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Multimode laser emission from dye-doped hollow polymer optical fibre

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Abstract. Well-resolved multimode laser emission was observed for the first time from a free-standing microring cavity based on Rhodamine B dye-doped hollow polymer optical fibre by transverse pumping. Fibres with different diameters such as 180, 460, 640 and 800 μm were fabricated from a dye-doped hollow polymer preform. A blueshift in the mode structure was observed with decrease in fibre diameter leading to wide range tunability of the laser emission.

Keywords. Fibre lasers; optical microcavities; whispering gallery modes.

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1. Introduction

Stimulated emission from a sample of polymethyl methacrylate (PMMA) containing a Rhodamine B (Rh B) dye excited with the second harmonic of an Nd:YAG laser was first obtained by Softer and McFarland [1]. Organic dye-doped polymers have been widely investigated as gain media in solid-state lasers [2–4]. The use of a synthetic polymer host for lasing dyes presents a number of advantages such as compactness, manageability, lack of toxicity or flammability and suppression of flow fluctuations and solvent evaporation [5]. In addition, these materials are amenable to inexpensive fabrication techniques, which would facilitate miniaturization and the design of integrated optical systems. Laser dye-doped fibre is a highly efficient medium for laser source with narrow pulse width and wide tunable range as well as for optical amplifier with high gain, high power conversion and broad spectral bandwidth [6]. In this paper we report the fabrication and observation of lasing modes from hollow cylindrical cavity made up of different diameters of Rh B-doped hollow polymer optical fibre pumped by a frequency doubled Q-switched Nd:YAG laser. Multimode laser emission from doped hollow optical fibre was first reported by Kailasnath *et al* [6]. In this method, modes observed were not clearly resolved as the

collection geometry used in this experiment was axial even though the excitation of the fibre was transverse. In this paper, we report the observation of well-resolved laser modes by collecting the laser emission by a transverse geometry.

2. Experiment

Dye-doped polymer optical fibre preforms were fabricated by the controlled polymerization of Rh B-doped methyl methacrylate (MMA). Hole in the preform can be achieved by placing a teflon rod on the centre of the glass tube during the polymerization. Final fibre structure with required diameter was obtained by heat drawing process. The diameter of the final fibre structure can be controlled by varying different parameters such as feed rate, draw rate and temperature of the fibre drawing workstation. Dye-doped hollow fibres with 180, 460, 640 and 800 μm outer diameters were used in this study.

A schematic of the experimental set-up for the laser emission studies from dye-doped polymer optical fibre is shown in figure 1. The dye (Rhodamine B) doped hollow optical fibre was placed in a fibre translational stage. The fibre was transversely pumped at 532 nm with a frequency doubled Q-switched Nd:YAG laser (Spectra Physics) with 8 ns pulses at 10 Hz repetition rate. The pump beam was focussed on the side of the optical fibre using a convex lens with appropriate focal length. The laser modes were collected from a distance of 4 mm from the point of excitation as shown in figure 1. The emission was recorded using a collecting fibre coupled to a monochromator-CCD system with a resolution of 0.03 nm.

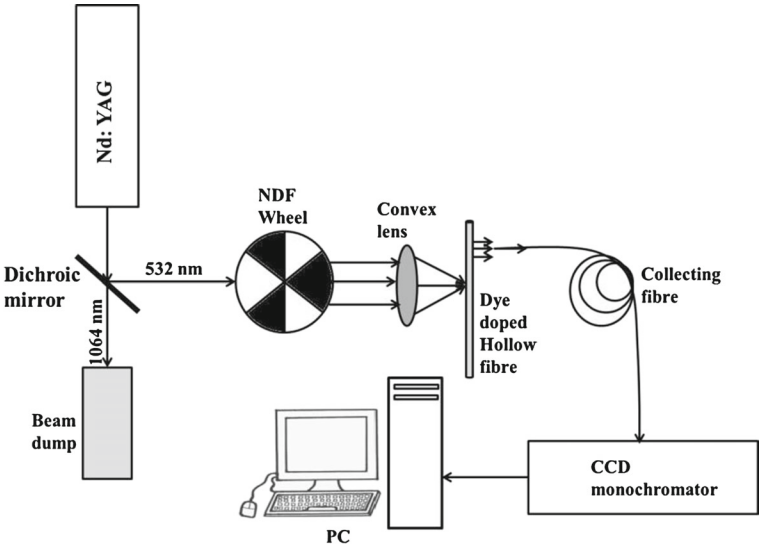

Figure 1. Schematic diagram of the experimental set-up.

