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Short Communication

The Fiber Random Laser with Double Cavities of Air Bubble

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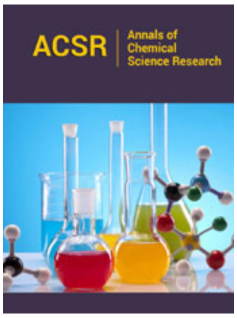

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Abstract

The multiple cumulative Rayleigh scattering is the key to the traditional fiber random laser. A double-cavity fiber random laser is fabricated in a capillary tube by a siphon method. Air bubbles are uniformly distributed along the axis of the capillary tube and two incoherent feedbacks to provide optical feedback. The double-cavity fiber random laser emits dual-mode output. The experiment and the theory are in good agreement, promoting the theoretical understanding of mode selection in the weak disordered structure. This work has guiding significance for regulating and optimizing the multi-mode output fiber random laser.

Keywords: Fiber random laser; Double cavities; Dual modes

Introduction

Random laser is a new type of laser with micro cavity and the photon is localized in the active region by scattered and amplified after multiple scattering [1-3]. Thus, the random laser greatly reduces the size than the traditional laser who has a big resonator. However, the random lasers usually lost control of the emission angle. In order to reduce the divergence angle, the fiber-type random laser has done a good job on it [4-6]. The structure of one-dimensional fiber makes the application of random laser have outstanding characteristics and the excellent flexibility of polymers makes fiber-type random laser have more possibilities for applications. From the initial dye-doped nano-scattering particle type to the randomly distributed grating feedback coherent type, and then to the traditionally commercial fiber distributed feedback type fiber laser, the fiber type random laser has experienced from incoherent to coherent, strong random structure to weakly disordered structure, achieved many characteristics such as high efficiency, bottom threshold, weak divergence angle, narrow line width, wide tuning, etc., and gradually expands to the study of time domain, polarization state, multi-mode and nonlinear mechanism [7-10].

If combine the microstructure of the fiber and optical cavity theory to limit and choose the output wavelength, it will have a bright guiding significance on this way of random laser wavelength control for random fiber. In this work, the fiber random laser with double cavities of air bubble is designed and fabricated.

Experiment and Discussion

The active material of Rhodamine (R6G) is dissolved in ethanol at the concentration of 1mg/ml and the R6G solution is blended with polydimethylsiloxane (PDMS) and curing agent at the ratio of volume and weight of 1ml: 1g: 0.1g. Then the blended solution is vacuumed at air pressure of 0.1 MPa for 30 minutes to remove ethanol. The ink of R6G, PDMS and curing agent is injected into a capillary tube with an inner diameter of 500μm. Then the capillary tube is placed in an ultrasonic oscillator with a frequency of 24kHz and oscillated for 15 minutes. After resting for about 24 hours at room temperature to ensure the crosslink reaction of PDMS, the random laser with double cavities of air bubble is fabricated in the capillary tube.

The schematic diagram and the double cavities random laser of air bubble is shown in Figure 1. As shown in Figure 1(a), the pump laser with 532nm wavelength irradiates the random laser with double cavities of air bubble, which emits random lasing with 560nm and 585nm wavelength. More details for the random laser are shown in Figure 1(b) & 1(c). A fabricated random laser with double cavities of air bubble is shown in Figure 1(b) and it should be noted that the length of random laser can be tuned by the siphoned ink column height. Due to the effect of ultrasonic oscillation, there are uniform air bubbles in the capillary tube, which separate the active layers, as shown in Figure 1(c). The capillary tube is cylinder and forms the air bubbles. The scale bar is 200μm.

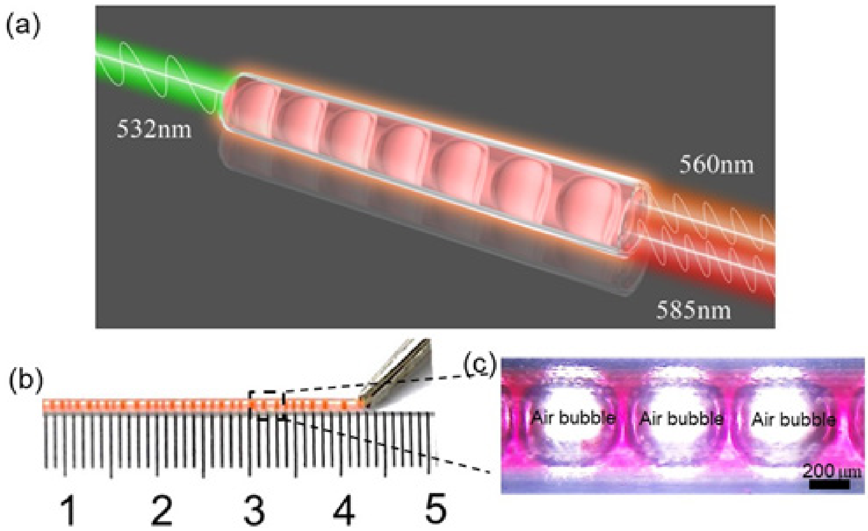

Figure 1: (a) The schematic diagram and the double cavities random laser of air bubble; (b) The photograph of a fabricated random laser with double cavities of air bubble; (c) The optical photograph showing partial details, and the red is R6G and PDMS, the white is air bubble. The black scale bar is 200μm.

