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Modulated dual-wavelength Er-doped fiber laser based on a semiconductor saturable absorber mirror

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ABSTRACT

A modulated dual-wavelength Er-doped fiber laser based on a semiconductor saturable absorber mirror (SESAM) is proposed and experimentally demonstrated. The proof of concept device consists of two cascaded fiber Bragg gratings and a semiconductor saturable absorber mirror. By changing the operation temperature of the fiber Bragg grating and adjusting the polarization controller, stable dual-wavelength modulated pulses are obtained. Results demonstrate that dual-wavelength simultaneous oscillation at 1549.69 nm and 1550.5 nm (1548.2 nm and 1549.69 nm) is achieved with the pump threshold power of ~110 mW, pulse repetition rate is a function of the operation temperature of fiber Bragg grating. Our experimental results demonstrate the new concept of SESAM based modulated dual-wavelength fiber laser and the technical feasibility.

1. Introduction

Dual-wavelength Er-doped fiber lasers with advantage of simple, compact construction and low cost have attracted considerable interests in recent years for their potential applications in microwave photonics, optical WDM systems, differential absorption spectroscopy measurements, fiber optic sensing, military and environmental sensing [1–6]. Till now many possibilities have been proposed to generate dual-wavelength lasing, such as cascaded fiber Bragg gratings (FBGs) in the laser cavity [7],optical choppers [8], fiber filter [9], acousto-optic modulators [10], and electro-optic modulators [11]. Semiconductor saturable absorber mirror (SESAM) [12], single-wall carbon nanotubes (SWCNTs) [13], and grapheme [14] with the advantage of low insert loss, short response times and good repeatability are usually as saturable absorbers (SAs) used in passively Q-switched fiber laser. Recently, Luo et al. reported a dual-wavelength Q-switched fiber laser based on graphene SA, with a wavelength spacing of ~ 0.2 nm [15]. In 2013, Liu et al. reported a dual-wavelength Q-switched fiber laser based on a single-wall carbon nanotube SA, with a wavelength spacing of ~ 26 nm [16]. In 2014, Sun et al. reported a dual-wavelength single longitudinal mode erbium doped fiber laser with widely tunable wavelength spacing from 2 nm to 8 nm [17]. However, using SESAM as the modulator to achieve dual-wavelength lasing is few reported.

In this paper, we propose and experimentally demonstrate a modulated dual-wavelength Er-doped fiber laser with SESAM as SA, a linear resonator is used with two cascaded fiber Bragg gratings (FBGs) as one cavity mirror and SESAM as another one, by controlling the operation temperature of the FBGs, dual-wavelength switched pulses are observed, and the wavelength spacing can be tunable by changing the operation temperatures of FBGs.

2. Experimental setup

The configuration of the experimental setup 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) with a length of ~25 cm. The doped fiber (Er110-4/125, nLIGHT Corporation) has a numerical aperture (NA) of 0.19, and the undoped fiber used is G652B standard fiber. The SESAM model used is SAM-1550-30-X, BATOP GmbH, Germany, its wavelength ranges from 1480 nm to 1640 nm, the loss of unsaturated absorption is 30%, modulation depth is 18%, and the saturation flux is 70 μJ/cm^2. All fibers used in our cavity are polarization-independent, i.e., they support any light polarization, even if this changes as a result of outside perturbations. Thus, to improve the output pulse stability, we place in the cavity a polarization controller (PC), consisting of 2 spools of SMF-28 fiber acting as retarders. The total retardation induced by the PC is a function of the fiber geometry in the spool [18]. A 1550 nm/980 nm WDM coupler is used to couple the 980 nm pump light into the cavity. Two couplers with output ratios of 90:10 and 95:5 are used. The operation is evaluated by a 1.2 GHz bandwidth

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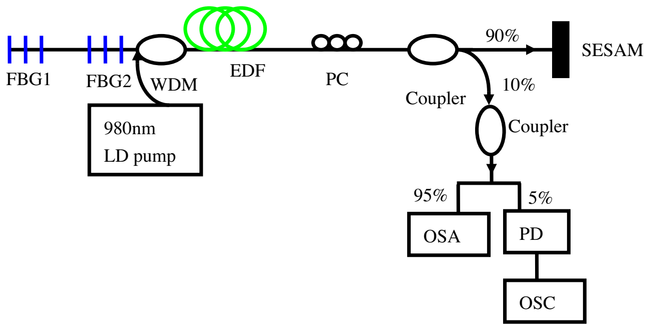

Fig. 1. Experimental setup for SESAM-based modulated dual-wavelength fiber laser.

photodetector (DET01CFC InGaAs, THORLABS INC) and a 200 MHz digital oscilloscope (TDS2022B, Tektronix). A spectrum analyzer (MS9710C, Anritsu) with 0.05 nm resolution measures the output spectrum.

3. Experimental results and analysis

The central wavelength of FBG is a function of operation temperature. When the operation temperature of FBG1 is 20 °C and that of FBG2 is 50 °C. The transmission spectrum of the two cascaded fiber Bragg gratings is shown in Fig. 2. Two central wavelengths, 1549.69 nm and 1550.50 nm, are obtained. By incorporating FBG1 and FBG2 into the linear cavity with a SESAM as SA, as shown in Fig. 1, modulated dual-wavelength lasing will be observed.

