Talk Titles and Abstracts
Nonlinear Guides Waves IX, Grantown-on-Spey, Highlands, Scotland, U.K.
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Gaetano Assanto,
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Nematicon enhanced random lasing in reorientational liquid crystals

Exploiting spatial optical solitons and their guiding properties in nonlocal birefringent dye-doped nematic liquid crystals, we report a few intriguing features of soliton-enhanced random lasers, including directional properties and all-optical modulation.

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Hydrodynamic optical soliton tunnelling

We introduce a conceptually new notion of hydrodynamic optical soliton tunnelling in which a dark soliton is incident upon an evolving, broad potential barrier that arises from an appropriate variation of the input signal. The barriers considered include smooth rarefaction waves and highly oscillatory dispersive shock waves (DSWs). Both the soliton and the barrier satisfy the same one-dimensional defocusing nonlinear Schrödinger (NLS) equation, which admits a convenient dispersive hydrodynamic interpretation. Under the scale separation assumption of nonlinear wave (Whitham) modulation theory, the highly non-trivial nonlinear interaction between the soliton and the evolving hydrodynamic barrier is described in terms of self-similar, simple wave solutions to an asymptotic reduction of the Whitham-NLS partial differential equations. We identify two adiabatic invariants of motion that predict trapping or transmission of solitons by hydrodynamic barrier. Under certain conditions, soliton interaction with hydrodynamic barriers gives rise to new effects that include reversal of the soliton propagation direction and spontaneous soliton cavitation, which further suggest possible methods of dark soliton control in optical fibers.

This is joint work with Patrick Sprenger and Mark Hoefer (University of Colorado, Boulder).

Ömer Ilday,
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Nonlinear thermodynamics of mode-locking

Serim Ilday,
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Ultrafast laser-driven self-assembly and self-organization far from equilibrium

We, humans, envy the level of complexity found in Nature, but we tend to regard its replication in human-made systems as an unattainable goal. This perception of un-unravelability of complexity is strongly biased by our dependence on, as well as the successes of, the deliberate linearization and suppression of noise that is pervasive in engineered systems. Can superior structures and functionalities, which are difficult or even impossible to achieve with linear and deterministic systems, be obtained by exploiting nonlinear dynamics far from equilibrium? Could control of complex systems, at times, be "simple"?

After giving a brief historical introduction to the complexity science, I will introduce ultrafast lasers as an excellent tool to control complex forms and functions by creating well-controlled spatio-temporal thermal gradients in far-from-equilibrium settings: Nonlinear interactions give rise to multiple fixed points in phase space during the dynamic evolution of the system. Each of these steady states correspond to a different pattern and their bifurcations. Amplified fluctuations, as a result of far-from-equilibrium dynamics, spontaneously drive transitions through bifurcations. Positive and negative feedback support exponential growth of perturbations, and their stabilization, respectively. This, in turn, allows control of great many degrees of freedom through the control of just a few. As concrete examples, I will demonstrate emergence of complex patterns and dynamic behavior from self-assembled polystyrene colloids (Nature Commun., 2017). I will also argue that this is a "universal" dynamic self-assembly methodology by showcasing four different microorganisms, namely, S. cerevisiae (immotile, about $\sim 7\mu m$ large, and elliptical in shape), M. luteus (spherical in shape, $\sim 500nm$ in diameter), E. coli and P. aerugosa (motile, rod-like with dimensions of $\sim 1\mu m \times 2\mu m$), sub-$5nm$ particles and cancer cells (immotile, about $\sim 40\mu m$ large). Finally, I will briefly show how we create self-organized nano and microstructures (Nature Photon., 2013 and Nature Photon., 2017) by invoking nonlinearities in the form of positive feedback between laser beam-induced changes in the material and material change-induced effects back on the laser beam.

Yana Izdbeskaya,
Australian National University, Australia

Nonlinear dynamics of optical vortices in nematic liquid crystals

This is an overview of our experimental observations of nonlinear dynamics of optical vortices and structured laser beams in nematic liquid crystals. The reorientational optical nonlinearity of nematics exhibits large scale of nonlocal response which dramatically modifies self-trapping of light and suppresses symmetry-breaking modulational instability. In particular, we discuss the formation of robust dipole azimuthons, the self-induced conversion between optical modes of different geometries, as well as composite solitons with hidden vorticity. Here we also discuss how optical vortices, which tend to be azimuthally unstable in local nonlinear materials, can be stabilized in nematic liquid crystals.

