Lab project / internship M1 PPN-QuanTEEM (1.5 months: 15/05-30/06)

2022-2023

Title of the project: Revisiting nonlinear waves in hydrodynamics and fiber-optic systems

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Laboratory / Department / Team: ICB / Photonics Dpt / SAFIR Team

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Summary:

Nonlinear wave equations arise naturally in optics and fluid dynamics. An important class of special solutions to the underlying equations are localized waves, often termed solitons or solitary waves. As a general rule, solitary waves retain their initial velocity and shape after a collision with another solitary wave, and are consequently referred to as solitons. Such solutions were discovered in the context of small amplitude, shallow water waves in the nineteenth century. They occur in nature due to a balance between nonlinear properties and dispersion of the propagating waves, and can be modelled by an exact solution to the Korteweg-deVries (KdV) equation. A much more recent application is found in fiber-optic communications where practical analysis leads to an equation, termed the nonlinear Schrödinger (NLS) equation, which has also a well-known envelope soliton solution. Note that the NLS equation also applies for modelling the propagation of the deep-water wave-trains.

To celebrate the 50-year anniversary of the numerical prediction of the existence of solitary waves or solitons in optical fibers made by Hasegawa and Tappert, the purpose of this internship is to revisit the different soliton dynamics through experimental measurements made in two different branches of wave physics, namely in optics and hydrodynamics. The experiments will be conducted on timescales of seconds in the water wave tank and picoseconds in the optical fiber. It is worth mentioning that simultaneously performing these experiments, at drastically different scales, in two different branches of wave physics, is extremely rare. Typical dynamics such as soliton collisions, soliton fission, dispersive wave emission will be investigated. Experimental parameters will be determined from numerical simulations. Next, the proposed work will be intended to complement our understanding of the general physics of solitons.

Rogue waves or freak waves in the ocean are one of the most destructive phenomena resulting in damage to ships and marine structures, while the mechanisms of the occurrence of rogue waves have not been fully explained so far. During the last decade, several works have unveiled the contribution of solitons to enhanced rogue wave occurrence. Consequently, research on solitons is still a very active field worldwide, through new trends of detailed and quantitative analyses by means of the development of complex mathematical tools combined with ultrafast real-time detection techniques.

Type of project (theory / experiment): numerical simulations and experiments.

Desired skills: wave propagation, fiber optics, nonlinear physics, basic fluid mechanics, Matlab simulations.