented.

Luigi Lugiato*, F. Prati*, G. Tissoni*, X. Hachair+. F. Pedaci+, E. Caboche+, M. Giudici+, J.R.Tredicce+, M. Brambilla x, M. Bache ^, R.Kheradmand &, and I. Protsenko $
*(*Università dell'Insubria, Como, +Institut Non-lineaire de Nice, x Università di Bari, ^Research Center COM, Lingby, & University of Tabriz, $ Lebedev Physics Institute, Moscow)*

Cavity Solitons in semiconductor microresonators

We experimentally demonstrate the existence and the control of cavity solitons in externally driven vertical-cavity semiconductor lasers above threshold, despite the presence of a Hopf instability which affects the background of the solitons. We show theoretically and numerically the possibility of realizing a cavity soliton laser, without any holding beam, by using a broad-area VCSEL with a saturable absorber. In this case, cavity solitons can be written and erased without need for controlling the phase of the writing pulse.

Paul Mandel
(Optique nonlinéaire théorique, Université libre de Bruxelles, Belgium)

Modeling quantum dot lasers

Quantum dot lasers are notoriously tricky to model. These nanolasers are too small to allow a direct probing of the processes that take place. Therefore, it is not possible to derive from first principles a model that explains and predicts the quantum dot laser characteristics. Thus, a phenomenological model has to built, based on selected experimental results. We shall show how recent experiments give a hint towards a list of relevant mechanisms in single mode and in multimode quantum dot lasers.

Ricardo Meucci
(Istituto Nazionale di Ottica Applicata, Florence, Italy)

Control and synchronization in lasers

We discuss a control method able to suppress bursting phenomena emerging in a modulated laser as a consequence of an interior crisis as well as to select an attractor in a bistable regime with jumps between independent attractors (generalized multistability). Furthermore, we report on different forms of synchronization in laser experiments. Identical, phase and generalized synchronization will be discussed in autonomous and non autonomous systems dealing with class B lasers.

Claudio Mirasso
(Departament de Fisica, Universitat de les Illes Balears)

Chaotic optical communications

Chaotic optical communication is a promising technique to improve privacy and security. It employs synchronized chaotic emitters/receiver lasers to encode/decode information. This talk describes a recent demonstration of an optical chaotic communication system.

Junji Ohtsubo
(Shizuoka University, Japan)

Polarization Dynamics and Chaos Synchronization in VCSELs

Polarization dynamics, optical feedback effects, and chaos synchronization in vertical-cavity surface-emitting lasers (VCSELs) have been theoretically and experimentally studied. Since VCSEL have a symmetrical spatial structure at the exit face of light, the dynamics of VCSEL are strongly affected by the polarization properties.
Therefore polarization directions and switching play important roles for the dynamics and synchronization in VCSELs. I discuss optical feedback effects of VCSELs and synchronization in mutually coupled VCSELs with the relation to the polarization dynamics.

Marcos Oria
(Universidade Federal da Paraiba, Joao Pessoa, Brazil)

Multistability in the frequency of a semiconductor laser

In this work we present our experimental observations of bi- and multistability in the emission frequency of a semiconductor laser. Such behavior, having more than one stable operation point together with a stable power emission, was obtained when the diode laser is submitted to a spectrally-filtered orthogonal-polarization feedback. The observed spectra are described by a model where we consider both the linear response of the laser frequency shift as a function of the feedback intensity and the spectrally nonlinear transmission of the filter. The experiment was carried out with a semiconductor laser coupled to the resonant cesium D2 line and we show that using a re-injected signal having both absorptive and dispersive lineshapes, we are able to control the laser spectral response exhibiting bistability or multistability. Also, we discuss the use of this system as a promising tool in optical telecommunication and computing, as an AM-FM converter, a switch or a memory.

