FIRST 'RIO DE LA PLATA' WORKSHOP ON NOISE, CHAOS, AND COMPLEXITY IN LASERS AND NONLINEAR OPTICS

PROGRAM

Organizers:

Cristina Masoller (Facultad de Ciencias, Universidad de la Republica, Uruguay)
Hernán Solari (Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina)

Acknowledgements:

We wish to thank the following institutions for their contribution to the success of this workshop: Embajada de Francia en Uruguay - Servicio de Cooperación y Acción Cultural; European Office of Aerospace Research and Development - Air Force Office of Scientific Research, United States Air Force Research Laboratory; Fundación Antorchas Argentina; Istituto Italiano Di Cultura In Uruguay; The Abdus Salam International Centre for Theoretical Physics, Office of External Activities.

Held at Colonia del Sacramento, Uruguay
December 1 - December 5, 2003

PROGRAM

Registration: Sunday November 30, 16 - 20 hs, Hotel Barcelo
Monday December 1, 9 – 17 hs, Hotel Barcelo

Monday, December 1

10:45 - 11:00 Opening

Chair: Cristina Masoller
11:00 - 11:45 Alejandro Hnilo (Buenos Aires, Argentina)
Kerr lens mode locked lasers as dynamical systems
11:45 - 12:30 Pierre Glorieux (Villeneuve d'Ascq, France)
Noise reveals spatio-temporal dynamics of the Kerr Slice with simple feedback

12:30 - 15:00 Lunch

Chair: Alejandro Hnilo
15:00 - 15:45 Arturo Lezama (Montevideo, Uruguay)
Noise atomic spectroscopy
15:45 - 16:30 Wolfgang E. Elsäßser (Darmstadt, Germany)
Quantum noise properties of vertical cavity emitting devices

16:30 - 17:00 Coffee break

Chair: Arturo Lezama
17:00 - 17:45 Giovanni Giacomelli (Firenze, Italy)
Experimental study of stochastic phenomena in vertical cavity lasers
17:45 – 18:30 Cristina Masoller (Montevideo, Uruguay)
Effect of noise in semiconductor lasers with time-delayed feedback

20:00 Welcome Dinner

Tuesday, December 2

Chair: Hernan Solari
9:00 - 9:45 Jorge Tredicce (Nice, France)
Dynamics of multimode semiconductor lasers
9:45 - 10:30 J. R. Rios Leite (Recife, Brazil)
Chaotic diode lasers with low frequency fluctuations: statistics of pulses and synchronism

10:30 - 11:00 Coffee break

Chair: Giovanni Giacomelli
11:00 - 11:45 Daan Lenstra (Amsterdam, The Netherlands)

Dynamics and noise in semiconductor lasers: a complex marriage

11:45 - 12:30 Mario Natiello (Lund University, Sweden)
Laser with injected signal: an overview

12:30 - 15:00 Lunch

Chair: Alan Shore

15:00 - 15:45 Tom Gavrielides (New Mexico, USA)
External cavity modes of semiconductor lasers with phase-conjugate feedback

15:45 – 16:30 D. M. Kane (Sydney, Australia)
Semiconductor laser systems for optical frequency comb and chaos generation

16:30 - 17:00 Coffee break

17:00 – 18:30 Poster session

Wednesday, December 3

Chair: Mario Natiello

9:00 - 9:45 Jia-Ming Liu (Los Angeles, U.S.A.)
Synchronizing semiconductor laser chaos for optical communications

9:45 - 10:30 K. Alan Shore (Bangor, Wales)
Synchronization of chaotic external cavity laser diodes for secure optical communication networks

10:30 - 11:00 Coffee break

Chair: Miguel Hoyuelos

11:00 - 11:45 Ulrich Parlitz (Goettingen, Germany)
Chaos and synchronization in laser systems

11:45 - 12:05 Immo Wedekind (Goettingen, Germany)
Synchronization of external cavity semiconductor lasers

12:05 – 12:25 Alexandre Locquet (Metz, France)
Time series analysis of chaotic laser dynamics

12:30 - 15:00 Lunch

Afternoon free

20:00 Conference Dinner

Thursday, December 4

Chair: Carlos Martel

9:00 - 9:45 Ramon Vilaseca (Terrassa, Spain)
Cavity solitons in class-C lasers

9:45 - 10:30 Luigi Lugiato (Como, Italy)

Cavity Solitons and all that

10:30 - 11:00 Coffee break

Chair: Ramon Vilaseca
11:00 - 11:45 William Firth (Glasgow, Scotland)
Optical patterns and cavity solitons
11:45 - 12:05 Oscar G. Calderon (Madrid, Spain)
From nearly tilted waves to phase solitons in broad area squeezed-pump lasers
12:05 – 12:25 Miguel Hoyuelos (Mar del Plata, Argentina)
Patterns in the Vectorial Swift-Hohenberg Equation for lasers

12:30 - 15:00 Lunch

Chair: Deb Kane
15:00 - 15:45 M. Lefranc (Villeneuve d'Ascq, France)
Instabilities and chaos in an optical parametric oscillator
15:45 - 16:05 Carlos Montes (Nice, France)
Coherent optical parametric oscillator driven from an incoherent pump
16:05 – 16:25 Carlos Martel (Madrid, Spain)
Material dispersion induced dynamics in light propagation in fiber gratings

16:30 - 17:00 Coffee break

Chair: Luigi Lugiato
17:00 - 18:30 Discussion: challenges ahead

Friday, December 5

Chair: Tom Gavrielides
9:00 - 9:45 Antonio Politi (Firenze, Italy)
Recoil induced lasing action
9:45 - 10:30 Jerome V. Moloney (Tucson, USA)
Optically turbulent terawatt femtosecond atmospheric light strings
10:30 - 10:45 Concluding remarks

TALKS

Oscar G. Calderon (*Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Spain*)

