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Soliton gas and generalized hydrodynamics in photonics

I will review recent experimental and theoretical advances on soliton gases and generalized hydrodynamics (GHD) in optical fibers, highlighting quantitative agreement between GHD predictions and experiments for intensity statistics in the defocusing regime and unequal-time correlations in the focusing regime. The concept of a soliton gas was first introduced by V. Zakharov in 1971 as an infinite ensemble of weakly interacting solitons within the framework of the Korteweg–de Vries (KdV) equation. In this theoretical model of a rarefied soliton gas, solitons with randomly distributed amplitudes and phases interact minimally and remain mostly non-overlapping. More recently, this concept has been extended to dense soliton gases, where strong and continuous interactions occur between solitons.
Soliton gases are inherently linked to integrable wave systems described by nonlinear partial differential equations, such as the KdV equation or the one-dimensional nonlinear Schroedinger (1DNLS) equation, which can be solved using the inverse scattering transform (IST). Profound connections between soliton gas theory and generalized hydrodynamics (GHD) have been recently established. In this talk, I will review the latest theoretical and experimental advancements in the study of soliton gases. I will first introduce key conceptual tools (IST, Generalized Gibbs Ensemble -GGE-...). I will then focus on two recent comparisons between optical fiber experiments and GHD theory.