Krassimir Panajotov
(Department of Applied Physics and Photonics, Vrije Universiteit Brussel, Belgium)

Polarization dynamics of VCSELs with Optical Feedback

We present a survey on our experimental results on optical feedback in Vertical-Cavity Surface-Emitting lasers (VCSELs) paying particular attention on its effect on their polarization behaviour. We demonstrate that a weak feedback may induce random anticorrelated hopping between the two orthogonal linearly polarized modes. This polarization mode hopping is accompanied by rapid anticorrelated oscillations in the linearly polarized intensities at the external-cavity frequency which manifest themselves as discontinuity and oscillations in the polarization resolved residence time distribution. The study of a simple stochastic delay differential equation suggests that these oscillations generated by the delay are typical of any hopping phenomenon between states. Specifically for VCSELs we consider two-mode single-delay model which gives very good agreement with the experiments We furthermore show numerically that an external noise source on the injection current allows observation of a coherence resonance phenomenon in VCSELs induced by the time-delayed feedback.
In the case of short external cavity we give an experimental evidence for the onset of pulse package dynamics in the total intensity of VCSELs. We characterize the pulse package dynamics via their spectral and correlation properties and demonstrate that it is strongly influenced by the polarization mode competition. An analysis of the cross-correlation properties of the two polarization modes indicates a transition from in-phase to anti-phase dynamics when increasing the injection current.
Finally, we will also present experimental and numerical results on polarization properties of VCSELs subject to optical feedback from an extremely short external cavity.

Antonio Politi (*Istituto dei Sistemi Complessi, Firenze, Italy*)
Partial synchronization in globally coupled oscillators

Understanding the behavior of globally coupled units is an important subject of research in many contexts including, e.g., information processing in the brain and metabolic systems. Many generic phenomena occurring even in simple networks have still to be uncovered and fully understood. Besides reviewing some macroscopic transitions occurring in such context, I will concentrate on the phenomenon of "partial synchronization", initially discovered in pulse-coupled integrate-and-fire neurons, but which has recently turned out to be much more general. A new approach that is able to describe the system dynamics both at the micro- and macroscopic level is presented.

Jose R. Rios Leite
(Departamento de Física, Universidad Federal de Pernambuco, Recife, Brazil)

On the Low Frequency Fluctuations of diode lasers with optical feedback

Rajarshi Roy
(University of Maryland, USA)

Mutually coupled laser dynamics

Coupled lasers are excellent experimental systems for testing concepts from the theory of dynamical systems and statistical physics. We show examples of the dynamics of these coupled nonlinear oscillators and measurements of their correlation and synchronization behavior. Comparisons with computations from numerical models are made for solid state, semiconductor and fiber lasers.

Marc Sciamanna
(SUPELEC, Campus de Metz, France)

Nonlinear polarization dynamics of VCSELs with orthogonal optical injection

Paul S. Spencer
(University of Wales, Bangor, UK)

Optimum time-delay identification for chaos synchronisation in semiconductor lasers

It is shown that the optimum correlation for chaos synchronisation of master/slave semiconductor lasers occurs at a delay time that is sensitive to both the injection strength and the frequency detuning of the driving field. This effect may be overlooked if the correlation function is not evaluated globally. The correlation function has been used as the de facto method for quantitatively determining the degree of synchronisation achieved between unidirectional coupled chaotic semiconductor lasers. The correlation function is a continuous function of the delay time but is normally evaluated at only two delay times. It is shown that this approach can cause a mis-identification of the dominant synchronisation process and can also mask important temporal fluctuations in the nature and quality of the chaos synchronisation.

Jorge Tredicce
(Institut Non-Linéaire de Nice, Université de Nice Sophia-Antipolis, France)

Multi and single mode spatio temporal instabilities in a laser with injected signal

We review experimental and theoretical studies on instabilities in a laser and/or amplifier with injected signal. We consider both single and multi longitudinal mode operation. We include also transverse effects which may yield localised structures, cavity light bullets and excitable optical waves.

Atsushi Uchida
(Department of Electronics and Computer Systems, Takushoku University, Tokio, Japan)

Consistency of driven laser systems

Many nonlinear dynamical systems have an ability to generate consistent outputs when driven by a repeated external signal. Consistency is defined as the reproducibility of response waveforms in a nonlinear dynamical system driven repeatedly by a signal, starting from different initial conditions of the system. Consistency of dynamics is essential for information transmission in biological and physiological systems and for reproduction of spatiotemporal patterns in nature. In this talk we introduce a quantitative measure of consistency, and experimentally and numerically demonstrate its measurement in the dynamics of a physical laser system driven repeatedly by a complex (chaos or noise) waveform.