From nearly tilted waves to phase solitons in broad area squeezed-pump lasers

A rich variety of extended patterns (tiled waves, vortex lattices) and localized structures (optical vortices) can be observed in laser and laser-like nonlinear optical systems, such as optical parametric oscillators (OPOs) and photorefractive oscillators (PROs). In these systems the phase of the radiation can have an arbitrary value and the transition from the nonlasing to the lasing regime is described by a supercritical Hopf bifurcation. However, we will show in this work that this scenario of transverse patterns can change dramatically when we consider a laser pumped by an incoherent source in a squeezed vacuum state. Marte et al. [Phys. Rev. A 37, 1235 (1988); Phys. Rev. Lett. 61, 1093 (1988)] demonstrated that the squeezed-pump breaks the phase invariance of the laser field and leads to a phase-locked steady-state laser field. Concerning to the pattern formation, we find two main regimes depending on the ratio between the cavity detuning and the parameter that measure the squeezing of the pump source. When the cavity detuning is lower than the squeezing parameter, the radiation prefers two values for the phase, both differing by pi. In this case the above mentioned patterns are inhibited due to the phase selection, and instead of that, stripes as extended patterns and phase domains and phase solitons as localized structures take place. These type of spatial structures have been found in other nonlinear optical systems such as degenerate optical parametric oscillators (DOPOs) and degenerate four-wave mixers (DFWMs) and are associated to a pitchfork bifurcation [Taranenko et al. Phys. Rev. Letts. 81, 2236 (1998)]. On the other hand, when the cavity detuning is larger than the squeezing parameter, the pattern consists in a strong and a weak counter-propagating waves (a nearly tilted wave). So in this case the system behaves closer to the standard lasers being the nature of the bifurcation the usual one (Hopf bifurcation).

Wolfgang E. Elsäßser (*Institut fur Angewandte Physik, Darmstadt University of Technology, Germany*)

Quantum Noise Properties of Vertical Cavity Emitting Devices

During the past years, Vertical-Cavity Surface-Emitting Lasers (VCSELs) have attracted increasingly broad interest in both, technological development and commercial applications for data communication and in fundamental physics questions like polarization effects, trans-verse mode behavior or quantum noise. The manifold polarization and multi-transverse mode behavior is one of the most interesting emission properties of Vertical-Cavity Surface-Emitting Lasers (VCSELs) and its understanding and control is a crucial aspect for applications and technological developments.

In this talk we shall present comprehensive and systematic investigations on the quantum optical noise behavior of vertical cavity surface emitting lasers (VCSELs) with various cavity designs and compare the results with those obtained for other types of semiconductor emitter devices, as e.g. edge emitters, or external cavity lasers. We investigate in detail the conditions for the generation of amplitude squeezed light in dependence on the spectral, spatial and polarization mode behavior, with particular emphasis on the correlation properties and including the noise investigations in the vicinity of the polarization switch.

All these our experimental findings with an achieved maximum squeezing of 1.3dB below the shot-noise for a lateral and polarization single mode VCSEL are in extremely good coincidence with the modeling results based on a semi-classical approach for the calculations of the amplitude fluctuations and the correlations. Furthermore, the quantum noise investigations will be extended to resonant-cavity light-emitting diodes (RCLEDs) where also sub-shot noise emission is observed for quiet pumping. However, the additional new feature of the observations of spatial correlations within the emitted light beam represents a new fascinating subject.

Finally, in conclusion, the future trends, the applications and the limitations of these non-classical states of light with respect to metrology applications are discussed.

William Firth (*University of Strathclyde, Glasgow, Scotland, U.K.*)

Optical Patterns and Cavity Solitons

Spontaneous spatial patterns occur in nonlinear optical systems with spatial coupling through diffraction and/or diffusion. Strong enough nonlinearity can induce spatial symmetry breaking, such that a pattern becomes more stable than the unpatterned state. The basic theory and phenomena of pattern formation are reviewed, with examples from experiments and simulations. Patterns usually consist of repeated units, and such units may exist in isolation as localized structures. Such structures are akin to spatial solitons, and are potentially useful in image and/or information processing. Their nature and properties are discussed and illustrated.

Tom Gavrielides (*Nonlinear Optics Center, Air Force Research Laboratory, USA*)

External cavity modes of semiconductor laser with phase-conjugate feedback

External cavity modes of a semiconductor laser with phase conjugate feedback are defined as pulsating intensity solutions exhibiting a frequency close to an integer multiple of the external cavity frequency. As the feedback is increased they appear sequentially as stable attractors in the bifurcation diagram. Analytical approximations to these pulsating intensity solutions are possible and it can be shown that they emerge from limit points. We show that periodic solutions branches connect steady state solutions with the pulsating intensity solutions through Hopf bifurcations. The numerical validity of the approximations is tested by comparison of numerical bifurcation diagrams by simulation and continuation techniques and with the analytical results.

Giovanni Giacomelli (*Istituto Nazionale di Ottica Applicata, Firenze, Italy*)

Experimental Study of Stochastic Phenomena in Vertical Cavity Lasers

The Vertical Cavity Laser allows for detailed experimental investigations of stochastic processes, due to its combination of fast time scales, stability of the setup and the possibility to calibrate the measurement parameters to compare the results with the theory. A review is presented of the results obtained.

G. Agez, E. Louvergneaux, C. Szwaj, M. Taki and **P. Glorieux** (*Laboratoire de Physique des Lasers, Atomes et Molécules, Université de Lille I, Villeneuve d'Ascq, France*)

Noise reveals spatio-temporal dynamics of the Kerr Slice with simple feedback

The Kerr slice with a simple feedback mirror is the reference system for studying pattern formation in non linear optical systems. A series of experiments has been carried out in 1D and 2D geometries to explore the influence of noise on the pattern formation and their dynamics. For instance, the region below threshold appears to reveal precursors that provide several features of the pattern that emerges at threshold. They also show multiwavelength noisy components, phase localization information,… . When the feedback mirror is tilted, noise induces sustained patterns in the convective regime. All the observations are compared quantitatively with the analytical and numerical predictions based on a stochastic model of this system.

