A switchable and tunable ytterbium-doped fiber ring laser with a Sagnac loop mirror*

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A switchable and tunable ytterbium-doped fiber ring laser (YDFL) is reported and demonstrated. Employing a Sagnac loop mirror fabricated by an 85-cm-long polarization-maintaining fiber (PMF), the proposed YDFL can operate with stable dual-wavelength lasing or tunable single-wavelength lasing around 1 064 nm. Both stable dual-wavelength lasing and tunable single-wavelength lasing are achieved by adjusting a polarization controller in the Sagnac loop mirror. The experimental results show that the output of the proposed fiber laser with two different operation modes is rather stable at room temperature.

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Wavelength switchable, wavelength tunable or multi-wavelength erbium-doped fiber lasers have been widely investigated[1-5]. For continuous wave (CW) operation, Tran et al[6] realized the switchable four-wavelength lasing in an erbium-doped fiber laser by the nonlinear optical loop mirror technique incorporating multiple fiber Bragg gratings. Zhang and Feng et al[7,8] realized more than 20-wavelength CW lasing in an erbium-doped fiber laser with the birefringent fiber filtering and nonlinear polarization evolution (NPE), respectively. Multi-wavelength lasing could also be realized by adding a long single-mode fiber (SMF) or photonic crystal fiber in the laser cavity to induce four-wave mixing effect[9,10]. The 42-wavelength lasing was realized in a CW thulium-doped fiber laser by nonlinear amplifier loop mirror[11]. For multi-wavelength operation in the pulsed regime, optical components, such as active modulator and saturable absorber, were required to be integrated in the cavity, which increased the complexity and overall loss of the system[12]. In the 1 μm and 1.5 μm wavelength regime, three-wavelength and five-wavelength pulsed lasing cases have been reported[13,14]. In the 2 μm regime, only dual-wavelength pulsed lasing has been reported so far, which was achieved by adjusting the polarization controllers (PCs)[15].

On the other hand, ytterbium-doped fiber lasers (YDFLs) have attracted increasing interest recently due to the broader gain bandwidth and larger gain saturation power compared with the erbium-doped fiber lasers. Recently, several YDFLs with wavelength controlling have been reported. With the broad gain bandwidth, ytterbium-doped fibers were taken to generate widely tunable fiber lasers[16,17]. There are relatively few reports on wavelength switchable YDFLs by employing the special fiber gratings[18,19] or photonic crystal fiber[20], which were fabricated based on costly equipments.

In this paper, we propose a switchable and tunable YDFL with a wavelength filter which is composed of a Sagnac loop mirror formed by an 85-cm-long polarization-maintaining fiber (PMF), a PC and an optical coupler (OC). The proposed YDFL can operate in either the mode of stable dual-wavelength lasing or the mode of tunable single-wavelength lasing. The operation modes of the fiber laser can be switched by adjusting a PC in the Sagnac loop mirror.

The schematic diagram of the proposed YDFL is shown in Fig.1. A 915 nm laser diode (LD) with maximum output power of about 20 W is used as the pump of YDFL, and a 915/1 064 nm wavelength division multiplexer (WDM) is employed to couple the power of the pump to the laser cavity. The ytterbium-doped fiber (YDF) with the length of about 22 m used in the experiment is home-made in our cooperative company (Futong Group). A Sagnac loop filter composed of a 1:1 OC, a PC and a section of PMF is employed in the laser cavity. The length and the refractive index difference

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around 1 060 nm of the Sagnac loop filter are about 85 cm and 3.441×10^{-4}, respectively. An isolator (ISO) is used to ensure a counterclockwise lasing cavity. The 30% arm of the OC is used as the output port of the fiber laser, and the lasing spectrum is observed by an optical spectrum analyzer (OSA).

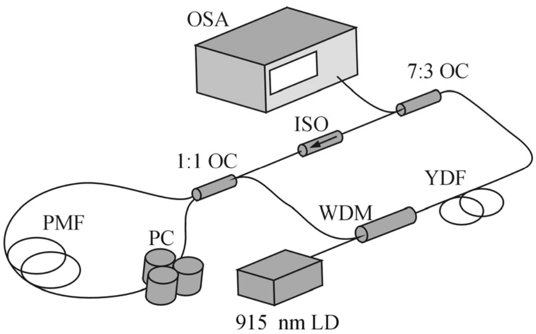

Fig.1 Schematic diagram of the proposed fiber laser

Fig.2 shows the spectra of the proposed fiber laser when it operates in the modes of single-wavelength lasing and dual-wavelength lasing. The switching of the two modes is realized by adjusting the PC in the Sagnac loop filter. The performance of the Sagnac loop filter is measured by using an amplified spontaneous emission (ASE) source based on a 22-m-long YDF.

