Spin-glass models for random lasers: how to expose the inner structure of the replica symmetry breaking distribution to experimental measurements

Luca Leuzzi

CNR-NANOTEC, National Research Council of Italy, Institute of Nanotechnology, Rome, Italy, [2]Sapienza University of Rome, Department of Physics, Rome.

The experimental measure of the complete equilibrium distribution of the overlap in a replica symmetry breaking thermodynamic phase is a challenging objective since the introduction of the Parisi solution to the Sherrington-Kirkpatrick model. We tackle the problem on a spin-glass-related model in which the spins are, actually, light modes, established and coupled in an optically random medium because of multiple light scattering. In presence of external power pumping, this model reproduces the behavior of glassy random lasers. We present a short journey through the analytic, numerical and experimental properties of mode-locked glassy random lasers.

We first introduce a theory of multimode light amplification in random media. The leading model, derived from fundamental light-matter interaction, is a phasor spin-glass model with multi-mode mode-locking couplings, undergoing an overall intensity constraint induced by gain saturation. Through analytic theoretical approaches, numerical simulations, and experimental measurements we investigate this class of random laser models, displaying properties such as a mean-field lasing phase transition at high power-pumping, displaying ergodicity breaking and (pseudo-)power condensation, glassiness and nonlinear mode-locking. Indeed, Replica Symmetry Breaking theory allows to identify a laser critical point and a glassy light regime. An intensity fluctuation overlap (IFO) parameter is introduced, measuring the correlation between intensity fluctuations of light waves, that is in a one-to-one correspondence to the Parisi overlap. IFO distribution signals the laser transition and the high pumping glassy phase purely in terms of emission spectra data, the only data so far accessible in random laser experimental measurements.