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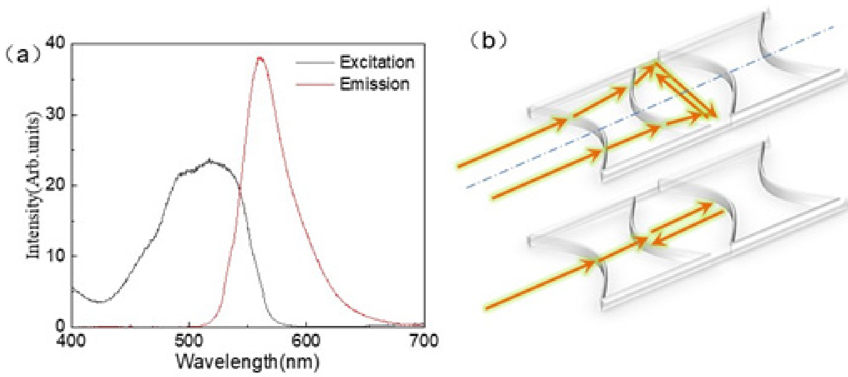

Figure 2: (a) Excitation spectrum and emission spectrum of R6G and PDMS; (b) Short axis resonant cavity optical path diagram (up) and long axis resonant cavity optical path diagram (down).

Generally, the photoluminescence of active materials affects the random lasing output. The ink of R6G and PDMS is spin coated on a silica slab, and the thin film of R6G and PDMS is fabricated after the consolidation of PDMS. The excitation photoluminescence (black) and the emission photoluminescence (red) for the thin film of R6G and PDMS are collected by a spectrometer (Hitachi, F7100) and shown in Figure 2. The wavelength of pump light increases from 400nm to 700nm at a step of 0.2nm and the excitation photoluminescence shows a peak around 525nm. A pump source with 532nm wavelength will be employed in random lasing experiment and the pump beam wavelength of 532nm locates in the absorbance band and benefits the emission of R6G.

The pumping output is shown in Figure 3 and in Figure 3(a) the dual-wavelength emission is clearly observed. The emission wavelengths are 560nm and 585nm respectively, which confirm the theory of dual-resonant cavity mode selection. The intensity of the 560nm wavelength at the pump energy density is significantly higher than the intensity of 585nm. Correspondingly, the threshold for 560nm wavelength output is significantly lower than that of 585nm because the distribution of the lateral length is more uniform than the distribution of the longitudinal length, which results in higher mode selection efficiency of the short-axis resonant cavity.

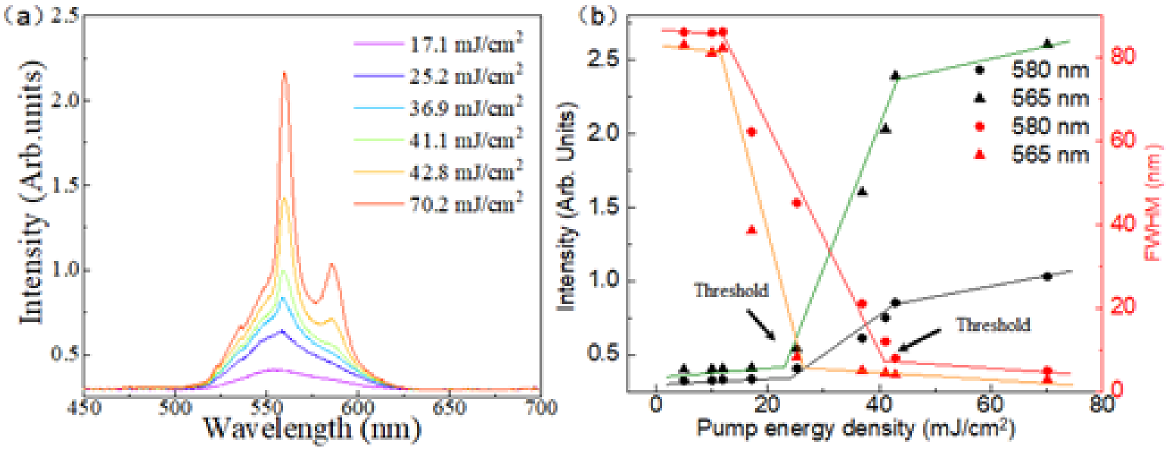

Figure 3:(a) The output of the double cavities random laser at pump power densities. (b) The intensity of the output lasing and FWHM at pump power densities.

Conclusion

A fiber random laser with double cavities of air bubble is prepared by a siphon method. The dual-wavelength emission at 560nm and 585nm is the result of the cascade double symmetric double-concave resonator participating in the two mode selections. The cavity length distribution corresponding to 560nm is more stable than the cavity length distribution corresponding to 585nm. This work has guiding significance for regulating and optimizing the multi-mode output fiber random laser.

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