Tunable multi-wavelength fiber ring laser based on a Hi-Bi fiber loop mirror

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A novel tunable multi-wavelength fiber ring laser based on semiconductor optical amplifier (SOA) is proposed by using a high-birefringence (Hi-Bi) fiber loop mirror (FLM) as wavelength filter. With this configuration, the wavelength spacing of this laser can be varied by using the different lengths of Hi-Bi fiber. 8 wavelengths spacing on 450 GHz are experimentally obtained with more than 25-dB signal-to-noise ratio (SNR) for each channel using 1.28-m Hi-Bi fiber in Hi-Bi FLM. The output power variation between different channels is measured to be less than 5.9 dB. The linewidth of each channel is compressed from 0.347 to 0.186 nm by 1.5-m unpumped erbium-doped fiber (EDF). Meanwhile, 17 wavelengths spacing on ITU-gird (100 GHz) are also obtained with 5.9-m Hi-Bi fiber in Hi-Bi FLM. All these channels can be tuned together over 0.4 nm.

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Recently, there has been increasing interest in the generation of tunable multi wavelength for applications related to wavelength division multiplexing (WDM) in fiber optic communications, optical sensing, and high-resolution spectroscopy. Several approaches have been demonstrated to produce multi-wavelength fiber lasers, such as erbium-doped fiber lasers (EDFLs), fiber Raman lasers (FRL), and fiber lasers based on semiconductor optical amplifier (SOA). Since erbium-doped fiber (EDF) is a homogeneous gain medium, techniques such as cooling the fiber to 77 K or using frequency-shifted feedback are required to obtain stable multi-wavelength operation, especially for narrow wavelength spacing[1,2]. As for FRL, pump source with large output power is absolutely necessary for its high critical pump power[3,4]. Fortunately, the homogeneous broadening linewidth of SOA is deduced to be about 0.6 nm around the wavelength of 1.55 μm at room temperature, which makes multi-wavelength oscillation with WDM ITU-grid spacing possible[5]. In 2003, Yu[6] proposed a novel multi-wavelength-switchable laser based on a SOA within a fiber ring cavity with a sampled high-birefringence (Hi-Bi) fiber grating. Four channels with 0.8-nm spacing were generated at room temperature and switched to other channels with 0.4-nm wavelength-shift by adjusting an inserted polarizer.

In this letter, we propose a tunable multi-wavelength fiber ring laser using SOA as gain medium, which relies on a Hi-Bi fiber loop mirror (FLM) for wavelength selection.

The structure of Hi-Bi FLM is shown in Fig. 1, which consists of a coupler, a polarization controller (PC), and a segment of Hi-Bi fiber. According to Ref. [7], the birefringence in the Hi-Bi fiber produces a phase difference between the fast and the slow components of a beam propagating in the fiber, namely $\delta\phi = \Delta\beta L$, where $\Delta\beta = 2\pi\Delta n/\lambda$ is the modal birefringence with Δn and λ being the normalized birefringence and the wavelength, respectively, and L is the length of the Hi-Bi fiber. If PC is set to produce a pure rotation of 90° in relation to the principle axes of the Hi-Bi fiber, it can be deduced that the reflectivity of the Hi-Bi FLM depends on the phase difference $\delta\phi$ and, therefore, is approximately a periodic function of the wavelength, namely, $R(\lambda) = 2K(1-K)[1+\cos\delta\phi(\lambda)]$, where K is the coupling ratio of the coupler with $K = 0.5$ giving the largest contrast. This suggests that Hi-Bi FLM can serve as a wavelength filter. According to the polarization direction of incident light, Δn of usual Hi-Bi fiber is in the order of 10^{-4}, which makes two interleaved wavebands be separated by sub-nanometers. Therefore, if the input light polarization direction is aligned from fast-axis to slow-axis, the wavelength location in reflection spectrum will change between these two wavebands with fixed wavelength spacing. To change the wavelength spacing of Hi-Bi FLM, one should use different length of Hi-Bi fiber. Figure 2 shows the measured reflection spectra of Hi-Bi FLM with Hi-Bi fiber lengths of 1.28 and 5.9 m, respectively. As expected, the corresponding wavelength spacings are about 3.76 and 0.8 nm.

