Solitons and coherent structures in optics and superconductivity

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Abstract

In this presentation the dynamics of coherent structures as solitons, solitary waves and vortices will be exemplified by cases from nonlinear fiber optics and superconductivity. The examples will in part pertain to cooperation between LMI-INSA, University of Rouen, and The Technical University of Denmark.

For fiber optics we have extended the energy method for the perturbed nonlinear Schrödinger (NLS) equation, where one governing equation for a slowly varying parameter in a soliton solution is determined. We have extended this idea by deriving a Lagrange function for multiple slowly varying parameters in a soliton solution by variation of the Lagrangian and by invoking generalized forces from the perturbations. From this method we can obtain a system of nonlinear ordinary differential equations for arbitrary numbers of slowly varying parameters. The method is exemplified by a perturbed NLS equation modelling an optical laser fiber.

Vortices in type II superconductors are another example of strongly coherent patterns. The vortices are modelled by the Ginzburg–Landau equations governing a quantum mechanical coherent variable coupled to the magnetic field. We have investigated the dynamics of vortices in a superconductor with pinning sites. Close to the first critical magnetic field separating the perfect diamagnetic state from the state with penetrating vortices, we observe complex dynamics of the vortices and their interaction with the pinning sites. In particular the simulation results demonstrate hopping of vortices between pinning sites, influenced by external magnetic fields and external currents. Future work pertain to studies of using type II superconductors with artificial pinning sites as permanent magnets. Vortices are introduced into the superconductor by an external magnetic field. Removing the magnetic field leaves back the pinned vortices on impurities creating a permanent superconducting magnet without an external magnetic field.