Alejando Hnilo (*Citefa, Argentina*)

Kerr lens mode locked lasers as dynamical systems

Kerr lens mode locked (KLM) lasers are the sources of the shortest light pulses nowadays. They can provide pulses shorter than 10-14 s, a few optical cycles. They are useful tools in scientific research and in many applications. However, their dynamical properties are not completely known. Filling this gap is interesting from the academic point of view and it is also important to improve laser designs. Physics of the KLM laser is intrinsically complex, because of the intricate coupling of several spatial and temporal effects. Multistability, period doubling and tripling, chaos, spatio-temporal dynamics and bifurcations affecting some of the pulse variables (what has been called "hidden instabilities") have been theoretically predicted and observed. We will review the basics of KLM description (mainly from the point of view of stroboscopic maps), the most important experimental results, and the questions that still remain to be solved.

Miguel Hoyuelos *(Departamento de Física, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Argentina)*

Patterns in the Vectorial Swift-Hohenberg Equation for Lasers

The consequences of introducing the polarization degree of freedom of the light are studied for the transverse patterns of a laser with detuning equal to zero. We deduce the vectorial Swift-Hohenberg amplitude equation from the corresponding Maxwell-Bloch equations. The vectorial character of the equation introduces modifications in the stability of travelling waves and new types of localized structures.

Deb M. Kane (*Department of Physics, Macquarie University, Sydney, Australia*)

Semiconductor Laser Systems for Optical Frequency Comb and Chaos Generation

Research on semiconductor laser with optical feedback (SLwOF) systems at Macquarie University has had the generation of broad bandwidth optical frequency combs as a key background aim. The potentially accessible bandwidth for such semiconductor laser optical frequency comb generators (SLOFCG) is similar to that of Kerr lens mode-locked laser systems and broad gain bandwidth FM lasers, but with a substantial cost and convenience advantage. Achieving this potential involves identifying and solving a number of problems which arise, in this context, from the basic differences of semiconductor lasers to most other lasers - such as large refractive index; small volume, waveguide resonator; enhanced spontaneous emission; large linewidth enhancement factor and the complex nonlinear dynamics that can and do occur in the coupled cavity systems, even with very weak coupling.

This talk will chart some of the results of experimental investigations we have completed including frequency modulated optical feedback, frequency shifted optical feedback, the frequency noise of SLwOF systems, SLs subject to both OF and optical injection (OI), SLs with spatially modified OF, and SLs with phase conjugate feedback and integrated device designs. The results will be presented in the context of how they impact on realising SLOFCGs but also for the new prospects for practically significant chaotic semiconductor laser designs they suggest.

A. Amon, P. Suret, M. Nizette, S. Bielawski, D. Derozier, J. Zemmouri, T. Erneux, and **M. Lefranc** (*Laboratoire de Physique des Lasers, Atomes, Molécules, Université des Sciences et Technologies de Lille, Villeneuve d'Ascq, France*)

Instabilities and chaos in an optical parametric oscillator

As lasers, optical parametric oscillators are nonlinear optical devices and thus are susceptible to instabilities and chaos. However, their dynamics has so far been relatively little studied: although periodic and chaotic behaviors were predicted some time ago to occur in triply resonant continuous-wave OPOs, it is only recently that experimental self-pulsing regimes have been reported. In recent work, we have observed and described instability mechanisms leading to periodic behavior as well to more complex regimes, including bursting oscillations and chaos.

Small perturbations such as thermal effects are often neglected under the assumption that they do not modify qualitatively the dynamics. However, this assumption does not hold in the presence of singularities, which can dramatically amplify small fluctuations. In particular, a periodic instability observed in an triply resonant OPO at frequencies of a few kHz has been traced back to slow variations of the crystal temperature. The mechanism responsible for this instability is remarkable in that (i) small fluctuations of the crystal temperature (around 10 mK) can result in a 100% modulation of the output intensity, (ii) it depends only on signal absorption, which can be as low as 0.1%/cm. As in the classical Van der Pol oscillator and other singularly perturbed systems, this mechanism is based on the oscillation of a slow variable (temperature) around the bistability cycle of a fast variable (the output intensity). A similar mechanism can also lead to a periodic alternation between different longitudinal modes.

Besides these thermo-optical instabilities, fast oscillations have also been observed at frequencies ranging from 1 to 300 MHz. We have recently shown that these oscillations stem from the interaction of two transverse modes. A perturbative analysis of a simple model unveils a surprising feature : these bimode regimes are in first approximation equivalent to a weakly detuned monomode regime whose properties do not depend on the separation between the optical frequencies of the two modes.

When these fast oscillations interact with the opto-thermal instabilities discussed previously, a large variety of bursting oscillations can be observed, with periodic or aperiodic fast oscillations. A theoretical analysis of these regimes shows that they can be simply described in terms of a phase plane analysis, contrary to most other examples of bursting regimes in optics.

Finally, we present the first evidence of deterministic chaos in an optical parametric oscillator. Remarkably, it has been obtained under conditions where the OPO is not stationary due to thermal drifts, and from a time series that displays irregular behavior only for a few dozens of cycles. The chaotic signature is provided by two very short time series segments containing unstable periodic orbits whose knot types can only exist in a chaotic system.