The experimental setup is shown in Fig. 3. The laser consists of a SOA (Inphenix), a Hi-Bi FLM, and a 10% output coupler. The ring cavity is unidirectional, which is ensured by two optical isolators. PC1 is used to adjust the overall gain spectrum of the cavity. The part in dashed frame is used to compress laser linewidth, which

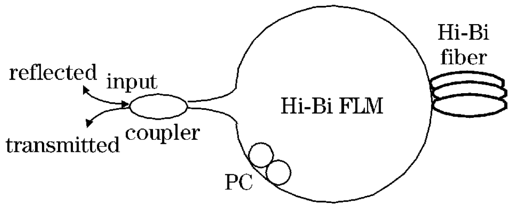

Fig. 1. The structure of a Hi-Bi FLM.

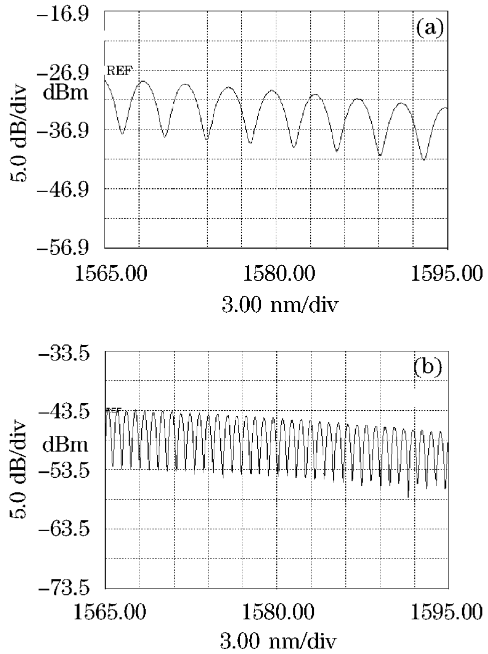

Fig. 2. Measured reflective spectra of Hi-Bi FLM with Hi-Bi fibers of 1.28 (a) and 5.9 m (b).

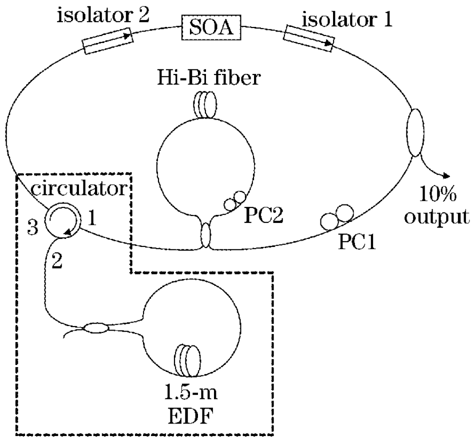

Fig. 3. Experimental setup of tunable multi-wavelength fiber ring laser.

consists of a circulator, a 3-dB coupler, and 1.5-m unpumped EDF. In the unpumped EDF acting as a saturable absorber, there is a standing wave producing periodic spatial hole burning (SHB). This creates an autotracking intra-cavity narrow-bandwidth bandpass filter[8]. The output is sent into an Ando AQ-6315A optical spectrum analyzer.

First, the part in dashed frame is disconnected. Figure 4(a) shows the output spectrum of 8 channels spacing on about 450 GHz when the SOA is driven with the injection current of 280 mA. The length of Hi-Bi fiber is 1.28 m.

As can be seen from Fig. 4(a), 8 laser channels oscillate with signal-to-noise ratio (SNR) over 25 dB. The output power variation between different channels is less than 5.9 dB. The unevenness in output power between different channels can in any case be overcome by the addition of a tailored broadband filter inside or outside the laser cavity. The linewidth of each channel is measure to be about 0.342 nm. As the unpumped EDF is coupled to the cavity by the optical circulator, internal cavity loss increases due to the increasing insertion loss. Output wavelengths move towards short wavelength since gain saturation effects is decreased[9], however, each laser linewidth is easily compressed to 0.186 nm, as shown in Fig. 4(b).

