WAVES
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A transdisciplinary conference on nonlinearity and disorder in wave phenomena, from microscopic to physiologic and astronomical scales

Plenary speakers

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- **Stéphane Nonnenmacher**, Université Paris-Sud
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- **Laure Saint-Raymond**, Ecole Normale Supérieure de Lyon
- **Evelyne Sernagor,** Newcastle University
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Topical meetings

- Nonlinear waves and turbulence in space plasmas
- Nonlinear waves at interfaces
- Nonlinear waves in biology
- Partial differential equations and modelization
- Spatio-temporal phenomena in nonlinear optics
- Wave phenomena in disordered systems

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color mid-infrared filaments [6,7].
[1] P. Panagiotopoulos et al., Nat. Commun. 4, 2622 (2013)
[2] K. Liu et al., Optica 3, 605-608 (2016)
[3] A. D. Koulouklidis et al., Phys. Rev. Lett. 119, 223901 (2017)
[4] M. Chanal et al., Nat. Commun. 8, 773 (2017)
[5] I. Dey et al., Nat. Commun. 8, 1184 (2017)
[6] V. Fedorov and S. Tzortzakis, Phys. Rev. A 97, 063842 (2018)
[7] V. Y. Fedorov, and S. Tzortzakis, Opt. Express 26, 31150-31159 (2018)

Nonlinear wave phenomena in delay differential models of multimode lasers

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Keywords: *multimode lasers, mode-locking, delay differential equations, bifurcations, dissipative solitons*

Multimode lasers are widely used in medical, industrial, and technological applications. In particular, mode-locked semiconductor lasers are low cost, compact, and efficient sources of short optical pulses with high repetition rates suitable for application in telecommunication networks. A conventional technique to the theoretical studies of these lasers is based on numerical integration of a system of partial differential equations for the electric field envelope and carrier density. Here we use an alternative approach to describe multimode lasers, based on the use of delay differential equations (DDEs). We investigate DDE models of different multimode laser devices, - nonlinear mirror mode-locked lasers generating short optical pulses, frequency swept lasers with a long dispersive fiber delay line, and broad area external cavity semiconductor lasers. In addition to numerical simulations of these models we perform an analytical linear stability analysis that reveals modulational, Turing-type, and flip instabilities of CW regimes. We demonstrate the existence of bistability, chaotic regimes, square waves, as well as temporal and spatio-temporal (light bullets) localised structures of light and discuss their properties and interaction.

Spatiotemporal multimode light waves

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Keywords: *optical fibers; nonlinear optics, fiber amplifiers, kerr effect*

Nonlinear propagation of optical pulses in multimode fibers is subject to complex spatio-temporal phenomena. We outline different strategies for the control and optimization of nonlinear mode coupling. The first approach involves transverse wavefront shaping of the input beams, which permits to launch an optimized mode combination, that results in the generation of a stable nonlinear mode alphabet at the fiber output. The second approach involves the longitudinal variation of the core diameter of multimode active and passive tapers, which leads to tailored supercontinuum generation with high spatial beam quality.