Investigations on Lasing Modes in Weakly Scattering Polymer and Optofluidic Random Structures

ABSTRACT

Random laser is an active disordered medium where multiple scattering mediated optical feedback enables light amplification. In a weakly scattering system, where leakage of photons through the boundary is strong, the actual underlying reason for the appearance of randomly distributed resonant modes in the emission spectra is still being explored. In this thesis, we study the characteristics of random lasing modes in weakly scattering systems by using active polymer waveguides and optofluidic devices. A highly stable 4-(dicyanomethylene)-2-methyl-6-(4-dimethylaminostyryl)-4H-pyran (DCM) dye doped polyvinyl alcohol (PVA) solid state film (DCM-PVA) has been fabricated. The film, having its refractive index greater than the substrate and density variations at the microscopic scale, acts as a disordered active planar waveguide and exhibits random laser (RL) emission when pumped. The laser output comprises of both the transverse magnetic (TM) and the transverse electric (TE) components. The film is then sandwiched between two silica opals. The overlap of the DCM-PVA photoluminescence with the photonic stop band (PSB) of the opals is controlled by the choice of the particle size used for opal fabrication. The random lasing threshold studies have been carried out for both TM and TE polarizations for opals with different particle sizes. A reduction in the threshold of RL emission, with respect to the bare DCM-PVA waveguide, by about 20 times (to 0.67 mJ/cm^2) was observed when the photoluminescence of the DCM-PVA film overlaps with the PSB of the opal structure for TM polarization, showing that the embedding of a RL in an engineered PSB material is an effective way to reduce the thresholds of RLs.

RL emission from two dimensional structured optofluidic random laser (ORL) has also been investigated. Concentric elliptical diffraction fringe pattern, which is a signature of the in-plane diffraction of light from on-average periodic scatterers, has been observed on the output plane. High resolution angular scan of the detector within a single diffraction fringe reveals that the lasing modes have different emission probabilities in different directions. Moreover, replica symmetry breaking (RSB), fluorescence to spin-glass phase transition of the ORL has been studied. Also, the spatial dependence of the RSB on the pump location in the ORL system has been investigated by employing a perturbation based two-beam pump-probe technique. It has been observed that, due to the lower thresholds of the lasing modes around the gain boundary, the system experiences the phase transition more efficiently when pumped at the gain boundary compared to centre. Furthermore, spatial distribution of the random lasing intensity in the device has been studied by using the two-beam pump-probe technique. We observe the accumulation of the lasing intensity at the gain boundary as predicted theoretically due to the lower thresholds of the lasing modes at the edges of the gain region. Numerical investigations carried out for the ORL endorse the experimental observations.

Keywords: *Random laser, Multiple scattering, Laser, Optofluidic random laser, Polymer waveguide random laser, Opal.*