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Editorial

Editorial on Dissipative Optical Solitons

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The fundamental mechanism that defines the concept of an optical soliton is the exact balance between two opposite mechanisms, one allowing for the spreading, the other for the concentration of a localized distribution of light. Historically, this was found in conservative systems and can be described by the nonlinear Shrödinger equation and other related equations. This situation applies both to the case of temporal solitons where group velocity dispersion and self-phase modulation counteract one another in the longitudinal dimension of light propagation and to the case of spatial solitons where diffraction spreading and Kerr lensing compensate, leading to a stable distribution of light with a constant beam waist.

Solitons have been known as an experimental evidence since the early observation by John Scott Russel of a water solitary wave in 1844. The study of temporal optical solitons more than a century later has benefited from the very rapid development during the 70's of optical fiber performance whose residual Kerr effect could be used to propagate short intense pulses across distances that can reach now thousands of kilometers.

From the 1990's a new branch of soliton studies has developed in dissipative optical systems defined as lossy systems fed with an external input of energy. Therein, it has been progressively shown through the pioneering theoretical work of Lugiato and Lefever [1], Rosanov [2], Mandel [3], and Firth [4] that nonlinear optical cavities or feedback systems can reach various levels of self-organization among which patterned and localized bistable states are expected. These predictions were rapidly confirmed by their observation in various systems including liquid crystal light valves [5], sodium vapors [6], photorefractive materials [7], and most recently semiconductors [8,9].

These localized states, when exhibiting bistability, were called *cavity solitons* and appeared to display new properties. The term "soliton", though not strictly matching the requirement of being an exact solution of a conservative non linear propagation equation, conveys however the concept that an equilibrium is reached between counteracting mechanisms, one of them at least being nonlinear. Indeed, in addition to obtaining fundamental advances in our knowledge on light-matter interaction and in the determination of new types of states, cavity solitons suggest quite novel functional properties in all-optical processing of information such as spatial information encoding, manipulation and reconfiguration based on the transverse distribution of light (see [10] for a complete review of dissipative optical solitons in photonic devices).

These aspects have been explored within two successive European FET-STREP projects. The first entitled "processing of information by arrays of nonlinear optical solitons" (PIANOS) took place between 1998 and 2002 and was devoted to an experimental demonstration of cavity solitons in semiconductor systems. The second, conducted between 2005 and 2008 and entitled "fundamentals, functionalities and applications of cavity solitons" (FunFACS [11]) led to the observation of cw cavity soliton lasers and pulsed localized states in semiconductor lasers.

This special issue of EPJD on *Dissipative Optical Solitons* is a consequence of an initiative taken within this consortium. It intends to establish, beyond the composition of FunFACS, the present state-of-the-art on this topic by gathering contributions from the whole community and to some extent is complementary to the previous EPJ-ST special issue on *Solitons in Nonlinear Optics* published in June 2009.

The first section is dedicated to theoretical developments based around the nonlinear equations for generic dissipative systems. It features two invited articles by two renowned experts that have contributed by their pioneering work to the progresses in the field. The first invited article from Prof. N. Rosanov and co-workers introduces the analysis of a linear chain of molecules and demonstrates the existence of soliton structures at the nanometer scale. Prof. W. Firth and his collaborators in the other invited article consider a very general configuration comprising a linear resonant filtering process as a mechanism of stabilization of cavity solitons in a third order Ginzburg-Landau equation. The third article by Gelens et al. analyzes the complex Swift-Hohenberg equation model for lasers and oscillators which is shown to lead in some parametric regions to a description in terms of the derived Cahn-Hilliard equation. The effect of noise on the

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excitable character of dissipative solitons is considered by Jacobo et al. in the fourth article. Finally, Clerc et al. focus on the possibility of controlling and managing a 2D system driven by injected patterns under noise conditions through a mechanism of coherence resonance.

The second section contains a single article dedicated to providing a technological answer to the critical problem of the uniformity of excitation in a large area vertical cavity semiconductor emitting laser (VCSEL) with electrical pumping. The approach developed in this article by Camps et al. marks a qualitative breakthrough in the actual implementation of theoretical concepts in real devices.

The third section contains several theoretical contributions that address the specific properties of cavity solitons that give them one of their peculiar characteristics: their mobility and their pinning by defects. Two articles, by Tlidi et al. and Panajotov et al., determine the mechanisms by which a delayed feedback induces the movement of cavity solitons in the transverse plane of an extended resonator, whereas Prati et al. study the interaction of cavity soliton motion with spatial boundaries in a semiconductor laser with a saturable absorber. Opposite to movements, the pinning of optical solitons to an arbitrary location by the use of local perturbations called hot spots is studied theoretically by Chow et al. The symmetry of these modes is questioned in relation with that of their stability.

The last two sections consider particular experimental configurations differing in the mechanisms by which competition that leads to bistability is introduced into the systems: the presence of saturable absorption or optical feedback. The first approach, reported in the fourth section by Elsass et al., consists of a compact monolithic implementation of a two-section laser system with saturable absorber, leading to the demonstration of cw laser CS and self-pulsing localized states. The second configuration uses two face-to-face VSCELs in a self-imaging configuration, respectively as an amplifier and as a saturable absorber. Genevet, Columbo et al. consider its theoretical spatio-temporal response and demonstrate the existence of left or right handed vortices. Genevet, Turconi et al., in an experimental paper, address the question of mutual coherence of single or multiple peaked solitons in such a system where no phase reference is introduced across the transverse dimension. In the last theoretical article, Columbo et al. consider long cavities with both gain and saturable absorber sections where they demonstrate the existence of cavity light bullets, i.e. cavity solitons having a non linear confinement in the three dimensions.

In the last section, different mechanisms of bistable competition are studied either through light injection or through partial re-injection of frequency filtered light into the gain medium. The latter system is implemented in the article by Radwell et al., where the spectral element is an external grating. The mechanisms by which solitons switch on and off are analyzed and the correlations between their spectral composition and spatial position with respect to the writing location are established. In the article by Ayoub et al., experimental and numerical evidence of symmetry-breakiarticleng bifurcations of a circular dissipative soliton with additional boundary conditions in the feedback of a liquid crystal light valve are described. Finally, in the paper by Prati et al., the dynamical instabilities affecting a VCSEL with injected signal are addressed and some applications of gradient-induced soliton motion are shown, such as an ultra-fast delay line obtained by tuning the injected frequency.

In addition to reviewing some of the work that has been developed within the FunFACS project, this special issue brings together a collection of theoretical and experimental results that will undoubtedly assist younger researchers willing to step into this expanding branch of physics. It will also provide specialists with a comprehensive overview of the state-of-the-art in this field. We also hope that our increasing theoretical understanding of the problems that has been gained in the last decade coupled with the development of experimental studies will pave the way for their application, especially in the frame of all-optical information processing.

Moreover, we hope the reader will appreciate the quality of the physics contained in this special issue as much as we enjoyed collating this volume.

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