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CW Operation of Optical Amplification in Organic Dye-Doped Polymeric Channel Waveguide

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Abstract: We have succeeded in cw operation of optical amplification in an organic dye-doped polymeric channel waveguide. The 19-dB optical gain was achieved for externally input light under 120-mW optical pumping from the waveguide end-face.

1. Introduction

Organic luminescent materials are very attractive for active media in organic lasers and waveguide-type optical amplifiers because of their large fluorescence efficiencies [1]. While there are a lot of reports about amplified spontaneous emission (ASE) and the lasing characteristics in the organic luminescent materials, the optical pumping has been carried out by nanosecond-pulsed lights. In any reports, the pulsed pump beam with tachistoscopically huge power has been focused on the sample surface by a cylindrical lens providing a rectangular excitation stripe, so that the sufficient waveguiding length for optical gain is ensured [2]. While this pumping method is available for evaluation of the optical gain coefficient, it is unrealistic to apply this method to the cw operation. One of clever solution for achievement of the cw operation, which is indispensable for practical applications, is optical pumping from the waveguide edge, as employed in rare earth-doped fiber amplifiers. For this pumping method, a channel waveguide structure is required for confinement of the pumping beam.

In this study, we have fabricated infrared organic dye-doped polymeric channel waveguide and firstly succeeded in observations of cw-stimulated emission and optical amplification by using a ~ 120-mW light source for optical pumping. This remarkable result was accomplished by the optical pumping from the channel waveguide end-face. The experimental scheme shown here is quite reasonable and practical for any organic luminescent materials.

2. Fabrication

The channel waveguide fabricated in this study consists of poly(methyl methacrylate) (PMMA) as host matrix and 4-[4-[4-(dimethylamino)phenyl]-1,3-butadienyl]-1-ethylquinolinium perchlorate (LDS798) as organic active medium [3]. LDS798 is a commercially available near infrared dye, and has maximum absorption at 566 nm and emission band of 650 – 830 nm. A solution of tetrahydrofuran and propylene glycol monomethyl ether acetate, in which powdery PMMA and LDS798 were solved, was spin-coated on a silica substrate. Here, rectangular grooves with 100-μm width and 10-μm depth were fabricated on the substrate by reactive ion etching method. After evaporation of the solvent, the channel waveguide of a reversed ridge-type structure buried in a silica substrate was obtained as shown in Fig. 1. The waveguide sample was cut to 2-mm length with a dicing machine. The dye concentration to the host PMMA was 0.1 wt%.

3. Performance

The fabricated channel waveguide sample was optically pumped from an end-face by using a cw-light source of frequency doubled diode-pumped solid-state laser (532 nm) with output power of 120 mW. The pumping beam was focused by an objective lens, and coupled to one side of the waveguide end-face. We

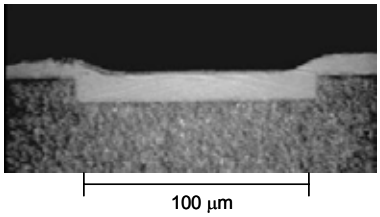

Fig. 1. A microphotograph of LDS798/PMMA channel waveguide end-face. The width and height of the waveguide are 100 and 12 mm, respectively.

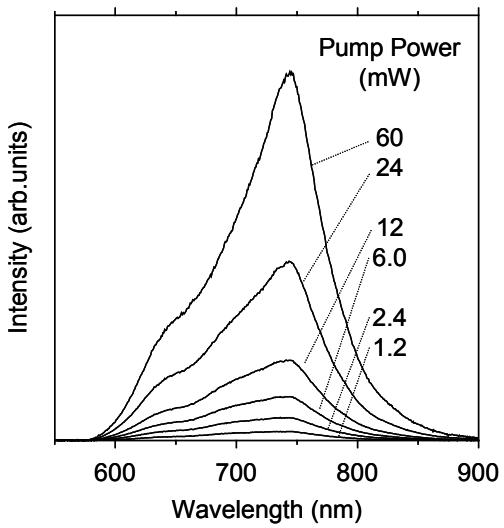

Fig. 2. Emission spectra monitored at output end-face. The waveguide was optically pumped from input end-face at 3-% duty. The pumping power was varied in a range of 1.2 – 60 mW.

found strong pumping light transmitted to the end-face in another side. At the same time, strong red emission, which is spontaneous emission of LDS798, was observed only at the channel waveguide. These observations indicate that all over the waveguiding cavity is excited and substantially activated by the pumping light.

Figure 2 shows emission spectra monitored at the output end-face of the LDS798/PMMA channel waveguide at various cw pumping power. To avoid degradation of the emission property by thermal deactivation, photo-oxidation, and/or optical aging of the dye, the pumping light was chopped at 100 Hz, so that the optical duty became 3 %. With increasing the pumping power, spectrally narrowed emission appeared at ~ 750 nm and rapidly grew up. This spectral evolution shows self-amplification of spontaneous emission in the channel waveguide, *i.e.* ASE. Following the ASE observation, we have carried out optical amplification measurement for externally input light in the LDS798/PMMA channel waveguide. A semiconductor laser diode with emission wavelength of 770 nm was employed as the light source for the input light. The input light with the power of ~ 1 μW was aligned on almost the same optical axis as the pumping light and coupled to the waveguide at the same time. After the fine optical coupling was confirmed, emission from the output end-face was butt-coupled to an optical fiber with the core diameter of 9 μm. The collected emission was introduced to a CCD spectrometer after filtering the pumping beam. The optical amplification of the input

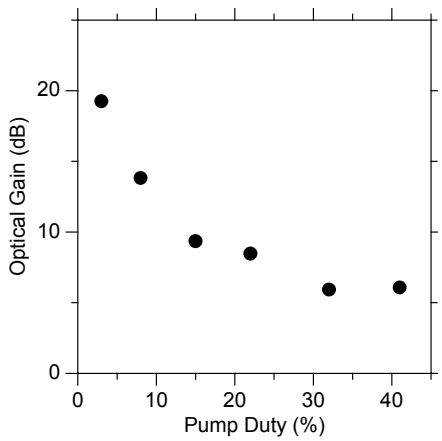

Fig. 3. Optical gain of externally input light as a function of pumping duty.

light was found at the pumping power larger than 2.4 mW. Figure 3 shows substantial optical gain as a function of the duty of optical pumping. The pumping power was 120 mW. At the pumping duty of 3 %, the optical gain of 19.3 dB was achieved. Furthermore, the gain value was > ~ 5 dB even at the pumping with 41-% duty, which is very nearly to the completely cw condition, while the gain degradation caused by optical aging of the dye was observed.

4. Conclusion

The cw-stimulated emission and optical amplification in polymeric waveguide doped with infrared organic luminescent dye were firstly demonstrated. A channel waveguide structure enabled us to effectively pump the active layer. Since this experimental scheme is quite reasonable and practical for any organic luminescent materials, we can say that the organic luminescent materials have great potentiality for lasers and waveguide-type optical amplifiers.

5. References

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