Wave turbulence in integrable systems: nonlinear propagation of incoherent optical waves in single-mode fibers

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Abstract

We study theoretically, numerically and experimentally the nonlinear propagation of partially incoherent optical waves in single-mode optical fibers. We revisit the traditional treatment of the wave turbulence theory to provide a statistical kinetic description of the integrable scalar NLS equation. In spite of the formal reversibility and of the integrability of the NLS equation, the weakly nonlinear dynamics reveals the existence of an irreversible evolution toward a statistically stationary state. The evolution of the power spectrum of the field is characterized by the rapid growth of spectral tails that exhibit damped oscillations, until the whole spectrum ultimately reaches a steady state. The kinetic approach allows us to derive an analytical expression of the damped oscillations, which is found in agreement with the numerical simulations of both the NLS and kinetic equations. We report the experimental observation of this peculiar relaxation process of the integrable NLS equation.