Daan Lenstra, Mirvais Yousefi, Gautam Vemuri, and Sebastian Wieczorek (*Dept. of Physics and Astronomy, Vrije Universiteit Amsterdam*)

Dynamics and Noise in Semiconductor Lasers: a complex marriage

Semiconductor diode lasers have proven to be a very useful tool for studying nonlinear dynamics, chaos and bifurcations, not the least because of their good experimental accessibility. These lasers have also found wide applications and can be considered as a first generation of optoelectronic nano-devices. All this may explain why nonlinear dynamics in semiconductor lasers has become such a booming topic.

This talk will first review some essential notions and recent developments of nonlinear dynamics of diode lasers and discuss the relevance of the omnipresent noise. The remarkable and surprising role of spontaneous recombination noise, being of microscopic origin, in the (macroscopic) dynamics of the laser will be discussed on the basis of results obtained from simulation studies. Finally, we will review our recent work on noise-driven multi-pulse excitability in an optically injected semiconductor laser and on multi-longitudinal mode diode lasers.

Arturo Lezama (*Instituto de Física, Facultad de Ingeniería, Montevideo, Uruguay*)

Noise atomic spectroscopy

The noise properties of a light field are modified if the light resonantly interacts with an atomic medium. After the interaction, the noise statistics carries information on the atomic dynamics and can be used for spectroscopic purposes. In this talk we review some results on atomic noise spectroscopy and present recent advances in noise detection of nonlinear magneto-optical effects.

Jia-Ming Liu (*Electrical Engineering Department, University of California, Los Angeles, U.S.A.*)

Synchronizing semiconductor laser chaos for optical communications

Nonlinear dynamics including chaos has been studied in many different semiconductor laser systems. Chaos synchronization has also been achieved in such systems. Semiconductor laser systems are of particular interest for chaotic optical communications at high bit rates because of their capability of generating and synchronizing fast chaotic waveforms. In a synchronized chaotic optical communication system, a transmitter semiconductor laser generates a chaotic optical waveform and an identical semiconductor laser chaos generator at the receiver end regenerates the chaotic optical waveform. The message to be transmitted is encoded in the time domain on the chaotic optical waveform through a certain chaotic encryption scheme. Message decoding is accomplished by comparing the received signal with this reproduced chaotic waveform. In this talk, I will review the dynamics and chaos synchronization of different semiconductor laser systems. Message encoding and decoding schemes for chaotic optical communications using such chaotic semiconductor lasers will be discussed. The basic issues regarding synchronized chaotic optical communications at high bit rates will be addressed. Recent experimental results will be presented.

Alexandre Locquet (*Georgia Tech Lorraine and Université de Franche-Comté, France*)

Time series analysis of chaotic laser dynamics

We perform a nonlinear analysis of the time series produced by chaotic semiconductor lasers subject to optoelectronic delayed feedback. We show how it is possible to recover the nonlinear function, the delay time, and the chaos dimension from experimental time series.

Luigi Lugiato (*Dipartimento di Scienze Chimiche, Fisiche e Matematiche, Università degli Studi dell'Insubria, Italy*)

Cavity Solitons and all that

We focus on cavity solitons in broad-area VCSELs driven by a coherent holding beam. We will discuss especially 1) The spontaneous motion of cavity solitons induced by the slow thermal dynamics, how one can control this motion and how, instead, chaotic motion can arise. 2) The possibility of generating and manipulating cavity solitons above the VCSEL threshold.

Carlos Martel (*Universidad Politécnica de Madrid, Spain*)

Material dispersion induced dynamics in light propagation in fiber gratings

The dynamics of nonlinear light propagation in periodic media (fiber grating) is typically described using the nonlinear coupled mode equations (NLCME) that represent the nonlinear interaction of two slowly modulated electromagnetic wave trains that propagate (backward and forward) along the fiber and are reflected by the grating. The NLCME formulation does not take into account the effect of the (always present) material dispersion. I will discuss in this talk the effect of adding small dispersion terms to the NLCME, and I will show how these small terms cannot be neglected because they produce new spatio-temporal complex states that are not captured by the NLCME.

Cristina Masoller (*Instituto de Física, Facultad de Ciencias, Universidad de la Republica, Montevideo, Uruguay*)

Effect of noise in semiconductor lasers with time-delayed feedback

I will discuss theoretical and experimental studies of the effect of noise on semiconductor lasers subjected to time-delayed optical or opto-electronic feedback. I will consider both, edge-emitting and vertical-cavity surface-emitting lasers (VCSELs).

Single-longitudinal-mode lasers with weak optical feedback are multistable devices because the external cavity introduces a series of new modes, the so-called external-cavity modes (ECMs). Under the influence of spontaneous emission noise there is *stochastic external-cavity mode hopping*. I will present numerical results that show that the time-delayed optical feedback has a strong influence on the statistics of the stochastic mode hopping. I will show that the probability of residence times in an ECM exhibits a structure of peaks at multiples of the external-cavity delay time. The strength of the peaks reaches a maximum for an optimal level of noise, a phenomenon resembling stochastic resonance.

I will also discuss the phenomenon of *stochastic polarization switching* in VCSELs. Close to threshold VCSELs usually emit linearly polarised light along one of two orthogonal directions associated with crystalline or stress orientations. As the injection current is increased, in many devices the polarization switches to the orthogonal state, and there is a region of injection currents where both polarizations coexist and noise induces stochastic polarization switching. It has been shown theoretically and experimentally that stochastic polarization switching agrees well with Kramer's law of noise-induced switching in a bistable potential: the probability of residence time in a polarization state decays exponentially. When the VCSEL is subjected to weak optical feedback the probability of residence times also decays exponentially, but exhibits a sharp discontinuity for residence times close to the external-cavity delay time. The numerical results agree well with analytic results based on a simple model of a noisy bistable system with a time-delayed feedback mechanism. Finally, I will present experimental results that give a confirmation of the theory, based on a VCSEL subjected to opto-electronic feedback.