By using another 5.9-m Hi-Bi fiber, this multi-wavelength laser can output 17 channels spacing on

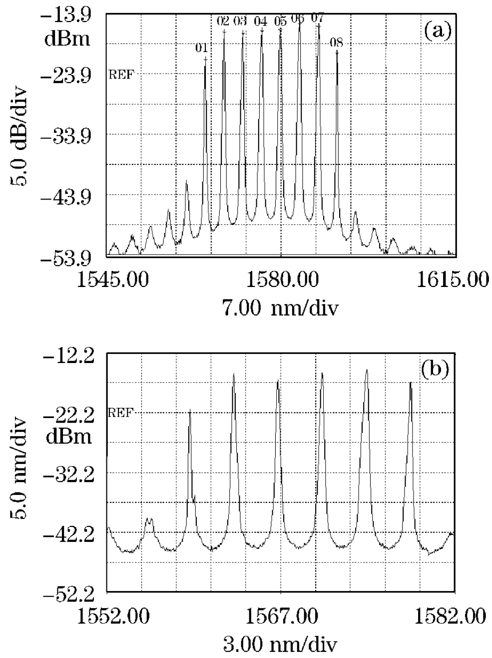

Fig. 4. The output 8 channels without unpumped EDF (a) and with unpumped EDF (b). The length of Hi-Bi fiber is 1.28 m.

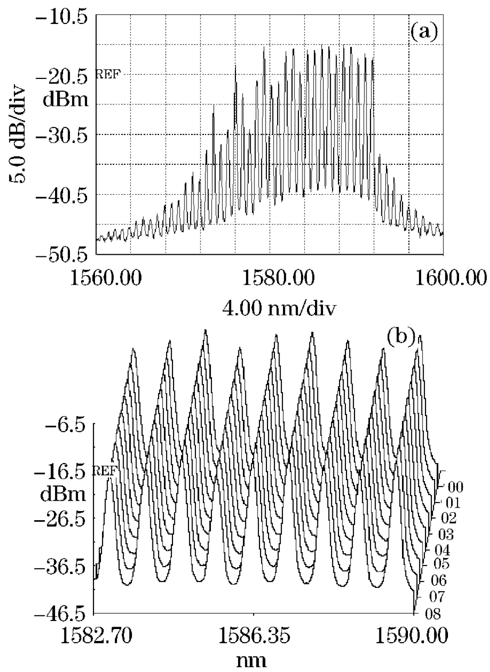

Fig. 5. Output spectra of 17 channels with 5.9-m Hi-Bi fiber in FLM (a) and repeated scan result (b).

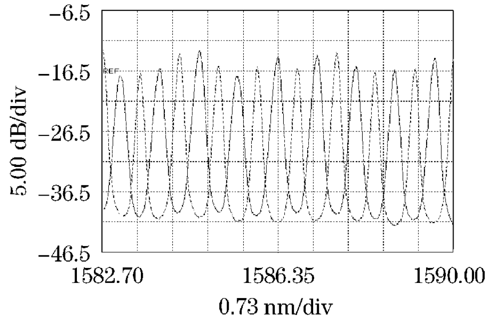

Fig. 6. 17 wavelengths can be continuously tuned over 0.4 nm.

100 GHz (ITU-grid) with SNR larger than 25 dB, as shown in Fig. 5(a). The linewidth of each channel is 0.102 nm without connecting the unpumped EDF. The output power variation between different channels is also less than 6 dB. Figure 5(b) shows repeatedly scanned output spectrum (10 times over 20 minutes). This result clearly indicates stable operation.

By adjusting the states of PC2, these 17 wavelengths can be tuned together over 0.4 nm, as shown in Fig. 6.

As Hi-Bi FLM is an interference filter, it is easily affected by outside environment. To further improve the laser's stability, the Hi-Bi fiber is twisted round an aluminum tube. Now further experiments are under way.

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