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Dispersive shock waves for the Whitham equation

Dispersive shock waves, also termed undular bores in fluid mechanics, governed by the nonlocal Whitham equation are studied in order to investigate short wavelength effects that lead to peaking and cusping waves within the DSW. This is done by combining the weak nonlinearity of the Korteweg-de Vries equation with full linear dispersion relations. The dispersion relations considered are those for surface gravity waves, the intermediate long wave equation and a model dispersion relation introduced by Whitham to investigate the 120^o peaked Stokes wave of highest amplitude. A dispersive shock fitting method is used to find the leading (solitary wave) and trailing (linear wave) edges of the DSW. This method is found to produce results in excellent agreement with numerical solutions up until the lead solitary wave of the DSW reaches its highest amplitude. Numerical solutions show that the DSW becomes a multi-phase wavetrain after the highest amplitude is reached.

Panayotis Panayotaros
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Optical solitons in nematic liquid crystals: effects of nonlocality and saturation

We consider two models of laser beam propagation in a nematic liquid crystal that describe a nonlinear response of the director field to the laser electric field. We show that this nonlinearity leads to a saturation effect for the director angle. The theory of the equation for the angle is also used to show results for the spatial evolution of the beam, especially boundedness of the solution for all times, decay of beams of small power, and the existence of energy minimizing soliton solutions. These results are similar to what we see with a simpler model where the director field responds linearly to the laser beam. The two models considered follow from the theory of Assanto and collaborators. The first model was derived under small angle assumptions, for both the pretilt, assumed slightly above $\pi/4$, and the additional deviation caused by the beam. The second model does not make any such assumptions and we show what appears to be the optimal bound that the total angle is never $\pi/2$, i.e. the director field is never aligned with the electric fields.

This is joint work with J.P. Borgna, U. San Martin, D. Rial, and C. Sanchez de la Vega, U. Buenos Aires, Argentina.

Roland Schiek
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Rogue Waves in optical film waveguides

The Fermi-Pasta-Ulam recurrence phenomena in nonlinear systems which are described by the nonlinear Schrödinger equation (NLS) has interesting manifestations in solitons and modulational instability (MI). An N-soliton (or Kuznetsov-Ma soliton) is a superposition of 1-solitons forming complicated oscillating channels of light with a periodic recurrence of the sech-formed input condition. MI is the initial stage of another nonlinear— now infinite wide— eigenmode, the Akhmediev Breather. These breather solutions can also be superimposed to form higher-order breathers with periodic recurrence. In the limit of infinite periodicity the breather becomes a Peregrine soliton with a very strong intensity peak on a cw-background. This is a prototype of a rogue wave (RW). Triggered by the occurrence of singular giant ocean waves these extreme events are widely studied. As propagation systems described by the NLS water waves and optical pulses on fibers have been chosen to study rogue waves in the past. We present the first observation of N-solitons, breathers of different order and peregrine solitons in an optical film waveguide thus obtaining the most similarity to the giant water waves, because it is observed in space dimensions. As nonlinearity we work with a cascaded quadratic nonlinearity which makes the experiment possible at adequate powers. The flexibility of the cascaded nonlinearity due to its simple— by phase-matching— adjustable nonlinearity makes interesting observations of competing cubic and quadratic nonlinearity in breathers possible.

Noel Smyth
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Tribute to Tim Minzoni, National Autonomous University of Mexico

Professor Tim Minzoni of the Department of Mathematics and Mechanics, National Autonomous University of Mexico, sadly passed away in Mexico City in July, 2017. Tim was a leading applied mathematician whose work included nonlinear wave theory, which is the subject of the *Nonlinear Guided Waves* conference series, but spanned mathematical biology and mathematical physics. Tim's work was characterised by deep insight and a deep knowledge of both the mathematics and the physical background of the problems he worked on. Tim was a gracious person and a true friend. He had an expansive knowledge of not only applied mathematics and science, but of history, politics, archaeology, . . . This talk will give a tribute to Tim's contribution to nonlinear wave theory and nonlinear optics. In addition, an excerpt of a recording of a seminar by Tim at the first *Nonlinear Guided Waves* meeting will be played.

Bryan Tope
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Modelling coupled dark solitons in nematic liquid crystals

An approximate model of two dark solitons in a nematic liquid crystal can be built using a Lagrangian formulation and suitable trial functions. When the results from this model are compared to numeric calculations from the governing equations there is good subjective agreement between the two models. Both models show that the beams oscillate around each other however looking at the results more closely shows that the oscillation has a larger amplitude with the full numeric calculations and there is a difference in the period of the oscillation. With the aim of bringing the results between the models closer together other factors that have been neglected in the initial build of the approximate model are considered. The manner in which these factors are incorporated into the approximate model are looked at and the effect of these factors with regard to the full numerical calculations are looked at.