Jerome V. Moloney (*Arizona Center for Mathematical Sciences and Optical Sciences Center, University of Arizona, Tucson, USA*)

Optically turbulent terawatt femtosecond atmospheric light strings

Multi-TW 50–100 fs duration laser pulses have been shown to propagate anomalously long distances in air[1]. A highly dynamic nonlinear waveguide, formed through competition between nonlinear self-focusing and plasma induced defocusing[2,3], causes recurrent bursts of intensity within and across the pulse. Each intensity spike is accompanied by explosive white-light supercontinuum and plasma generation. Plasma channels, left in the wake of each intense focused spot within the optical pulse, subsequently recombine and emit a strong, highly transient, burst of RF/Microwave radiation[4]. In principle, TW fs pulses contain many hundreds of critical powers for selffocusing collapse (critical power in air is 3-4 GW). One could imagine a scenario where many hundreds of chaotically collapsing light filaments would consume most of the power in the propagating pulse. This is not the case however. Instead, about 80% of the pulse power remains within a long wavelength background, with the latter acting as an energy reservoir for feeding filaments.

This talk will highlight recent advances in developing physically self-consistent and mathematically rigorous models of light string propagation in air[5]. The collapse singularity of the higher dimensional Nonlinear Schrödinger (NLS) equation forms the robust nonlinear persistent mode that is continually fed from the lower intensity, long wavelength background. This long wavelength background "mode" plays a central role in sustaining the propagating dynamic fs waveguide. Although, the 3D+time NLS equation provides a reliable qualitative picture of the light string propagation phenomenon, it fails to accurately capture the extremely broad spectral features that develop during individual collapses.

In particular, we will discuss the role of optical turbulence as a mechanism for initiating and sustaining the pulse over kilometer distances. Group velocity dispersion is not an important player for fs pulse propagation in air. However, it plays a prominent role in high-power fs pulse trapping in condensed matter. As an example of the latter, we will introduce a novel nonlinear fs dynamic X-wave mode[6] that supports recent experimental observations of anomalously long waveguide propagation in water[7]. Potential applications of this phenomenon to atmospheric remote sensing, laser guide stars, penetration through obscurants etc will also be discussed. We have shown that the recent experimental observation of light filament penetration though opaque obscurants[8] can be explained in terms on nonlinear replenishment of the destroyed light filament by the long wavelength background reservoir[9].

1. J. Kasparian et al, “White-Light Filamenst from Atmospheric Analysis”, *Science,* **301,** 61 (2003).
2. M. Mlejnek, E.M. Wright and J.V. Moloney, “Dynamic spatial replenishment of femtosecond pulse propagating in air”, Opt. Letts., **23**, 382 (1998).
3. M. Mlejnek, M. Kolesik, J.V. Moloney and E.M. Wright, “Optically turbulent femtosecond light guide in air”, Phys. Rev. Letts., **83**, 2938 (1999).
4. C.C. Cheng, E.M. Wright and J.V. Moloney, “Generation of electromagnetic pulses plasma channels induced by femtosecond lights trsings”, Phys. Rev. Letts., **87**, 1 (2001).
5. M. Kolesik and J.V. Moloney, “Unidirectional pulse propagation equation”, Phys. Rev. Letts., **89**, 2839021 (2002).
6. M. Kolesik, E.M. Wright and J.V. Moloney, “Dynamic nonlinear X-waves for femtosecond pulse propagation in water” , Phys. Rev. Letts., (submitted) (2003).
7. A. Dubietis et al, “Self-guided propagation of femtosecond light pulses in water”, Opt. Letts., **28**, 1269 (2003)
8. F. Courvoisier et al, “Ultraintense light filaments transmitted through clouds”, Appl. Phys. Letts., **83**, 213 (2003)
9. M. Kolesik and J.V. Moloney, “Self-healing femtosecond light filaments”, Opt. Letts., (in press) (2003).

Carlos Montes and Antonio Picozzi (*Laboratoire de Physique de la Matiere Condensee, Universite de Nice - Sophia Antipolis, France*)

Coherent Optical Parametric Oscillator Driven from an Incoherent Pump

Nondegenerate three-wave interaction in the backward Optical Parametric Oscillator (OPO) driven from an incoherent pump generates coherent signal through the convection-induced phase-locking mechanism.

Mario Natiello (*Centre for Mathematical Sciences, Lund University, Sweden*)

Laser with Injected Signal: An overview

We discuss a series of approximations with increasing complexity to the problem of Laser with Injected Signal.

Ulrich Parlitz (*Drittes Physikalisches Institut, Universitaet Goettingen, Germany*)

Chaos and synchronization in laser systems

In the first part of the talk we give a brief review of different synchronization phenomena in chaotic systems. Then experimental and numerical results for synchronizing semiconductor lasers are presented. Furthermore, we shall discuss the issue of time series analysis and modeling of complex laser dynamics.

Antonio Politi (*Istituto Nazionale di Ottica Applicata, Firenze, Italy*)

Recoil induced lasing action

At low temperature, a correct description of the interaction between atoms and electromagnetic fields must account for atomic recoil as well. This effect is so important that is indeed a means to slow down atoms. Besides its direct mechanical consequences, recoil may play a crucial role also in the (back)propagation of a coherent field, mediated by the spontaneous formation of a density grating (this is the so-called Collective Atomic Recoil Laser - CARL). In the past limitations of the initially proposed model allowed only investigations of the transient regime. Here I show that, after including the interaction with of an effective thermal bath, a stationary CARL action can be generated and that its onset occurs thorugh a continuous nonequilibrium phase-transition. Moreover, I discuss: (i) connections with the synchronization transition occurring in the Kuramoto model; (ii) a comparison with recent experimental results; (iii) similarities and differences with another phase-transition corresponding to the onset of a polarization grating.