Kevin Wegener
(Air Force Office of Scientific Research)

Doing with Business with AFOSR

The Air Force Office of Scientific Research (AFOSR) is the funding arm of the U.S. Air Force. We invest in basic research throughout the world in hopes of pushing the boundaries of the cutting edge. In this talk I will discuss the various options for working with my organization. These options include being sponsored to visit our scientists in the U.S., supporting conferences of interest to the Air Force and funding small seed grants.

POSTERS

Gonzague Ages and Marcel Clerc
(Departamento de Fisica, Universidad de Chile, Santiago, Chile)

Using noise speckle pattern for the measurements of dynamical constant of liquid crystals

A purely optical method based on speckle analysis is used to measure the diffusion length and the relaxation time of an aligned nematic liquid crystal, commonly used in optics as Kerr medium.
Obtained values agree with those measured by previous more complicated methods.

Felipe Beltran and Efrain Solarte
(Lab. de Optica Cuantica, Fac. de Ciencias, Universidad del Valle, Cali, Colombia)

Analysis of the Gordon-Haus effect in systems of quasi-solitons

When an input soliton pass through an optical amplifier, the soliton is boosted along together with the noise signal, and a random variation in the arrival time, called the Gordon-Haus effect, is induced.
By the use of programmed chirp and a continuous dispersion profile, as envisaged by Kumar and Hasegawa, it is possible to produce a soliton like pulse called the quasi-soliton. This kind of pulse needs less peak power than the soliton and reduces the soliton-soliton interaction while keeps the benefits of optical solitons.
Based on the results obtained by Kumar and Lederer for the Gordon-Haus effect on dispersion managed systems, we studied the influence of this effect in the quasi-soliton propagation. We have obtained an analytical solution for the mean square frequency shift. The expression obtained depends on the dispersion map parameters and the amplifier spacing. The results are shown for different values of the initial chirp.

Martine Chevrollier
(Departamento de Física, Universidade Federal da Paraiba, Brazil)

Levy flights in photons diffusion in a resonant atomic vapor

Resonant photons may diffuse in a vapor due to successive cycles of absorption and emission by the atoms of the vapor. This phenomenon, called radiation trapping, has been largely studied since the early works of Holstein [1] describing the evolution of the atomic excited state by integro-differential equations. A recent theoretical investigation [2] shows that, in the case of complete frequency redistribution by the atoms, the jump size distribution of the emitted photons follows a Levy statistics, i.e., the photons trajectories are superdiffusive flights, characterized by a long tail distribution, with diverging statistical moments. We have set up an experiment to characterize such a photon distribution in a thermal cesium vapor. The very first measurements indicate a deviation from the normal (Brownian-type) diffusion, evolving to a power law distribution as the distance from the excitation region is increased. Monte-Carlo simulations of the photons trajectories in the vapor allow us to get numerical distributions for the photons random walk and thus to infer the distribution of their frequency-dependent jump sizes. The asymptotic power law depends on the emission and absorption profiles, as well as of the geometry of the cell containing the vapor.

[1] T. Holstein, Phys. Rev. **72**, 1212 (1947).
[2] E. Pereira et al., Phys. Rev. Lett. **93**, 120201 (2004).

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Noise induces coarsening

The effect of thermal noise in the coarsening in one dimension extended system is studied. It is shown that the coarsening in the presence of additive noise is radically changed. From a prototype models that exhibit coarsening dynamic, real Ginzburg-Landau and Cahn-Hilliard equation with noise, we have deduced, using a kink and anti-kink interaction approach, that the characteristic length satisfies a power law ($t^{1/2}$). Nevertheless, this law is logarithmic in absence of noise.

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Multistability in the emission frequency of a semiconductor laser

We report on the observation of frequency multistability in a semiconductor laser emission. We experimentally study the spectral behavior of a semiconductor laser under a spectrally-filtered orthogonal-polarization feedback and we show that using a re-injected signal having both absorptive and dispersive lineshapes, we are able to control the laser spectral response exhibiting bistability or multistability.
We explain all the observed spectra through a simple phenomenological model.

