# Anomalous thermalization of nonlinear wave systems

Stephane Randoux[1], Antonio Picozzi[1], Hans Jauslin[2], & Pierre Suret[2]

[1] Laboratoire de Physique des Lasers, Atomes et Molecules, UMR-CNRS 8523, Universite de Lille, France
[2] Institut Carnot de Bourgogne, UMR-CNRS 5209, Universite de Bourgogne, Dijon, France
stephane.randoux@univ-lille1.fr

In complete analogy with a system of classical particules colliding inside a gas medium, an incoherent optical field can evolve, owing to nonlinearity, towards a thermodynamic equilibrium state [1]. In this respect, the spatiotemporal dynamics of the light field is governed by the nonlinear Schrodinger equation and its equilibrium spectrum has been determined in the framework of the weak turbulence theory [1,2]. It is expected that experiments made in the field of nonlinear optics can possibly lead to the observation of turbulence or thermalization of nonlinear waves [1,2]. Here we present an experiment in which we study the equilibrium spectra reached by a set of two partially-coherent light waves copropagating inside an ultra-low birefringence single-mode fiber. The two waves have opposite circular polarizations and are coupled through optical cross-Kerr effect. Using kinetic wave theory, we show that the wave system may exhibit a process of anomalous thermalization which is characterized by an irreversible evolution of the waves towards a specific equilibrium state [3]. This equilibrium state is of a fundamental different nature than the conventional RJ equilibrium state and in particular, the tails of the equilibrium spectra do not meet the property of energy equipartition. The theoretical analysis reveals that the interaction is submitted to degenerate resonances which prevent the system to reach the usual thermodynamic Rayleigh-Jeans (RJ) equilibrium distribution. The anomalous thermalization is characterized by a process of entropy production: The novel family of equilibrium states is associated to a maximum of the nonequilibrium entropy subject to an additional constraint due to the existence of a local invariant in frequency space. In the experiments, the Raman effect induces a non negligible dissipation over only a few nonlinear interaction lengths so that only the transient nonlinear regime leading to anomalous thermalization is experimentally accessible. However the observation of this transient regime reveals that some of the phenomenom signatures which are predicted in the kinetic regime (where linear effects dominates nonlinear effects), are robust enough to be preserved in the nonlinear interaction regime. The robustness of the behaviors found in experiments performed far from the kinetic regime opens theoretical questions about nonlinear propoagtion of incoherent waves in dispersive nonlinear media.

[1] A. Picozzi, Opt. Express, **15** 9063 (2007)
[2] S. Dyachenko, A. C. Newell, A. Pushkarev, and V. E. Zakharov, Physica D, **57** 96 (1992)
[3] P. Suret, S. Randoux, H. R. Jauslin, and A. Picozzi, Phys. Rev. Lett. **104** 054101 (2010)