Jhon F Martinez, Hugo L D de S Cavalcante and **J R Rios Leite** (*Universidad Federal de Pernambuco*)

Chaotic Diode Lasers with Low Frequency Fluctuations: Statistics of Pulses and Synchronism

The statistics of power drops in a diode laser, chaotic by optical feedback, was obtained as function of pump current. The experimental results were compared to the numerical integration of Lang-Kobayashi equations. These equations have also been integrated for two laser coupled by light intensity and their partial synchronism in chaos will be described.

K. Alan Shore, M. W. Lee, Y. Hong, J. Paul, R. Ju, I. Pierce, P. S. Spencer, P. Rees and S. Sivaprakasam (*University of Wales, Bangor, UK*)

Synchronization of chaotic external cavity laser diodes for secure optical communication networks

Synchronisation of chaotic lasers is an attractive field of study for researchers with interests ranging from fundamental non-linear dynamics through to applications and, in particular, secure optical communications. The talk will focus on the use of chaotic external cavity laser diodes for implementing secure optical communication networks.

In the talk, attention will be given to both experimental and theoretical aspects of the development of chaotic transmitter/receiver configurations for message transmission and recovery. Some emphasis will be placed on the use of edge-emitting laser diodes in such configurations but opportunities for the use of VCSELs will also be identified. The talk will address the key requirements for successful demonstration of message transmission using a chaotic carrier and will examine means for enhancing system performance through multiplexed message transmission and chaos broadcasting. Some consideration will be given to both the quality of message recovery achievable in such systems and the security of message transmission. Prospects for practical deployment of chaotic communications will be briefly addressed.

Ramon Vilaseca, M.C. Torrent, C. Serrat, J. Garcia-Ojalvo, M. Brambilla, R. Corbalán, V. Ahufinger, and J. Mompart (*Departament de Física i Enginyeria Nuclear, Universitat Politècnica de Catalunya, Spain*)

Cavity solitons in class-C lasers

We review and present new results about the generation of cavity solitons in lasers. Class-C lasers will be considered, in several light-atom interaction configurations. Attention will be focused on two-photon solitons, where the properties of the localized structures will be described in detail, and on lasers with dense media, where local effects play a crucial role for cavity soliton formation. Possibilities of generation of cavity solitons in other classes of lasers will be pointed out.

Immo Wedekind *(III. Physikalisches Institut Universitaet Goettingen, Germany)*

Synchronization of external cavity semiconductor lasers

Experimental observations of synchronization and anti-synchronization of low-frequency power drop-outs and jump-ups of chaotic semiconductor lasers are presented. With an extended version of the well known Lang-Kobayashi model equations it is possible to simulate the synchronization and antisynchronization of power drop-outs and power jump-ups numerically.

POSTERS

Italo Bove (*Instituto de Física, Facultad de Ingeniera, Montevideo, Uruguay*)

Phase synchronization of non-autonomous chaotic oscillators

We give evidence of phase synchronization between two coupled chaotic self sustained non-autonomous oscillators. At variance with the autonomous case, the phenomenon is here characterized by the vanishing of a previously positive Lyapunov exponent in the spectrum, which takes place for a broad range of the coupling strength parameter. Such a novel state is studied also for the case of chaotic oscillators with ill-defined phases due to the absence of a unique center of rotation. Different phase synchronization indicators are used to circumvent this difficulty.

Eduardo Cabrera Granado (*Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Spain*)

It is well known that the presence of a small amount of inhomogeneous broadening in the gain profile of a laser introduces important qualitative changes in the temporal dynamics of the output intensity [Idiatulin and Uspenskii, Radiotek. Elektron. 18, 580 (1973)]. One of the main features of this system is the lowering of the instability threshold. This allows more feasible gain levels to see chaotic behaviour. We extend the previous works analyzing the spatiotemporal dynamics of a broad transverse pattern arised at the first laser threshold. The semiclassical two-level Maxwell-Bloch equations are used and a single longitudinal mode is assumed. It is found that the competition of different frequency groups implies a weaker selection of a dominant size in the structures of the pattern compared with the homogeneuos case. We develop numerical simulations of the evolution of the pattern for the cases of good and bad cavity configurations, using a simplified model of 5 groups of atoms at different resonant frequencies. This model allows us to integrate the set of equations maintaining the main features of the physical system.

Adrián Jacobo (*Departamento de Física, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Argentina*)

Characterization of defects in the Vector Complex Ginzburg-Landau Equation

The VCGLE has been used as a model for, for example, transverse laser patterns or Bose-Einstein condensation. Phase singularities, or defects, in the VCGLE play an important role in determining the dynamics of the system. For example, different kinds of defects can compete to impose a determined frequency in the whole system. It is, therefore, interesting to classify the defects that can be present in the VCGLE. We also study how the size of the defect changes as a coupling parameter is modified.

Jon Paul and K. Alan Shore (*School of informatics, University of Wales, Bangor, UK*)

Wavelength division multiplexing of external-cavity chaotic semiconductor lasers

We experimentally demonstrate that two chaotic optical secure communication channels can be configured over a single transmission path using two external-cavity laser diodes as transmitter lasers, and a single receiver laser which is a solitary laser (subjected only to optical injection from the transmitter lasers). Each channel can be driven to chaos and independently synchronised. Two megahertz messages of different frequencies, encoded in the bias current of the transmitter lasers, can be masked by the chaos, transmitted through each channel and recovered at the receiver laser by the use of a fourth, decoder laser. The decoder laser is necessary to select which message is decoded. We show that there is good message recovery with little crosstalk between the two channels. Since the channels are separated in wavelength, they constitute a wavelength division multiplexing scheme.

Min Won Lee, **Jon Paul** and K. Alan Shore (*School of Informatics, University of Wales, Bangor, UK*)

Chaotic message broadcasting using DFB laser diodes

Chaotic message broadcasting has been demonstrated using an external-cavity transmitter DFB laser diode and two stand-alone receiver DFB laser diodes. An encoded 1 GHz message has been successfully broadcasted and decoded with 14 dB signal-to-noise ratio.

