Amplified Spontaneous Emission of Side-pumped Step-index Rh640 perchlorate-dye-doped Polymer Optical Fiber

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Abstract: Step-index Rhodamine 640 perchlorate-dye-doped polymer optical fiber with a lightly dye-doped core and relatively high dye-doped cladding is fabricated, and its amplified spontaneous emission performance by side pumping is demonstrated.

OCIS codes: (060.2280) Fiber design and fabrication; (060.3510) Lasers, fiber.

1. Introduction

Polymer optical fibers (POFs) have been intensively studied in the past decades due to their ease of fabrication on, low cost and versatile applications. The low manufacturing temperature makes them very suitable hosts for organic dopants such as organic dyes. Organic dye-doped POFs have the advantages of non-volatile, non-flammable, non-toxic, compact, and mechanically stable. Because of these advantages, increasing number of studies on solid-state POF lasers and amplifiers [1-13] has been carried out for two decades.

However, in recent developments of dye-doped POF lasers, the laser cavities were formed by butting highly reflective dielectric mirrors, dichroic mirrors or some bulk optics to the fiber-ends, which made the dye-doped POF laser bulky, complicated and expensive. There is a lack of simple and integral dye-doped POF laser that the cavity reflector is integrated into the dye-doped POF laser. Although other researchers had coated aluminum reflector directly on the surface of a dye-doped thin polymer sheet [10]. No one has integrated the cavity reflector directly to the small fiber end-face of a dye-doped POF to study the lasing characteristic. Therefore, it is important and interesting to investigate the luminescent performance of a dye-doped POF with integrated cavity reflector.

Moreover, among the reported POF lasers, it was observed previously that organic laser dye was typically doped only in fiber core, or doped in the whole fiber without cladding. These kinds of POF lasers suffer from high optical loss and gain saturation at high pump power, because the core was highly doped in order to maintain an acceptable level of output power and the required operating lifetime. In view of this, we propose a doping structure of step-index dye-doped POF in which the cladding is highly doped and the core is slightly doped with organic laser dye to implement a prolonged operating lifetime with useful output power.

2. Experiment

In this study, the step-index dye-doped POF was drawn from a preform produced by the casting/moulding method as stated in our previous publication [14]. The POF has an outer diameter of ~950µm, and a core diameter of ~430µm. The fiber core was made of copolymer of methyl methacrylate (MMA) and Benzyl methacrylate (BzMA) in mole ratio of 75 to 25, and the cladding was made of pure MMA. Four different kinds of POFs were fabricated. All the claddings were doped with 200ppm Rh640 organic laser dye. The cores of three POF samples were doped with 200ppm, 50ppm, and 20ppm dye respectively. A POF sample with an undoped core was used to serve as a reference and a control sample. Another POF sample with 20ppm of Rh640-doped core and undoped cladding of poly methyl methacrylate (PMMA) was also fabricated for comparison. The dye-doped POF was cut into 5cm long pieces, and their end-faces were polished to optical grade. As shown in Fig. 1(a), one fiber end-face was then coated with a gold layer through DC sputtering, and acted as a back reflector with reflectance of 96%. The other polished end-face acted as an output coupler. The dye-doped POF was transversely pumped at 532nm by a frequency-doubled Q-switched Nd:YAG pulse laser (pulse width ~6ns, repetition rate ~2.5Hz).

Fig. 1(b) shows the plots of the fiber output power measured from the four dye-doped POFs as a function of pump power for 200ppm, 50ppm, 20ppm Rh640-doped core POFs, and an undoped core POF, all with 200ppm Rh640-doped cladding. A plot of POF with 20ppm Rh640-doped core and undoped cladding was also included for comparison. For all POFs, the output power grew slowly at low pump power for all the POFs mainly due to the spontaneous emission of the organic dyes as their populations of excitation state are less than that of the ground state. When the pump power was further increased, population inversion occurred; the output power increased dramatically, and this is mostly attributed to the amplified spontaneous emission (ASE).

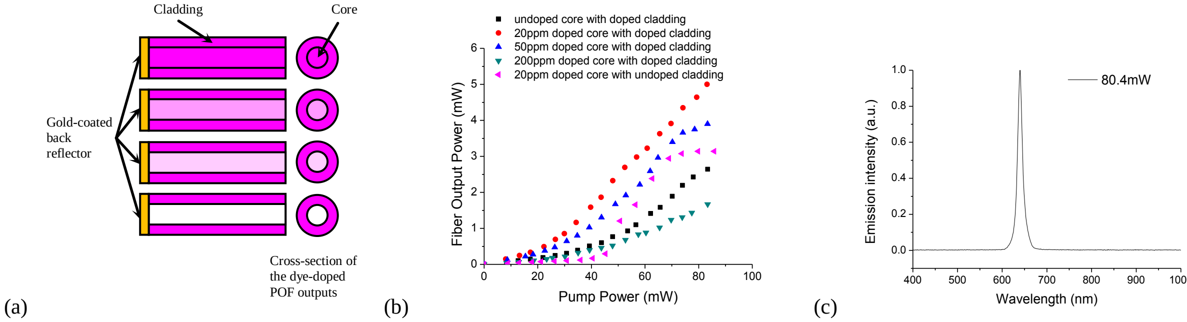

Fig. 1. (a) Schematic diagram of step-index POF with cladding doped with 200ppm Rh640 dye, and cores doped with 200ppm, 50ppm, 20ppm and 0ppm Rh640 dye (top to bottom). (b) The output power as a function of pump power for the POFs in (a) and for the POF of 20ppm dye-doped core with undoped cladding. (c) The spectrum of the 20 ppm dye-doped core with undoped cladding POF pumped at 80.4 mW.

It can be seen that the 200ppm doped core POF has the lowest output power among the doped core POFs tested, which is even lower than that of the undoped core POF. The reason is that the emitted lights from the cladding propagating in the core of 200ppm dye-doped core POF experience a relatively higher optical loss due to the overlap between absorption and emission spectra of the highly-doped dye molecules. It is worth noting that, although the emitted lights from the dyes (in core and/or cladding) were amplified when they propagated along the gain medium in the core, the total optical loss is higher than the gain in the optical cavity. To reduce the optical loss in the POF core, the concentration of dye doped in the core was reduced to 50ppm and 20ppm. It was found that a significant increase in the output power was observed for doping concentrations of 50ppm and 20ppm. It can also be seen that the POF with 20ppm dye-doped core and 200ppm dye-doped cladding shows highest output power without saturation at high pump power. It is clear that low doping concentration of organic dye in the core can attain higher optical gain in the core and that doping the cladding with laser-dye can improve the performance significantly. Fig. 1(c) illustrates the emission spectrum of the POF with 20ppm dye-doped core and 200ppm dye-doped cladding. This POF with specialty dye-doped structure showed a lifetime of more than 7 hours or 63000 pulses at 2.5Hz. The proposed POF design has the potential to be used for the development of POF lasers.

3. Summary

Side pumping of a simple and integral step-index Rh640 perchlorate-dye-doped POF using a lightly dye-doped core and relatively highly dye-doped cladding was demonstrated.

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