Injection-switchable erbium-doped fiber laser with two output ports

Daru Chen (陈达如) and Shan Qin (秦 山)

Centre for Optical and Electromagnetic Research, Joint Research Centre of Optical Communications, Zhejiang University, Hangzhou 310058

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An injection-switchable erbium-doped fiber laser (EDFL) with two output ports based on a ring structure is proposed. Wavelength switching together with the switching of the dominating output port of the fiber laser is achieved by controlling the power of a tunable injection laser. The characteristics of the wavelength switching for different levels of the pump laser power and different wavelengths of the injection laser are studied experimentally.

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Erbium-doped fiber lasers (EDFLs)[1−3] have been widely investigated due to their advantages such as the high power conversion efficiency and low threshold. Wavelength switching in EDFLs has attracted considerable attention recently because of its important applications in wavelength division multiplexing (WDM) fiber communication systems, fiber sensors, spectroscopy, and optical instrument testing etc.. So far, several techniques have been reported to achieve wavelength switching in EDFLs, such as the use of a semiconductor optical amplifier[4], sampled fiber Bragg gratings (FBGs)[5], cascaded FBGs[6], spectral polarization-dependent loss elements[7], Sagnac loop reflector[8], few-mode FBGs[9], multimode FBGs[10], hybrid gain medium[11], and injection-seeded technique[12].

In this letter, we propose a novel injection-switchable EDFL with two output ports based on a ring structure. The lasing at the centre wavelength of the FBG can be switched by controlling the power of an injection laser (which also results in the switching of the dominating output port of the fiber laser). The characteristics of the wavelength switching for different levels of the pump power and different wavelengths of the injection laser are studied experimentally.

Figure 1 shows the schematic configuration of the proposed fiber laser. A tunable laser diode (LD1) with a tunable region from 1500 to 1590 nm is employed as the injection laser and a 980-nm laser diode (LD2) is used as the EDF pump. The length, numerical aperture, cutoff wavelength, and peak absorption of the EDF at 1531 nm used here are 4 m, 0.25, 950 nm, and 19.2 dB/m, respectively. A FBG is used as the wavelength selection component. The centre wavelength, full-width at half maximum (FWHM) and reflectivity of the FBG are 1559.98 nm, 0.098 nm, and 51.3%, respectively. An optical circulator (OC) and an isolator (ISO) used here ensure that the lasing cavity is a counter-clockwise ring. The port (P1) of the 3-dB coupler and the port (P2) of the FBG are the two output ports of the fiber laser.

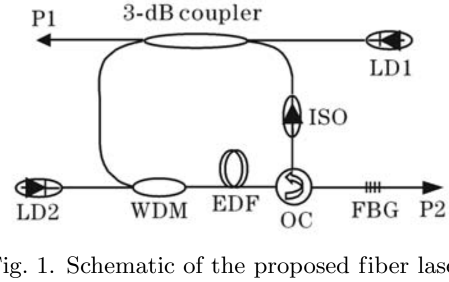

Fig. 1. Schematic of the proposed fiber laser.

In the experiment, the power of the LD2 is fixed first to 16 mW. When the LD1 is switched off, the output spectra of the laser are shown by the solid curves in Figs. 2(a) and (b) for the P1 and the P2, respectively. The structures are lasing only at 1560.1 nm (corresponding to the centre wavelength of the FBG) with a peak power of −10.3 (−16.8) dBm at the P1 (P2). This means that the P1 with larger output power is the dominating output port of the fiber laser when the LD1 is switched off. When the LD1 with the tunable wavelength of 1550.2 nm is switched on to 0 dBm, the structures only output at 1550.2 nm with a peak power of −6.5 (−3.5) dBm at the P1 (P2) which are shown by the dashed curves in Figs. 2(a) and (b) for the P1 and the P2, respectively. In this case, the P2 with larger output power is the dominating port of the fiber laser. Note that the resolution and sensitivity of the optical spectrum analyzer (OSA) used in the measurement are 0.06 nm and

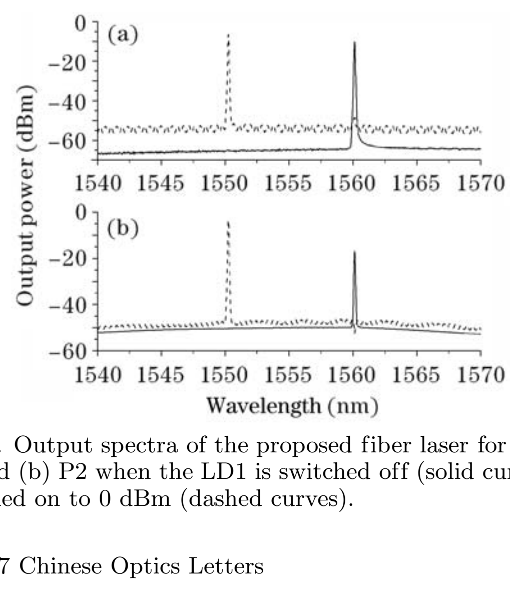

Fig. 2. Output spectra of the proposed fiber laser for (a) the P1 and (b) P2 when the LD1 is switched off (solid curves) or switched on to 0 dBm (dashed curves).