Laura Sanchez and Alejandro Hnilo (Ceilap, Citefa, Argentina)

Kerr lens mode-locking dynamics

Many short pulse lasers are based on the so called Kerr lens mode locking effect (KLM). A description of KLM is possible in terms of a five variables iterative map. For usual values of the laser parameters, the complete map can be simplified to two maps with complex variables and one map with a real variable, which become uncoupled after a transient has evolved. After appropriate scaling, the two complex maps have the same form, and can be thought as a perturbed isometry in the hyperbolic plane. In spite of the maps' simplicity, their asymptotic solutions are found to depend not only on the values of the parameters, but also on the initial conditions, what gives rise to intricate dynamics. In particular, the space spanned by the map's iterations can expand or contract as well depending of the initial conditions. If there is a contraction the KLM solution arises, even in the absence of spatial apertures or bandwidth limitations. Hence, the Kerr perturbation modifies the system from non-dissipative to dissipative. The border between the initial conditions leading to expansion and contraction is numerically found to show a self-similar geometry, which fades out if apertures are present in the corresponding laser cavity. In parameter's space, the periodic solutions accumulate near the solutions corresponding to orbits of the unperturbed (i.e., without the Kerr term) map. The stable solutions for varying parameters are also drawn, displaying an astonishingly complicate diagram of bifurcations.

Osvaldo A. Rosso, Luciano Zunino, Dario G. Perez and Mario Garavaglia (*Instituto de Calculo, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina*)

Characterization of laser propagation through turbulent media by quantifiers based on the Wavelet Transform

The propagation of a laser beam through turbulent media is modelled as a fractional Brownian motion (fBm). Time series corresponding to the centre position of the laser spot (coordinates *x* and *y*) after travelling across air in turbulent motion, with different strength, are analyzed by the wavelet theory. Two quantifiers are calculated, the Hurst exponent, H, and the mean Normalized Total Wavelet Entropy, S_{WT}. It is verified that both quantifiers gives complementary information about the turbulence state.

A comparison between average Hurst exponent and mean NTWS are presented. It is known the entropy is a measure of the order of a given system. In this case, the mean NTWS shows the same behavior for both coordinates. As the turbulence increases the mean NTWS do the same. But, the Hust exponent discriminates between the coordinates: for the *x*-axis no noticeable change is observed, and for the *y*-axis the Hurst exponent decreases (increasing the roughness) with the increasing turbulence. Thus, it is observed that the Hurst exponent is sensitive to the mean flow of the hot air. It distinguishes the anisotropy characteristic of the convective turbulence. Because the entropy measures the order obviously it does not detect the mean flow. In any case, the value of the obtained quantities indicates those memories as well as self-similarity and scale invariance are significant properties of these time series.

In relation with the Hurst exponent a useful generalization consists in allowing the singularity exponent to become time-dependent $H(t)$. Provided that variations of $H(t)$ are smooth enough, the time series can be divided in time windows where this requirement is satisfied and for each one the similar techniques based on time-scale energy distributions can be applied locally. In any case, we must to emphasize that for each one a scaling region must be defined. The time evolution of NTWS could be easily implemented. Moreover, the NTWS is capable of detecting changes in a nonstationary signal due to the localization characteristic of the wavelet transform, the computational time is significantly shorter since the algorithm involves the use of wavelet transform in a multiresolution framework and, the NTWS is parameter-free and not scaling region are necessary for its evaluation.

LIST OF PARTICIPANTS

Italo Bove
Instituto de Física, Facultad de Ingeniería
Montevideo, Uruguay
Email: italo@fing.edu.uy

Eduardo Cabrera Granado
Dpto. Optica, Facultad de Ciencias Físicas, UCM,
c/ Ciudad Universitaria,
28040 Madrid, Spain
Tel: 34 91 394 4508
Fax: 34 91 394 4683
Email: ecabrera@fis.ucm.es

Oscar G. Calderon
Dpto. Óptica, Facultad de Ciencias Físicas, UCM,
c/ Ciudad Universitaria,
28040 Madrid, Spain
Tel: 34 91 394 4508

Fax: 34 91 394 4683
Email: oscargc@opt.ucm.es

Wolfgang E. Elsäßser
Institut fur Angewandte Physik
Darmstadt University of Technology
Schlossgartenstr. 7,
D-64289 Darmstadt, Germany
Tel: 49 6151-16-6463
Fax: 49 6151-16-3022
Email: elsaesser@physik.tu-darmstadt.de

William Firth
University of Strathclyde,
Glasgow, Scotland, U.K.
Email: willie@phys.strath.ac.uk

A. Gavrielides
AFRL/DELO
3550 Aberdeen Avenue SE
Kirtland AFB, NM 87117, USA
Email: tom@ouzo.plk.af.mil

Giovanni Giacomelli
Istituto Nazionale di Ottica Applicata (INOA)
Via G. Sansone 1,
50019 Sesto Fiorentino (Firenze) - ITALY
Tel: 39 055 457 2007
Fax: 39 055 457 2139
Email: giacomelli@inoa.it

Pierre Glorieux
Laboratoire de Physique des Lasers, Atomes et Molécules
Université de Lille 1
Bat. P5; B.P. 36, 59655 Villeneuve d'Ascq, France
Tel: 3 20 43 49 99
Fax: 3 20 33 70 20
Email: pierre.glorieux@univ-lille1.fr

Alejando Hnilo
Citefa, Argentina
Email: ahnilo@citefa.gov.ar

Miguel Hoyuelos
Dep. de Física, FCEyN UNMdP, Funes 3350,
7600 Mar del Plata, Argentina
Tel: 54-223-4756951
Fax: 54-223-4753150
Email: hoyuelos@mdp.edu.ar