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Characterization of a CO_2 laser for the thermal processing of ceramic materials

A continuous wave CO_2 laser has been designed and built.
The system is water cooled and the DC discharge tube is separated from the optical resonator, leading enough space to assemble a cavity modulator to produce high power pulses. This system produces about 17 W (cw), working in the TEM_{00} mode. In this work the results of the optical and electrical system characterization are presented. Typical curves of laser power as a function of the discharge voltage for different pressure values, and the dependence of the maximum emitted power with the gas mixture composition, were measured.
Optical measurements of the laser beam parameters allowed to determine the beam waist as (2.31 ± 0.07) mm; the laser beam divergence as (1.5 ± 0.3) mrad, and the laser wavelength as (10.7 ± 0.8) μm.
The laser intensity distributions in the TEM_{00} and the TEM_{01} modes were observed and measured.

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Bragg grating tunable erbium-doped fiber linear laser: modelling and construction

In this work, the modelling and construction of a Bragg grating tuneable Erbium-Doped fiber linear laser are reported. The laser was designed following a two levels model for the Erbium ion based on parameters that can be directly determined from fiber-transmission measurements. The cavity was performed with 35 m of 980-nm laser-diode-pumped Erbium-doped fiber and two high reflectivity Bragg gratings. Laser tuning was carried out with a mechanical assembly, which allowed synchronously shifting of the grating spectra. Experimental results agree well with our theoretical model.

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Excitability mediated by localized structures

We consider a ring cavity filled with a nonlinear self-focusing Kerr medium pumped by an external field. Localized structures (cavity solitons) in the form of bright spots surrounded by a dark ring appear in the transverse field under appropriate conditions [1]. For some region of the parameters this cavity solitons display an oscillatory behavior and above certain threshold this behavior becomes excitable [2]. This means that if the localized structure is perturbed beyond certain threshold it grows to a large value and then decays exponentially emitting a wave that dissipates the remaining energy. Furthermore after one perturbation the cavity soliton can not be excited again within a refractory period of time. It is important to remark that the system itself it is not excitable, and that the excitability only appears mediated by the localized structure as an emergent effect coming from the spatial dependence. The wave emitted by one of this cavity solitons can excite the excursion of another cavity soliton placed in a different location. We study this interaction as a function of the distance between the two localized structures.

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Dynamics of the all solid state passively Q-switched Nd:YVO4 laser from experimental time series

Q-switching is a technology widely used in lasers to generate short pulses with high peak powers. Such pulses are useful in many applications, such as laser machining, surgery, laser pumping, rangefinder and LIDAR systems. In solid state lasers, Q-switching can be realized actively, using either acousto-optical (AO) or electro-optical (EO) modulators, or passively, using a saturable absorber. Compared to active Q-switching methods, the passive technique has the advantage of a simpler configuration and shorter cavity length, not to mention the reduction of cost. The key drawback of this technique is the instability of the time separation between successive pulses. This behavior, caused by the nonlinear nature of the mechanism responsible for the pulse formation, makes difficult the use of the passive Q-switched lasers in applications requiring a controllable repetition rate (as LIDAR systems). The understanding of the intrinsically complex dynamics of the physics of this laser is therefore not only an interesting subject of study in itself, but it also opens a door to practical uses. In this poster, we present the results obtained from the analysis of the experimental time series generated by a diode pumped, passively Q-switched with a Cr:YAG crystal, Nd:YVO4 laser. The Cr:YAG is a saturable absorber that has the advantage of being solid-state, but its slow response time complicates the dynamics. By employing nonlinear tools of analysis the dynamics of the underlying attractor of the system can be determined. With this information, it is possible to develop chaos control schemes.

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Recovery of the Low Frequency Fluctuations in Diode Lasers with Optical Feedback

Experiments were done on the chaotic Low Frequency Fluctuation (LFF) in the power output of a semiconductor laser with optical feedback. Measurements and calculations, with the single-mode Lang-Kobayashi equations, of the drops and recoveries are shown to have exponential behavior. Their corresponding time constants give the Lyapunov exponents of the unstable and stable manifolds within the phase space of an excitable dynamical system model for this laser.

Gabriel Martinez Niconoff
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Characteristic solution for the nonlinear Schroedinger equation: geometric description of solitons

We describe the structure of solution for the non-linear Schrödinger equation using a modal representation. With this treatment, we obtain a reduced partial differential equation, whose characteristic solution has an eikonal structure. The soliton solutions are generated by means of an envelope of eikonal trajectories. The treatment permit us to establish an analogy with caustics of diffraction fields and associate a catastrophe function for optical path length in the nonlinear media.

