Abstract

Random lasers (RLs) are optical devices that utilize the multiple scattering of light from disordered systems for optical feedback. The disorder-induced feedback in RLs makes the lasing modes highly sensitive to perturbations in the system, making them ideal for various sensing applications. This thesis investigates the modes of RLs under various spatial, spectral, and thermal perturbations in the random lasing systems. Finite difference time domain method has been employed to simulate a spatial perturbation of 10 nm in a two dimensional active disordered system. As a result of perturbation, a slight shift in the spectral position and spatial field distributions of modes was observed. In order to locate the defect, a tracking parameter (TP) was introduced, which considers the cumulative changes in all the modes. The accuracy of TP improves with the number of modes considered. It is observed that TP can accurately identify single-step displacements of $\sim$ 20 nm or smaller. The theoretical explorations in this work establish a initial framework for utilizing RLs in diagnostics to monitor and track tumor growth in complex biological systems.

In subsequent works, the observed sensitivity of RL modes to various perturbations was experimentally verified. Initially, the impact of spectral perturbations in the gain of the RL system was investigated by exploiting the metal-gain interactions in a plasmonic random laser (PRL). The PRL consists of Au nanoisland (NI) decorated ZnO nanorods (NRs) infiltrated with three different gain media with varying degree of spectral overlap with the localized surface plasmon resonance (LSPR) band of Au NIs. A plasmon-quenched emission was observed in all three cases, with a greater quenching for the larger spectral overlap. For the off-resonant condition, a lower lasing threshold was observed in presence of Au NIs due to the dequenching of the coherent intensity in the RL emission as the RL modes couple to plasmonic nanocavities with reduced absorption and enhanced scattering. Hence, a synergy of optimized spectral overlap and plasmonic nanocavities coupled with RL modes has been utilized to dequench plasmon-quenched emission, opening new avenues for RLs in chemical and biological sensing. For the on-resonant condition, a unique unprecedented double threshold lasing behavior was observed. The phenomenon arises from two distinct mechanisms. At low pump fluence, dominant absorption of emission due to plasmonic nanocavities coupled with RL modes gives the first lasing threshold. At high pump fluences, the nonlinear behaviour of Au NIs leads to nonlinear scattering and absorption of the pump beam, leading to the second lasing threshold.

Finally, the thermal perturbations were introduced in an optofluidic random laser (ORL) based on dichromated gelatin (DCG) volume hologram. A single-mode ORL was achieved by shaping the pump beam intensity using a spatial light modulator. The temperature induced changes in the DCG photonic bandgap were utilized to tune the single-mode ORL. The proposed ORL holds potential for on-chip tunable laser sources and highly sensitive temperature sensors.

Keywords: Random laser, Tunable laser, Optofluidic random laser, Plasmonic nanocavities, Metal-gain interactions, Nonlinear absorption, Finite difference time domain method.