Adrián Jacobo
Dep. de Física, FCEyN UNMdP,
Funes 3350,
7600 Mar del Plata, Argentina
Tel: 54-223-4756951
Fax: 54-223-4753150
Email: adrian@gamebox.net

Deb Kane
Dept. of Physics, Macquarie University
Sydney NSW 2109, Australia
Tel: 61(0)2 9850 8907
Fax: 61(0)2 9850 8115
Email: debkane@ics.mq.edu.au

Marc Lefranc
Laboratoire de Physique des Lasers, Atomes, Molécules
Bat P5, UFR de Physique
Université des Sciences et Technologies de Lille
F-59655 Villeneuve d'Ascq CEDEX (FRANCE)
Tel: 33 (0)3 20 33 64 50
Fax: 33 (0)3 20 33 70 20
Email: Marc.Lefranc@univ-lille1.fr

Daan Lenstra
Dept. of Physics and Astronomy,
Vrije Universiteit Amsterdam,
De Boelelaan 1081, 1081 HV Amsterdam,
The Netherlands
Email: daanlenstra@planet.nl

Arturo Lezama
Instituto de Física,
Facultad de Ingenieria
J. Herrera y Reissig 565
Montevideo, Uruguay
Email: alezama@fing.edu.uy

Jia-Ming Liu
Electrical Engineering Department
University of California, Los Angeles
Los Angeles, CA 90095, U.S.A.
Email: liu@ee.ucla.edu

Alexandre Locquet
GTL-CNRS Telecom
2-3 rue Marconi
57070 Metz, FRANCE
Tel: 33 387 203935
Fax: 33 387 203940

Email: alocquet@georgiatech-metz.fr

Luigi Lugiato
Dipartimento di Scienze
Via Valleggio 11
22100 Como, Italy
Tel: 39-031-2386213
Fax: 39-031-2386209 or 2386119
Email: luigi.lugiato@uninsubria.it

Cristina Masoller
Instituto de Fisica
Facultad de Ciencias
Igua 4225, Montevideo 11400, Uruguay
Tel: 5982-5258618
Fax: 5982-5250580
Email: cris@fisica.edu.uy

Carlos Martel
Depto. Fundamentos Matemáticos, E.T.S.I. Aeronáuticos
Universidad Politécnica de Madrid
Plaza Cardenal Cisneros, 3
28040 Madrid. SPAIN
Tel: 34 91 336 32 88
Fax: 34 91 336 63 07
Email: martel@fmetsia.upm.es

Jerome V. Moloney
University of Arizona
Tucson, AZ 85721, USA
Tel: (520)-621-6755
Fax: (520)-621-1510
Email: jml@acms.arizona.edu

Carlos Montes
C.N.R.S. Laboratoire de Physique de la Matiere Condensee
Universite de Nice-Sophia Antipolis
Parc Valrose. F-06108 NICE Cedex 2. FRANCE
Tel: 33 4 92 07 67 76
Fax:33 4 92 07 67 54
Email: Carlos.Montes@unice.fr

Mario Natiello
Centre for Mathematical Sciences, Lund University
Box 118, S-221 00 LUND, SWEDEN
Tel: 46-46-2220919
Fax: 46-46-2224010
Email: Mario.Natiello@math.lth.se

Ulrich Parlitz

Buergerstr. 42-44, 37073 Goettingen, Germany
Tel: 49 - 551 - 397716
Fax: 49 - 551 - 397720
Email: parlitz@physik3.gwdg.de

Jonathan Paul
University of Wales, Bangor, School of informatics,
Dean Street, Bangor, LL57 1UT, Wales, UK
Tel: 441248-382618,
Fax: +441248361429
Email: jpaul@informatics.bangor.ac.uk

Antonio Politi
Istituto Nazionale di Ottica Applicata
Largo E. Fermi 6
I-50125 Firenze - ITALY
Tel: 39 055 2308227
Fax: 39 055 2337755
Email: politi@ino.it

J. R. Rios Leite
Physics Department, Universidade Federal de Pernambuco
50670-901 Recife PE, Brasil
Tel: 55-81-32718450
Fax: 55-81-32710359
Email : rios@df.ufpe.br

O. A. Rosso
Instituto de Calculo,
Facultad de Ciencias Exactas y Naturales,
Universidad de Buenos Aires.
Pabellon II, Ciudad Universitaria.
1428 Ciudad de Buenos Aires, Argentina.
Email: rosso@ba.net

Laura Sanchez
Juan Bautista de La Salle 4397,
1603 Villa Martelli, Argentina
Tel : 54-11-4709-8100 Ext.1205
Fax: 54-11-4709-8217
Email: Lsanchez@citefa.gov.ar

K. A. Shore
University of Wales, Bangor, School of Informatics
Dean Street, Bangor,
LL571UT, Wales, UK
Email: alan@informatics.bangor.ac.uk

Hernan Solari
Fac. Cs. Exactas y Naturales - UBA

Pabellón I, Ciudad Universitaria
1428 Buenos Aires, Argentina
Email: solari@df.uba.ar

Jorge Tredicce
Institut Non Linéaire de Nice, France
Tel: 33 4 92 96 73 55
Fax: 33 4 93 65 25 17
Email: jorge.tredicce@inln.cnrs.fr

Ramon Vilaseca
Universitat Politècnica de Catalunya
Campus Nord – Edifici B4, 2a planta
c/ Sor Eulalia d'Anzizu, s/n
08034 Barcelona, Spain
Tel: 34 93 401 6970
Fax: 34 93 401 7100
Email: ramon.vilaseca@upc.es

Immo Wedekind
Buergerstr. 42-44, 37073 Goettingen, Germany
Tel: 49 551 397723
Fax: 49 551 397720
Email: wedekind@physik3.gwdg.de