Gabriel Martinez Niconoff
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Analysis of optical vortices using catastrophe theory

The synthesis of caustic of diffraction fields using geometrical theory of diffraction is described. The study is applied to transmittances with a temporary dependence. The analysis permits us to identify adiabatic regions associated to the phase function, which, in its turn, can be interpreted as a catastrophe function with temporary parameters. The dynamics of focusing regions offers the possibility to describe optical vortices. Experimental results are shown.

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Topological analysis of experimental chaotic signals from an edf ring laser.

The response of an erbium-doped fiber unidirectional ring laser under pump power sinusoidal modulation has been experimentally observed for different combinations of modulation parameters (amplitude, mean value and frequency of the pump power modulation) leading to chaotic behaviour.

Topological analysis was applied to the sampled signals, that is to say, unstable periodic orbits were found, their linking numbers in the 3D phase space were calculated and, eventually, the template which models each strange attractor was obtained.
A remarkable variety of behaviours has been found, ranging from regimes described by the classical Smale horseshoe template to complex structures whose modelling might require a template of four or more branches. In their study, difficulties arise due to the need of a greater number of reliable linking numbers, which will hopefully contribute to make us refine some aspects of this method of analysis.

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Modeling spatial effects in multi-longitudinal-mode semiconductor lasers

The multi-longitudinal-mode dynamics of a semiconductor laser is studied theoretically, based on travelling-wave equations for the slowly-varying amplitudes of the counter-propagating optical fields in the laser cavity, coupled to an equation for the carrier population dynamics. The model considers key ingredients describing the semiconductor medium, such as the spatial variations of the carriers and optical fields in the longitudinal direction, a parabolic frequency-dependent gain and phase-amplitude coupling, and does not assume a-priori a fixed number of active longitudinal modes. We find deterministic out of phase modal oscillations which leave the sum of total modal intensities nearly constant. These oscillations become faster as the injection current increases, in good agreement with recent experimental observations. In our model the origin of modal oscillations is spatial hole burning in the envelope of the carrier grating, which is due to the interaction of different longitudinal modes.

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Qualitative Study on Nonlinear Amplification for Dark Solitons in Presence of Raman Effect

Was analyzed the effect produced by optical amplification model with nonlinear gain in systems of high-speed transmission for optical fibers using dark solitons. By means of perturbation theory for dark solitons, the evolution equation was written, in presence of nonlinear gain, for the fundamental parameter of the dark soliton (angle of internal phase). Numerically was studied the evolution of the soliton amplitude along the transmission line. In presence of the Raman effect, the amplification model with nonlinear gain is effective stabilizing the amplitude in black and gray solitons.

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Experimental study of polarisation switching of vertical-cavity surface-emitting lasers as a dynamical bifurcation

We study the role of the bias current sweep rate in measurements of polarisation switching (PS) of vertical-cavity surface-emitting lasers (VCSELs). We show that the polarisation-resolved L-I curve depends on the current sweep rate. As the current sweep rate increases the PS occurs at higher bias current for upwards scans and at lower bias current for downwards scans. We also show that the delay of the dynamical bifurcation follows a power law relationship with the frequency of the ramp, in good agreement with recent theoretical predictions.

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Relative intensity noise and polarization stability of vertical-cavity surface-emitting lasers subject to polarization-resolved optical feedback

Vertical-cavity surface-emitting lasers (VCSELs) have many advantage compared to edge-emitting semiconductor lasers, such as low threshold current, single-longitudinal mode operation, circular output-beam profile and wafer-scale integrability. The noise characteristic is a very important parameter in optical communication. VCSELs have proved to be low-noise devices. However, a salient feature of VCSELs is their tendency to exhibit polarization switching. Near threshold VCSELs are usually linearly polarized along one of two preferred orthogonal directions. When the bias current is increased, the polarization often switches to the orthogonal polarization. Such polarization switching has a strong effect on their noise properties. Despite VCSELs' high facet reflectivity, they also exhibit sensitivity to optical feedback due to the short cavity length. In this paper, we experimentally study the relative intensity noise (RIN) of VCSELs subject to optical feedback. We compare the effects of polarization-selective and polarization-preserving optical feedback on the RIN of VCSELs. We also examine the polarization stability of VCSELs subject to optical feedback and find that polarization selective feedback can be used to control polarization intensity fluctuations. The RIN of the VCSEL operating in the polarization stable regime has also been investigated. The results show that polarization-selective feedback is more effective to influence the dynamics of the VCSEL.

