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Different distributed feedback (DFB) configurations in optically pumped polymer lasers, including the active Bragg grating structures, the dielectric grating structures spin-coated with polymeric semiconductors, and the actively waveguide dielectric grating structures (AWGS), are studied systematically. In the experiment, the F8BT polymer poly[9,9-diocetylfluorenyl-2,7-diyl-alt-co-(1,4-benzo-[2,1,3]-thiadiazole)] is employed as the active medium in the three laser configuration. And all grating structures are fabricated through interference lithography or interference ablation. It is found that the AWGS design has advantages over the other two. The continuous and high-quality active waveguide in the AWGS enables low-threshold (115 µJ/cm²) laser emission with narrow linewidth (∼0.4 nm at full-width at half-maximum). The experimental verifications are in good agreement with the theoretical analysis. These results reveal some interesting mechanisms in optically pumped DFB polymer lasers, and it may be enlightening to the construction of electrically driven organic lasers.

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laser sample is estimated to be about 200 μm in radius. The pump pulse energy is controlled by sending the laser beam through an attenuator wheel. Figures 3(a)–(c) show the photographs of the laser action based on different structures depicted in Figs. 1(a)–(c), respectively. A strip consisting of two arc lines can be observed for the laser device. Most of the laser energy is focused into the center area of the spot. The horizontal profile of the laser beam is defined by the Bragg diffraction of the DFB structures. It can be seen that the radiation energy of the polymer laser based on AWGS is confined almost completely in the center of the vertical rainbows (Fig. 3(c)), implying much improved transverse mode as compared with that in the design of Figs. 1(a) and (b). A comparison is made for the transverse modes measured at the same distance from the laser configuration shown in Figs. 1(a)–(c). The half divergence angles of the beam from the laser design shown in Figs. 1(a)–(c) are measured to be about 3°, 2°, and 0.44°, respectively, which implies significantly improved transverse mode by the AWGS configuration.

The characterization of the laser output influences the performance of the laser device. Therefore, the spectroscopic characterizations of the output of different polymer lasers (Figs. 1(a)–(c)) are shown in Fig. 4, where Fig. 4(b) summarizes the spectral intensity of the laser emission as a function of the pump fluence. For the configurations shown in Figs. 1(a)–(b), the laser emission are centered at about 569 nm in the spectrum and has a bandwidth of about 1.3 nm at full-width at half-maximum (FWHM), while for the configuration shown in Fig. 1(c), the laser emission is centered at 564 nm and has FWHM of about 0.4 nm. The spectra are measured with an Ocean optics Maya 2000 PRO spectrometer, which has a resolution of 0.2 nm. Therefore, the practical spectral linewidth of the laser emission is smaller. The narrow linewidth implies excellent oscillation modes in the DFB cavity based on AWGS shown in Fig. 1(c).

As can be evaluated using Fig. 4(b), the pump threshold of three laser configurations shown in Figs. 1(a)–(c) are about 130, 150, and 115 μJ/cm², respectively. And the largest output slope of the AWGS shown in Fig. 4(b) also indicates the DFB structure based on AWGS enable more efficient operation of the laser device.
has more advantages in laser performance, which lies the following aspects: (1) High-quality thin film of the active materials is produced without being modulated by the grating structures, ensuring narrow linewidth of the laser emission. (2) AWGS configuration enables the most efficient utilization of the active volume, ensuring low operating threshold. (3) AWGS configuration facilitates stronger confinement, ensuring a small divergence angle of the laser beam. (4) AWGS is insensitive to the defects or inhomogeneity in the grating structures.

To examine the advantages of the AWGS configuration, we do some full wave simulations using the finite-element method. It can be seen that the eigen modes are distributed partially in the active waveguide in Figs. 5(a)-(b). However, for the AWGS configuration, the field distribution of the eigen mode is confined almost completely in the active waveguide layer (Fig. 5(c)), which is consist with its first three advantages. In the simulations, the polymer layer \((n_{\text{polymer}}=1.8)\) has a thickness of 200 nm, and the PR grating \((n_{\text{PR}}=1.67)\) has a period of 350 nm and a modulation depth of 200 nm. The substrate is made of silica \((n_{\text{silica}}=1.5)\) and the medium on top of the laser device is air \((n_{\text{air}}=1.0)\).

Also, we note that the DFB configuration that the conjugated polymer is spin-coated onto the grating structures and more sensitive to the defects in the grating structures. Figure 6 compares the sensitivity of different cavity configurations shown in Fig. 1 to the similar defects in the grating structures. It can be seen clearly that any defects or inhomogeneity of the grating structures may destroy the mechanisms for DFB in the laser design. However, for the AWGS and the polymer grating structure, the DFB mechanisms are almost not disturbed.

In conclusion, we study the laser radiation mechanisms of the polymer lasers employing different distributed feedback designs. The AWGS structure is demonstrated as a new DFB configuration that favors better laser performance, which is based on the homogeneous layer of the active medium without being modulated spatially. This kind of configuration of the laser device possesses a number of advantages, which are verified both by theoretical simulations and by the experimental results.

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