3. Results

Multimode laser emission was observed from Rh B-doped hollow optical fibre, when the fibre was transversely pumped at 532 nm with a frequency doubled Q-switched Nd:YAG laser (Spectra Physics) with 8 ns pulses at 10 Hz repetition rate. The multimode laser emissions from hollow fibres with different diameters for a pump power of 0.003 W are shown in figure 2.

The average pump power for the largest diameter fibre (800 μm) for clearly resolving modes was 0.003 W. These modes are the circumferential (tangential) modes in the microring cavity of the hollow fibre. The laser modes from the hollow fibres can be viewed in analogy with the modes of a Fabry–Perot resonator with plane-parallel mirrors, whose mirror spacing is equal to half the circumference of the hollow fibre. Similarly, the circumferential modes of the microring resonator correspond to the longitudinal modes of the Fabry–Perot resonator. The wavelength spacing between adjacent modes can be calculated from $\Delta\lambda = \lambda^2/\pi nd$, where λ is the peak emission wavelength, n is the refractive index of the fibre and d is the diameter of the fibre. It can be seen from figure 2 that there is a shift in the wavelength of emission corresponding to the dominant mode of each fibre. For a given pump power, better confinement of optical power to low diameter fibre

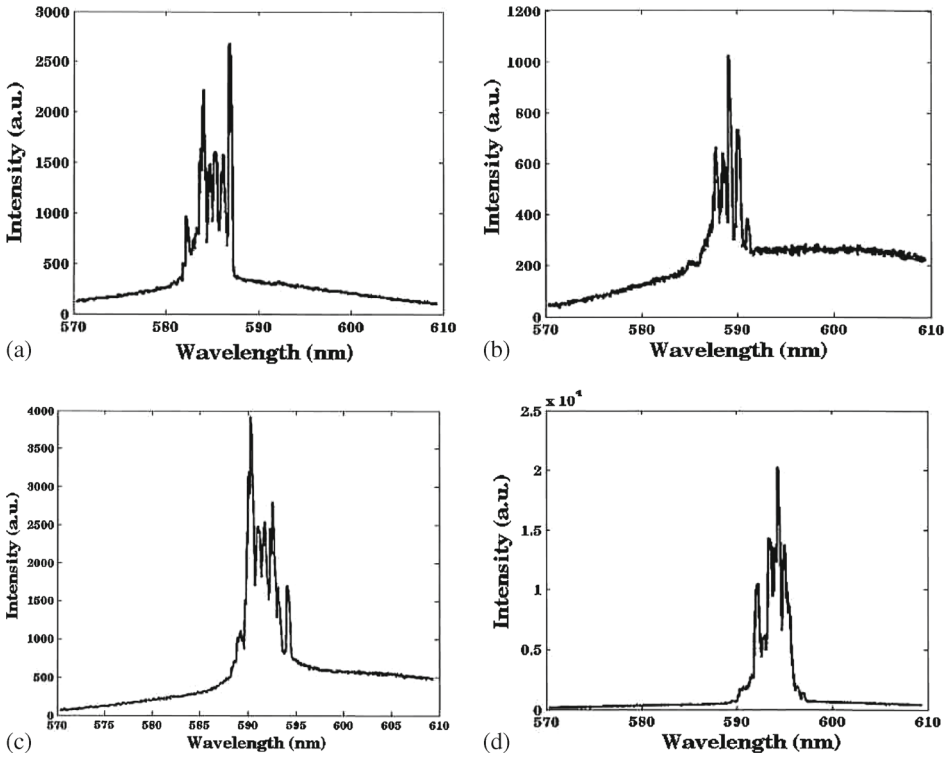

Figure 2. Multimode laser emission from dye (rhodamine B) doped hollow optical fibres with diameter (**a**) 180 μm, (**b**) 460 μm, (**c**) 640 μm and (**d**) 800 μm.

leads to the efficient excitation of modes corresponding to the higher energy results in this blueshift.

4. Conclusion

Dye-doped hollow optical fibres with different diameters were fabricated. Multimode laser emission from these hollow fibres has been observed when excited transversely by a 532 nm pulsed laser from an Nd:YAG laser. As the diameter of the fibre is decreased, a blueshift in the mode structure has been observed leading to wide range tunability of the laser emission.

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