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Calculation of the non linear refractive index in optical fibers using autocorrelation functions

Calculations of the non linear refractive index in optical fibers using autocorrelation functions are presented. The theoretical method, involving the IGA traces, was reviewed for small width Gaussian pulses and for solitonic hyperbolic pulses. It was found that for solitonic pulses, the IGA traces content important information about the Self Phase Modulation (SPM) and about the pulse broadening just like in the Gaussian case.

Raúl M-Quiroz
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Optical Parametric Amplification and IR Spectroscopy: Theory and Experimental Considerations on Water Modes

The pulses can interact and vary in different ways depending on their own characteristics, medium of propagation and the induced responses. In nonlinear interactions, the theory of wave mixing can be approached assuming a dissipation less medium with monochromatic waves, having slow amplitude variations and energy flow with directionality and conservation, evolving amplifications depending on their phase matching conditions. In ultrafast pulses, the velocity groups, the phase matching and pulse duration determine the amplification. At high intensities, velocity dispersion and self phase modulation become present.

When dealing with experiments, variations in the mixing process through optical means, nonlinear crystals and temperature, amplifying, difference frequency mixing, compressing, stretching and polarizing with a given geometry of configuration, allow the construction of specific type of pulses to follow, induce and interrogate molecular events. The combination of transient and linear IR spectroscopy permits then to study dynamic conditions and relaxations toward an equilibrium. While looking into water modes, femtosecond pulses resolve picoseconds stretching vibrational relaxation processes. Microseconds scale absorption FTIRs give then equilibrium information. The poster will show theoretical and experimental considerations as well as measurements of these water modes in a life-mimicking system.

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Characterization of laser propagation through turbulent media by quantifiers based on the wavelet transform: a dynamic study

We analyze, within the wavelet theory framework, the wandering over a screen of the centroid of a laser beam after it has propagated through a time-changing laboratory-generated turbulence. Following a previous work (Fractals 12 (2004) 223) two quantifiers are used, the Hurst parameter, H, and the Normalized Total Wavelet Entropy, NTWS. The temporal evolution of both quantifiers, obtained from the laser spot data stream is studied and compared. This allows us to extract information of the stochastic process associated to the turbulence dynamics.

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Modeling transverse effects on index-guided vertical-cavity surface-emitting lasers

The dynamics of vertical-cavity surface-emitting lasers (VCSELs) is studied numerically, using a model that, in addition of taking into account the vector nature of the laser field, takes into account the spatial transverse variation of the laser field and of the carrier population. The model considers two optical fields, which are orthogonal linearly polarized, coupled to two carrier populations, which are associated with different magnetic sublevels of the conduction and valence bands in the quantum-well active region. The transverse optical profiles correspond to index-guided VCSELs with transverse cylindrical symmetry, and are fixed by the built-in refractive index step between the active and cladding regions. We study spatial hole burning and carrier diffusion effects in the regime of fundamental-transverse-mode operation on both linearly polarized optical fields. We find that for large-area lasers carrier diffusion has little influence on the polarization dynamics, as it only modifies the value of the injection current at which the polarization switching occurs. For small-area lasers, carrier diffusion has a crucial effect, inducing self-sustained oscillations of the laser output due to a saturable-absorber effect of the cladding region. As the injection current is increased above a certain value, the laser starts to oscillate and the amplitude of these oscillations increases with the injection; however, there is a saturation effect and the self-pulsations disappear at higher injection levels. The dependence of the amplitude of the oscillations with the injected current is found to be in good qualitative agreement with the predictions of a recently developed model that considers an intensity-dependent transverse confinement factor [Van der Sande {\it et al.}, Opt. Lett. {\bf 29}, 53 (2004)].

Second 'Rio de la Plata' Workshop on Noise, Chaos, and Complexity In Lasers and Nonlinear Optics

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