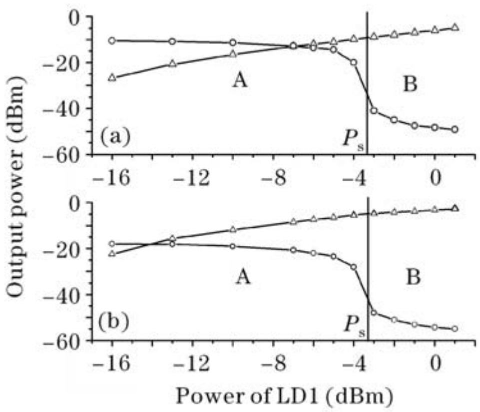

Fig. 3. Output power at 1560.1 (circles) and 1550.2 nm (triangles) against the power of LD1 for (a) the port P1 and (b) P2.

−65 dBm, respectively. The above experimental results show that the lasing wavelength together with the dominating output port of the fiber laser can be switched by controlling the power of the injection laser.

As the power of the LD1 increases and the power of the LD2 is fixed to 16 mW, the detailed behaviours of the wavelength switching are shown in Figs. 3(a) and (b) for the P1 and the P2, respectively. The output powers at 1560.1 and 1550.2 nm are indicated with triangles and circles, respectively. Obviously, when the LD1 is switched off, the fiber laser is simply an EDFL with output wavelength of 1560.1 nm. However, when the LD1 is switched on and its output power increases, one sees that there are two regions where the fiber laser is in different operational modes. In region A where the power of the LD1 is below the switching power P_s of −3.2 dBm, the laser's outputs are at both 1560.1 and 1550.2 nm. As the power of the LD1 increases, the output power at 1550.2 nm increases while the output power at 1560.1 nm decreases. In region B where the power of the LD1 is higher than the switching power of −3.2 dBm, the structures only output at 1550.2 nm. Note that the behaviours of the wavelength switching at the P1 (see Fig. 3(a)) and the P2 (see Fig. 3(b)) are similar.

The operation principle of the present injection-switchable fiber laser can be explained as follows. When the LD1 is switched off, only the lasing at 1560.1 nm can be achieved since a FBG feedback in the ring cavity exists at 1560.1 nm. When the LD1 is switched on, the light is injected into the ring cavity and is amplified (traveling with a trip on the EDF and output at the P2). In this case, the injection light reduces the population inversion required for the lasing at 1560.1 nm, and the cavity gain at 1560.1 nm decreases. Consequently, the output power at 1560.1 nm decreases due to the gain competition as the power of the LD1 increases. When the power of the LD1 is higher than the switching power of −3.2 dBm, the emission stimulated by the injection light at wavelength of 1550.2 nm consumes the most of the pump power and reduces the population inversion, consequently the cavity gain becomes less than the cavity loss at 1560.1 nm and the lasing at 1560.1 nm becomes impossible. It results in a drastic drop of the power at 1560.1 nm and finally only the output power at 1550.2 nm can be observed.

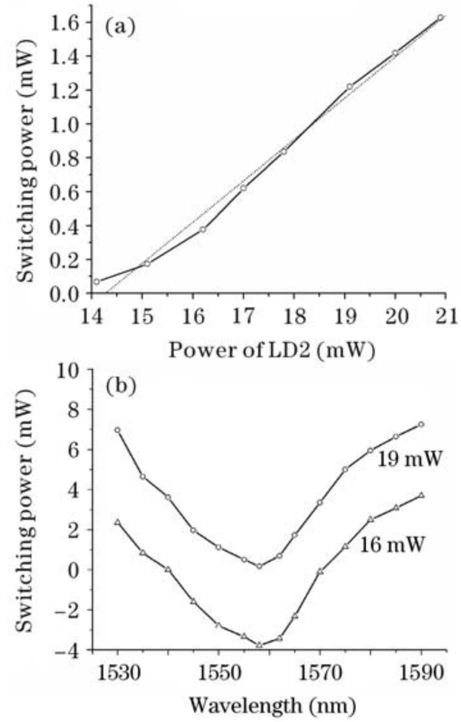

Fig. 4. Relationship between (a) the switching power and the power of the LD2, (b) the switching power and the operation wavelength of LD1, with different pump powers.

The characteristics of the wavelength switching for different levels of the pump power and different wavelengths of the injection laser are also experimentally studied. The results show a good linear relationship between the switching power and the power of the LD2 as shown in Fig. 4(a) when the wavelength of the LD1 is fixed at 1555 nm. The switching powers for the different operation wavelengths of the LD1 are shown in Fig. 4(b) when the pump power is fixed at 16 mW (triangles) or 19 mW (circles). Figure 4 indicates that the switching power increases when the wavelength of the LD1 becomes far from the centre wavelength of about 1558 nm, which can be understood due to the fact that the saturated gain peak of the EDF amplifier (consisting of LD2, WDM, and EDF in Fig. 1) in the laser cavity is around 1558 nm, thus lower injection power is needed to reduce the population inversion to the same level when the wavelenth of the LD1 is close to 1558 nm.

In summary, an injection-switchable EDFL with two output ports is proposed and demonstrated. The wavelength switching is controlled by the power of the injection laser and the operation principle is explained. The dominating output port of the fiber laser which has larger output power than the other, can be switched from one to the other by controlling the power of the injection laser. The characteristics of the wavelength switching for different levels of the pump power and different wavelengths of the injection laser are studied experimentally.

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