A temperature sensor based on switchable dual-wavelength fiber Bragg grating laser with a semiconductor saturable absorber mirror*

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A temperature sensor based on a switchable dual-wavelength fiber Bragg grating (FBG) laser with a semiconductor saturable absorber mirror (SESAM) is presented and demonstrated experimentally. The repetition rate of Q-switched pulses is ~17 kHz. The results demonstrate that the measured temperature has good linearity to the wavelength spacing of the two lasing wavelengths and has a temperature sensitivity of 21 pm/ºC covering a range of -10—22 °C. The experimental results prove the feasibility of the proposed temperature sensor.

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Temperature sensors based on fiber Bragg grating (FBG) laser have been widely used[1-6]. Two kinds of FBG lasers in wavelength demodulation, single-wavelength and dual-wavelength FBG lasers, are used for temperature sensing. Many possibilities have been proved to generate dual-wavelength lasing, such as symmetric linear FBG Fabry-Perot (F-P) cavity[7], phase-shift Bragg gratings[8], fiber loop cavity with cascaded fiber Bragg gratings and birefringent fiber filter[9], ring cavity with polarization-maintaining chirped Moiré fiber Bragg grating (PM-CMFBG) filter[10], high birefringence FBG[11], compact fiber filter with fiber modal interferometer and an FBG[12], chirped two-phase-shifted grating filter[13], and polarization-maintaining FBG[14]. In our previous studies, we reported dual-wavelength FBG lasers with semiconductor saturable absorber mirror (SESAM) and asymmetric linear FBG F-P cavity and their applications in photonic generation of microwave and millimeter waves[15-18].

In this paper, we present and experimentally demonstrate a novel switchable dual-wavelength FBG laser with an SESAM for temperature sensing. A switchable dual-wavelength lasing is achieved and the effect of temperature on wavelength spacing is investigated.

The model construction of the experimental structure is shown in Fig.1. A 980 nm laser diode (LD) with the maximum power of 500 mW is used for pumping the highly Er^{3+} doped fiber (EDF) via a wavelength division multiplexing (WDM) coupler of 980 nm/1 550 nm. The cavity consists of a couple of uniform FBG1 and FBG3 as the cavity mirrors connected by a length of ~25 cm highly Er^{3+} doped fiber (Er110-4/125, nLIGHT Corporation) with the numerical aperture (NA) of 0.19. The FBG2, connected with a temperature controller, is used as the temperature sensing element. The used SESAM model is SAM-1550-30-X (BATOP GmbH, Germany), and its wavelength ranges from 1 480 nm to 1 640 nm, the loss of unsaturated absorption is 30%, modulation depth is 18%, and the saturation flux is 70 μJ/cm^2. The operation temperatures of the two FBGs (FBG1 and FBG3) are controlled by temperature controller (Opwit Laser CA8004 System), and the output spectrum is measured by an optical spectrum analyzer (OSA, MS9710C, Anritsu) with 0.05 nm resolution via Coupler1 with output ratio of 90:10. All elements in our setup are connected by single-mode fibers (SMF-28).

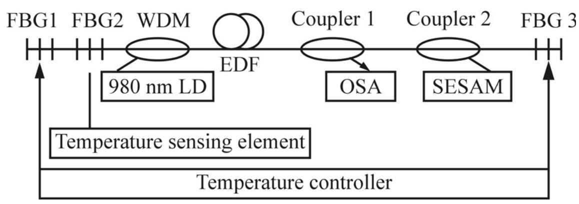

Fig.1 Temperature sensor based on FBG laser with an SESAM

When the operation temperature of FBG1 is 10 °C and that of FBG2 is 32 °C, the transmission spectrum of the two cascaded fiber Bragg gratings is shown in Fig.2. Two central wavelengths, 1 549.96 nm and 1 549.38 nm, are obtained. By incorporating FBG1 and FBG2 into the linear cavity with an SESAM as saturable absorber (SA), as shown in Fig.1, a passively Q-switched dual-wavelength

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lasing will be observed, as shown in Fig.3.

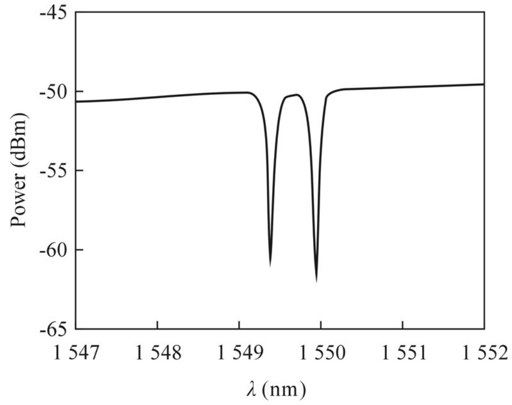
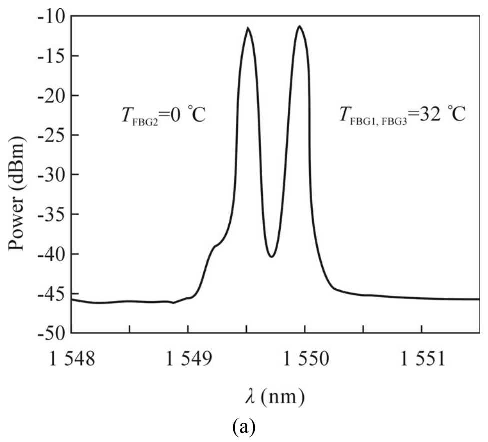


