Dispersive shocks and complexity of nonlinear waves

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Dispersive shock waves are ubiquitous phenomena originated by the regularization of wave breaking of nonlinear waves. Wave breaking, in turn, is characterized by the formation of singular and multivalued regions that, in dispersive media, act as precursors for the generation of periodic nonlinear wavetrains (i.e., cnoidal waves), whose dynamics defines the dispersive shock. In this talk I will review my activity in the field, discussing various theoretical approaches to the problem, including the Whitham theory of modulation and new statistical mechanics frameworks based on the thermodynamics of chaos. I will also discuss the implications of shock waves on the complexity of Soliton waves.

Destabilization of localized structures induced by delayed feedback

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We are interested in the stability of localized structures in a real Swift-Hohenberg equation subjected to a delayed feedback. We shall show that variation in the product of the delay time and the feedback strength leads to complex dynamical behavior of the system, including formation of oscillons, soliton rings, labyrinth patterns or moving structures. We provide a bifurcation analysis of the delayed system and derive a system of order parameter equations for the position of the localized structure as well as for its shape. In a special case, a normal form of the delay-induced drift-bifurcation is obtained, showing that spontaneous motion arises without change of shape.

The way to powerful single-cycle pulses: laser filaments and electron jets

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The unique conversion efficiency of laser radiation in supercontinuum is achieved in SF6 forming uniform over-octave 300-950 nm spectrum. The different parts of this supercontinuum within 440-800 nm were compressed down to 8 fs. With a single broadband compressor the sub-5 fs pulses were detected. The filamentary mechanism admits the scalability to higher pulse energies with the example of self-compression of 3.8 mJ pulses. Another new two-step approach for generation of attosecond hard X-rays is exploited. In the first stage, hot electrons are produced in a primary water target and accelerated in forward direction towards the second interaction stage to generate hard X-ray or up-shifted radiation. First experimental evidence is supplied by generation of Cu K-shell flashes in new set-up.

Random perturbations in the nonlocal nonlinear Schrodinger equation

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We consider the interplay between nonlocal nonlinearity and randomness in the nonlinear Schrodinger equation. By means of both numerical simulations and analytical estimates we show that the stability of bright solitons in the presence of random perturbations increases dramatically with the nonlocality-induced finite correlation length of the noise in the transverse plane. We characterize soliton stability using two different criteria based on the evolution of the Hamiltonian and the soliton power. For the physically relevant case of weakly correlated noise we derive a simplified mean field approach which allows us to calculate the power loss analytically.

Plasmon-assisted high harmonic generation in vicinity of metal nanostructures

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We develop a theory of high harmonic generation enabled by plasmonic field enhancement in a vicinity of metal nanoparticles. The theory accounts for the changes in the harmonic spectrum due to the field inhomogeneity and collisions of electrons with the metallic surface. The possibilities to use this technique for generation of single attosecond pulses, high harmonic generation in the vicinity of random surfaces, as well as high harmonic generation in gas-nanoparticle mixtures are also studied.

Generalization of the all-optical Kerr effect in gases and wide bandgap solids

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We present our recent results related to the controversy on the all-optical Kerr effect and the actual intensity dependence of the nonlinear refractive index.Using a Kramers-Kronig type relation between nonlinear refraction and absorption enables us to calculate the nonlinear refraction coefficients of noble gases and wide bandgap solids, which is in remarkable agreement with literature values for the lowest order coefficient n_2. In addition, we point out the importance of ab-initio numerical methods and possible approaches to obtain conclusive results on the current debate.