Keeping the operation temperature of FBG1 at 20 °C, the optical spectrum of the lasing is a function of the operation temperature of FBG2, as shown in Fig. 3. In Fig. 3(a), when FBG2 works at 50 °C, a dual-wavelength simultaneous oscillation at 1549.69 nm and 1550.5 nm is achieved with the pump power of 140 mW. In Fig. 3(b), when FBG2 works at −20 °C, a dual-wavelength simultaneous oscillation at 1548.2 nm and 1549.69 nm with wavelength spacing of 1.49 nm is achieved. Theoretically, the maximum wavelength spacing of 2.3 nm can be obtained by controlling the operation temperature of FBG1 at −20 °C and FBG2 at 50 °C. The peak power of lasing is mainly caused by its polarization state and can be changed by careful adjustment of polarization controller.

Keeping the operation temperature of FBG1 at 20 °C and FBG2 at 50 °C, adjusting the polarization controller, a dual-wavelength lasing with almost the same power level (∼2dBm difference) is

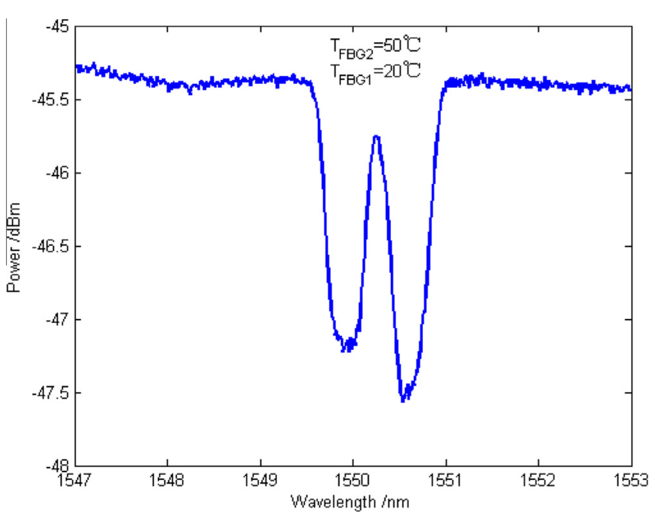

Fig. 2. Transmission spectrum of the two cascade fiber Bragg gratings.

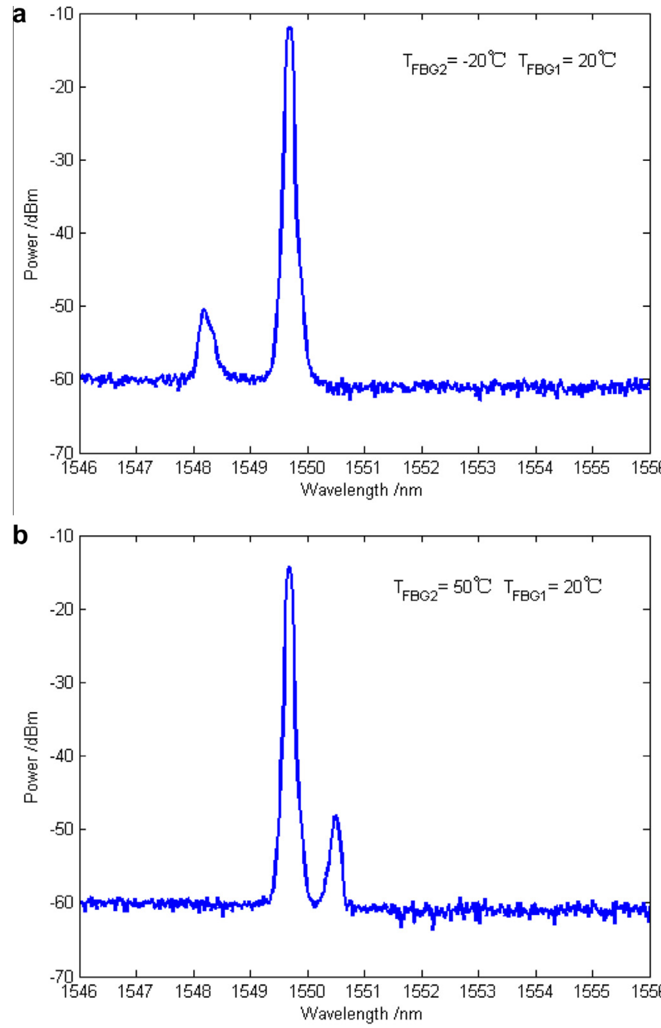

Fig. 3. Output spectrum of modulated dual-wavelength fiber laser with different operation temperature of FBG2. (a) 50 °C; (b) −20 °C.

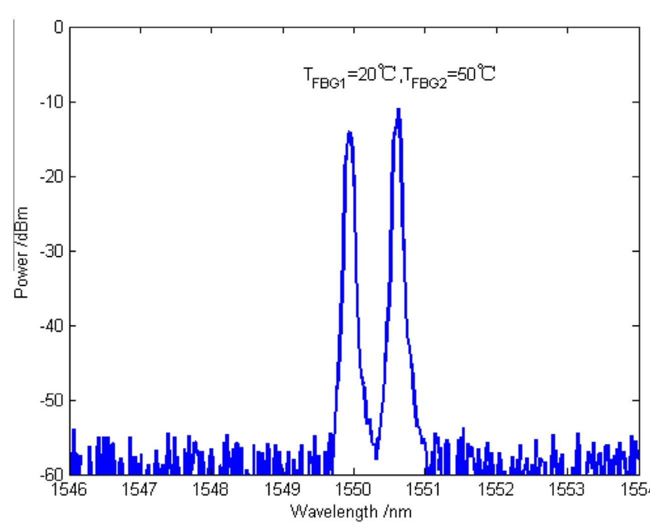

Fig. 4. Output spectrum of modulated dual-wavelength fiber laser (effect of polarization controller).

achieved, as shown in Fig. 4. The signal-to-noise ratios of the two wavelengths are more than 40 dB. The lasing wavelengths have ∼0.1 nm shift, this is caused by the lower stability of the temperature controller.