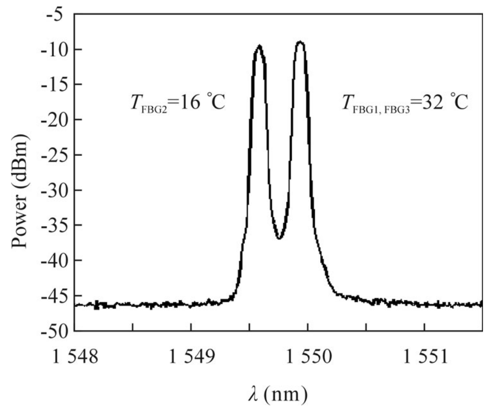
Fig.2 Transmission spectrum of the two cascaded fiber Bragg gratings

Keeping the two identical uniform gratings FBG1 and FBG3 at the same temperature of 32 °C, and changing the operation temperature of FBG2, a tunable switchable dual-wavelength lasing will be observed. When FBG2 works at 0 °C, a dual-wavelength simultaneous oscillation at 1 549.232 nm and 1 549.92 nm with signal-to-noise ratio (*SNR*) of >35 dB is achieved with the pump power of 310 mW, as shown in Fig.3(a), and the wavelength spacing is 0.688 nm. When FBG2 works at 16 °C, a dual-wavelength simultaneous oscillation at 1 549.6 nm and 1 549.936 nm with the *SNR* of >35 dB is achieved with the pump power of 310 mW, as shown in Fig.3(b), and the wavelength spacing is 0.336 nm.

When FBG1 and FBG3 work at 32 °C, and FBG2 works at 20 °C, a switchable dual-wavelength simultaneous oscillation at 1 549.666 nm and 1 549.9 nm with the wavelength spacing of 0.234 nm is achieved, and the output power of the dual-wavelength lasing as a function of pump power is plotted in Fig.4. The threshold pump power is ~292 mW with slope efficiency of 0.269% at1 549.666 nm lasing. For 1 549.9 nm lasing, the threshold pump power of ~278 mW with a slope efficiency of 0.264% is obtained. This is because the connection loss and the intra cavity loss are large, the lasing slope efficiency is lower, and the lasing threshold power



(a)



(b)

Fig.3 Output spectra of the switchable dual-wavelength FBG laser with an SESAM (T_{FBG1}=T_{FBG3}=32 °C, T_{FBG2}= (a) 0 °C; (b) 16 °C)

is large. It demonstrates that different lasing wavelengths have different slope efficiencies and threshold powers, and the oscillation threshold power at 1 549.666 nm is larger than that at 1 549.9 nm, which is consistent with Fig.2. The output waveform of the switchable fiber laser is shown in Fig.5. A repetition rate of 17 kHz can be obtained.

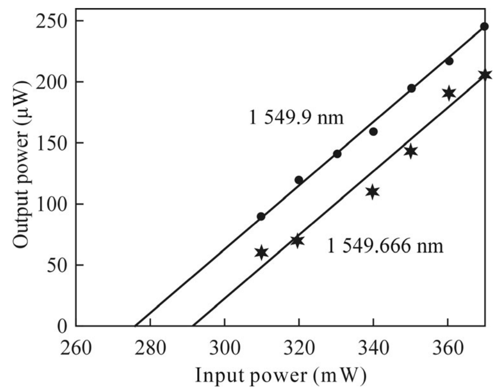


Fig.4 Output performance of the dual-wavelength FBG laser

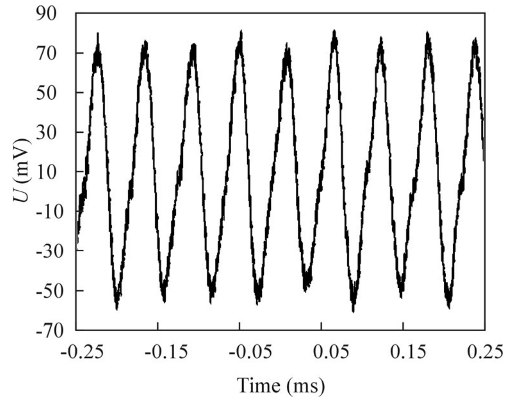


Fig.5 Output waveform of the switchable fiber laser

Keeping the two identical uniform gratings FBG1 and

FBG3 at the same temperature of 32 °C, the output spectrum of the dual-wavelength FBG laser is a function of the operation temperature of FBG2, and the wavelength spacing of the generated dual-wavelength lasing is also a function of the operation temperature of FBG2, as shown in Fig.6. It demonstrates that the wavelength spacing is inversely proportional to the operation temperature of FBG2. When the operation temperature of FBG2 increases from −10 °C to 22 °C, the wavelength spacing will decrease from 0.884 nm to 0.192 nm, and the temperature sensitivity is 21 pm /°C.

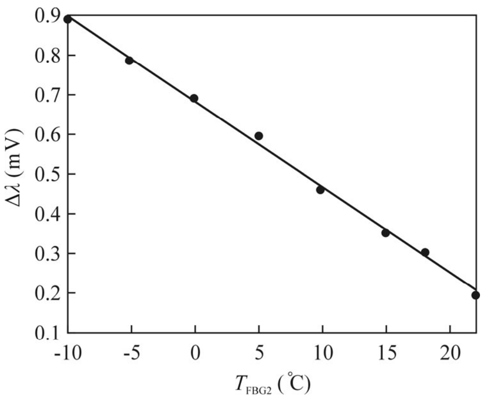


Fig.6 Effect of operation temperature of FBG2 on wavelength spacing

In this paper, we present and experimentally prove a temperature sensor based on a dual-wavelength FBG laser with an SESAM. The wavelength spacing of the generated dual-wavelength lasing is a function of the operation temperature of FBG2. When the operation temperature of FBG2 increases from −10 °C to 22 °C, the wavelength spacing will decrease from 0.884 nm to 0.192 nm, and the temperature sensitivity is 21 pm /°C.

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