Preface

Photonics deals with the generation, emission, transmission, modulation, signal processing, switching, amplification, detection and sensing of light. The application and potential advantages of optics and photonics have been the enabling factor in the shift of modern information technology era from the Electronics age to Photonics age. In the last few years, interest in polymer optical fibers (POFs) has increased significantly because of its ease of handling, flexibility and potential low cost. Availability of inexpensive sources in the visible region has increased the utilization of POF in data communication.

However, the higher loss factor is a major handicap for POF. Recently developed techniques for decreasing losses in poly (methyl methacrylate) (PMMA)-based POF have raised much interest in different fields such as short distance communication, lasing and sensing applications. One of the important advantages of the PMMA compared to the traditional optical materials is that it is possible to introduce organic dyes or other compounds that can play the role of active components into the polymers, which appreciably changes the characteristics of the polymer matrix. Laser dyes, which act as highly efficient media for amplification and lasing have a wide range of tunability in the visible region. The main advantage of incorporating laser dyes in solid matrices such as POF is that it is easier and safer to handle them than when they are in liquid form. Rhodamine dyes are the best known of all laser dyes, which have been frequently investigated in solid-state dye lasers in a variety of hosts, on account of their high fluorescence quantum yield, low intersystem crossing rate and low excited state absorption at both pump and lasing wavelengths.

The thesis presented in seven chapter's deals with the work carried out on different types of dye doped polymer optical fiber and dye doped polymer coated waveguides.

Chapter 1 gives an overview of guided Polymer Optical Fibers (POFs). Historical developments of polymer waveguides/fibers and commonly used polymer materials together with their applications have been covered in this chapter. It also deals with the potential advantages of POFs over silica fiber.

Chapter 2 provides useful information on the photophysical properties of Rhodamine B (Rh B) dye in different solvents with theoretical support. The structural geometries, UV-vis absorption spectra and emission intensities of Rh B in various solvents have been determined for different excited states by density functional theory (DFT) and time-dependent (TD) with polarizable continuum model (PCM) methodologies. This chapter also demonstrates the pulsed, photo-pumped multimode laser emission in the visible spectral range from Rh B dye dissolved in various solvents. The cavity lasing spectral structure and the number of longitudinal modes are easily controlled by changing the solvents. A shift in the emission spectra observed by changing the solvent allows a limited range of tuning of laser emission wavelength. The gain coefficients, stimulated emission cross-section and life time for the Rh B dye dissolved liquid laser system are also determined in this chapter.

Chapter 3 discusses in detail about the various fabrication techniques of Rhodamine 6G (Rh6G) doped polymer optical fibers, such as step index, graded index and hollow fiber. This chapter also gives the details of the optical characterization of different types of dye doped POFs drawn under different initial conditions like, draw rate, feed rate and temperature. Cut back method and Side Illumination Fluorescence (SIF) technique have been employed to characterize the drawn fiber. Detailed measurements were made to understand the amplified spontaneous emission (ASE) and photo degradation phenomena in these POF systems. Measurements of peak emission wavelength, optimum length, line-width and half-life of Rh6G doped hollow, GI and SI POFs are included in this chapter.

In chapter 4, we report the observation of multimode laser emission at wavelengths corresponding to whispering gallery modes (WGMs) from a free-standing micro-ring cavity based on Rh6G dye doped hollow polymer optical fiber (DDHPOF). Theoretical modelling of WGM resonator has also been realized using COMSOL Multiphysics software package. Cylindrical microcavities with different diameters were fabricated and their performances have been evaluated. Resonant modes of the microring laser are excited inside the gain medium which is strongly confined along the radial direction so that the spacing of lasing modes is controlled by the diameter of the cylindrical microcavity. A reduction in the free spectral range of WGM spectra along with a red-shift is observed with an increase in the diameter of DDHPOFs. In the second part of this chapter, we discuss two different types of pumping schemes to characterize the DDHPOF; 1) stripe illumination and 2) spot illumination. As the pump power is increased, stripe illumination shows a blue-shift and spot illumination shows a red-shift for the emission spectra. By using spot illumination, the slope efficiency of system is enhanced by more than three times than that of stripe illumination. However, due to higher power density, spot illumination will lead to quicker degradation of dye molecules as compared to stripe illumination.

Chapter 5 describes multimode laser emission from symmetric (SRC) as well as asymmetric resonant cylindrical (ARC) microcavity based on a Rh B dye doped hollow polymer optical fiber by transverse pumping. An SRC can provide a circularly symmetric whispering gallery mode (WGM)-like laser emission from its surface with a quality factor (Q) of ~1.2×10^4, while an ARC supports a strongly chaotic internal ray dynamics, which will in turn lead to an anisotropic emission with a lower Q of $\sim 8 \times 10^2$ with a far field divergence of about 20° in the plane of the cavity. An ARC can be fabricated by a controlled deformation of SRC, which enables dumping out the stored light effectively with minimum loss. Such deformed free-standing cylindrical polymer microcavities also provide a stable and constant laser emission in a desired direction, which can effectively utilized in the design of highly sensitive fiber laser sensor and low threshold micro-lasers for organic optoelectronic integrated devices. We also observed two different sets of resonant laser modes: namely, fundamental whispering gallery high Q modes (HQMs) and leaky unidirectional low Q modes (LQMs) from an asymmetric hollow polymer optical fiber. It is found that the far-field emission pattern of LQM shows a good directionality with a narrow divergence angle when compared with HQM. Numerical results for asymmetric resonant cavity (ARC) with suitably positioned air hole can support LQM with highly directional emission. It has also been found that the emission directionality can be tuned by adjusting the deformity of the microcavity.

In Chapter 6, we demonstrates pulsed, photo-pumped multimode laser emission in the visible spectral range from cylindrical microcavities of dye doped thin polymer film deposited on silica core optical fiber. The laser emission is characterised by two different sets of resonant modes viz; waveguided modes (WMs) and whispering gallery modes (WGMs). Simultaneous occurrence of the WGM and WMs will lead to a resonant modulation in the laser emission spectrum. In the second part of this chapter, a detailed study of amplified spontaneous emission from a polymer thin film doped with Rh6G is presented. The emission spectrum of the dye-doped polymer thin film on a glass substrate exhibits high directionality, narrow linewidth and presence of soft threshold behavior. Performance of a compact solid-state laser based on leaky mode propagation from dye-doped polymer free-standing film waveguide is also discussed. The partial reflections from the broad lateral surfaces of the free-standing films provided the optical feedback for the laser emission.

Chapter 7 deals with the fabrication and characterisation of Rh B doped microring resonator embedded in the inner walls of the silica capillary. Strongly modulated multimode laser emission has been observed from such microresonators by transverse pumping. We have studied the lasing behavior of different thickness microring cavities with enhanced mode selection and particularly almost single mode lasing with a side mode suppression ratio of up to 10.2 dB is obtained from a very thin microring cavity. The lasing modes inside such cavities can be easily collected from one end due to its very good propagation characteristics.

Chapter 8 deals with the main conclusions of the work presented in this thesis. A brief sketch of future research prospects is also mentioned in this chapter.