Nonlinear Wave-Mixing in Random Lasers

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Random Lasers (RL) are excellent photonic platforms to study complex systems. They operate without an optical cavity and the feedback for laser action is provided by the multiple scattering of light in disordered media — for example: powders containing luminescent grains. The majority of the RL reported were operated by exciting the gain medium by using a conventional laser which enables the observation of Stokes laser emission. However, anti-Stokes RL excited by multiphoton absorption or energy-transfer among the active ions or molecules were likewise reported. Also efficient multi-wavelength RL based on parametric optical effects was demonstrated. Although no external optical cavity is employed, in general RL are multimode due to the possible closed loops formed by the light propagating inside the disordered media. For excitation intensities near and above the RL threshold, nonlinear wave-mixing among the various lasing modes contributes to photonic phase-transitions accompanied by strong non-Gaussian heavy-tailed intensity fluctuations distributions.

In this talk I will review recent experimental and theoretical advances in the RL research with examples for one-, two-, and three-dimensional systems operating in the pulsed and continuous-wave regimes. The nonlinear optical mechanisms governing the behavior of RL based on colloidal-suspensions of dielectric nanoparticles and luminescent dyes, powders consisting of nanocrystals doped with neodymium ions, and random fiber lasers, will be discussed. The contribution of three wave-mixing will be exemplified by the multi-wavelength emission and tunable UV-blue RL generation from powders of neodymium-doped nanocrystals. Four-wave-mixing among the lasing modes and their influence on the statistical behavior of the RL intensity fluctuations will be discussed with examples from experiments with colloidal RL and an erbium-doped random fiber laser. The observation of Lévy-type distribution of intensity fluctuations, the replica-symmetry-breaking transition to the photonic spin-glass phase, and the extreme intensity events with heavy power law asymptotic tail are examples of remarkable effects in RL that will be discussed.