Wave turbulence in a multimode chaotic optical fibre

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Abstract

In analogy with the quantum Bose-Einstein condensation, classical non-linear waves can exhibit a phenomenon of condensation, due to an irreversible process of thermalisation, caused by wave interactions (1,2). Wave condensation results from the divergence of the thermodynamic equilibrium Rayleigh-Jeans distribution, which is responsible for the macroscopic population of the fundamental mode of the system. Optical fibres are useful systems in order to study wave thermalisation and condensation thanks to the small size of the core facilitating the appearance of non-linear effects and the finite number of modes preventing the UV catastrophe to occur. A specific transversally truncated step-index optical fibre is suspected of accelerating thermalisation. This fibre is also mentioned as "chaotic" since it exhibits features associated to chaotic wave systems. In particular, the lack of symmetries within this fibre induces repulsion between energy levels (or propagation constants) and speckle spatial distributions. Those properties are expected to improve energy transfer among the modes and therefore thermalisation We compared the case of a multimode fibre with a regular geometry (e.g., circular fibre), with the case of the "chaotic" multimode fibre. We realised numerical simulations of a generalised wave turbulence kinetic equation ruling the evolution of the fibres' discrete spectra. It involves a coupling between second and fourth-order moments of the random field. The simulations reveal explicit differences between the dynamics of thermalisation for the regular and chaotic geometries. The analysis of (quasi-)resonant four-wave interactions underlying optical thermalisation, allows us to understand those different behaviours.

(1) S. Nazarenko, Wave Turbulence (Lectures Notes in Physics, New-York, Springer, 2011)

(2) A. Picozzi & al, Phys. Reports 542, 1-132 (2014)

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