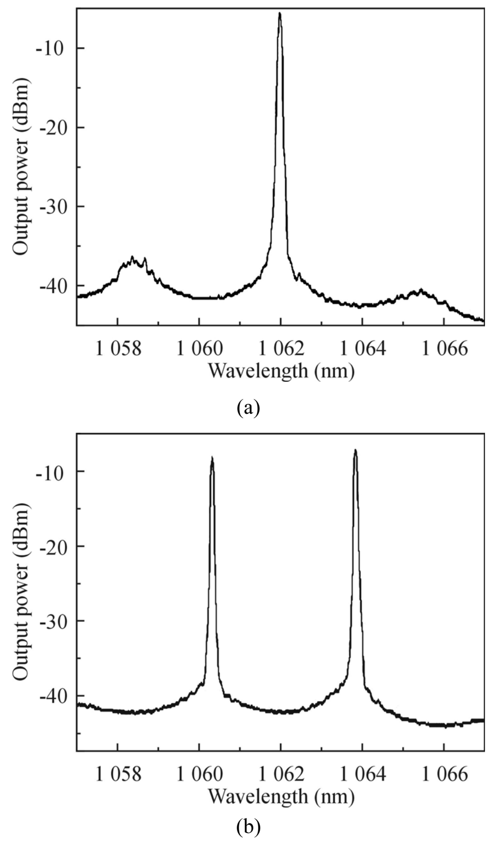

Fig.2 Output spectra of the proposed fiber laser with (a) single-wavelength lasing and (b) dual-wavelength lasing

Fig.3 shows the spectrum of the ASE source, the spectrum after the Sagnac loop filter, and the transmission spectrum of the Sagnac loop filter. A comb spectrum of the Sagnac loop filter is achieved. The peak wavelength spacing and the signal-to-noise ratio of the comb spectrum are about 3.5 nm and 30 dB, respectively.

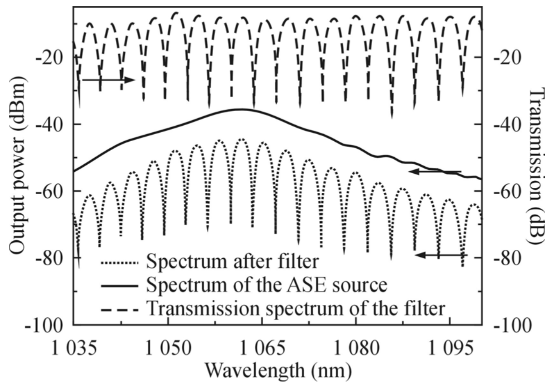

Fig.3 The spectrum of the ASE source, the spectrum after the Sagnac loop filter, and the transmission spectrum of the Sagnac loop filter

The wavelength tunability of the fiber laser based on the polarized device in the cavity has been well investigated[21]. In this paper, by adjusting the PC in the Sagnac loop filter, lasing wavelength can be tuned in the proposed fiber laser. Fig.4 shows the output spectra of the proposed fiber laser with single-wavelength lasing mode, in which the lasing wavelength can be tuned in the range of about 6 nm.

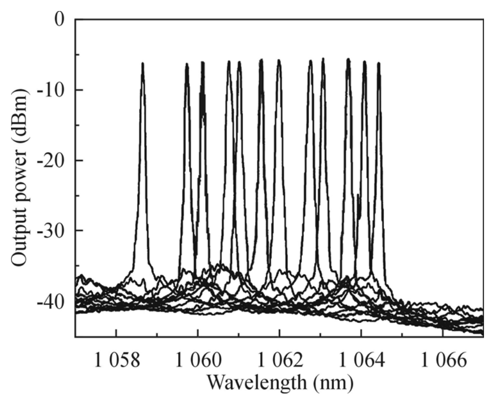

Fig.4 The tunable single-wavelength operating mode for the proposed YDFL with a tunable range of 6 nm

The proposed fiber laser can also operate in the dual-wavelength lasing mode when we carefully adjust the PC. Fig.5 shows the measured 10 spectra with a time interval of 5 min, which indicates the fiber laser is rather stable when it operates in the dual-wavelength lasing mode. The dual-wavelength lasing mode can be understood as the Sagnac loop filter results in two cavities with different lengths. Thus dual-wavelength lasing is possible with different polarization states. Due to the gain grating produced by spatial hole-burning in the erbium-doped fiber (EDF)[22], the proposed ring cavity can support stable dual-wavelength lasing at room temperature.

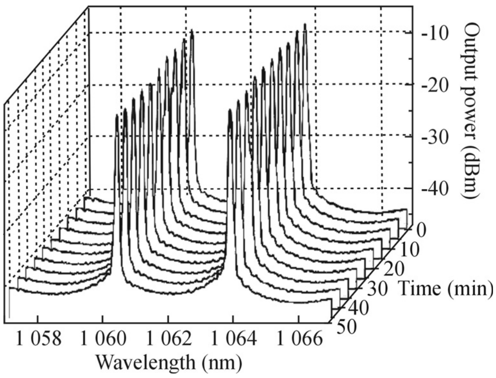

Fig.5 The stable dual-wavelength operating mode for the proposed YDFL

We propose and demonstrate a wavelength switchable and tunable YDFL with a Sagnac loop filter made by an 85-cm-long PMF. A PC is used to control the operation mode of the fiber laser. By adjusting the PC in the Sagnac loop filter, the proposed fiber laser can operate in the modes of tunable single-wavelength lasing and stable dual-wavelength lasing. The experimental results show that the proposed fiber laser is rather stable while it operates in two different modes at room temperature.

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