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Dual-wavelength Erbium-doped fiber laser based on Erbium-doped Zirconia fiber

A. HAMZAH[a], M. C. PAUL[b], S. W. HARUN[a,*], N. A. D. HURI[a], A. LOKMAN[a], R. SEN[a], M. PAL[b], S. DAS[b], S. K. BHADRA[b], H. AHMAD[c]
[a]*Department of Electrical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia*
[b]*Fibre Optics Division, Central Glass and Ceramic Research Institute, 196, Raja S.C. Mullick Road, Kolkata 700 032, India*
[c]*Photonics Research Center, University of Malaya, 50603 Kuala Lumpur, Malaysia*

We proposed a room temperature stable dual wavelength Erbium-doped Zirconia fiber (EDZF) based fiber laser using a polarization maintaining fiber(PMF) that cascaded with the polarization –insensitive 3dB coupler as the wavelength-selective filter in a ring configuration. Two simultaneous lasing lines at 1565.5 nm and 1567.2 nm were obtained by adjusting a state of polarisation inside the cavity with peak powers of 0.17 mW and 0.18 mW respectively at the maximum pump power of 120 mW. Both lasing lines have a signal to noise ratio of more than 30 dB and threshold pump power of about 30 mW. The fluctuation of wavelength and peak power is less than 0.1 nm and 0.1 dB over 1.5 hours, which indicates an excellence stability of the proposed laser.

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1. Introduction

Dual-wavelength fiber lasers are of great interests for such applications as the generation of soliton pulse trains in an optical fiber [1], generation of beat signals at microwave frequencies for electronic signal processing systems [2], and multi-wavelength differential-absorption-lidar (DIAL) measurement of trace gases [3]. Two main ingredients of a laser are a gain medium that provides amplification and a suitable cavity that provides positive optical feedback [4-8]. To date, extensive research has been done on gain medium materials such as advanced Erbium-doped fiber (EDF), Erbium/Ytterbium-doped fiber and Bismuth-based EDF [9-12]. These materials allow a flat-gain operation as well as higher Erbium ion concentration in the fiber without any concentration quenching effect. Other factors such as mechanical strength, temperature limitations and hygroscopic and photochromic behavior can also be important in certain environments and applications. These issues make the Erbium host material extremely important to realizing quality optical amplifiers and lasers.

Zirconia (ZrO_2) has been used extensively as a coating in various applications due to its mechanical strength and chemical corrosion resistance. It is also non-hygroscopic, does not demonstrate photochromic behavior and exhibits excellent transmission in the visible and near infrared. These qualities alone make zirconia an excellent candidate for applications in integrated optics. The most notably advantages, however, stem from its high refractive index in the visible and near infrared. High index materials tend to exhibit wide emission and absorption bandwidths. In this paper, a dual wavelength EDFL is demonstrated using a Erbium-doped Zirconia fiber (EDZF) as a gain medium and a fiber loop mirror as a wavelength selective filter in a ring configuration. The laser only uses a 2 m long EDZF instead of more than 10 m long conventional EDF as the gain medium.

2. Experimental set-up

The experimental set-up of the proposed EDZF laser is shown in Fig. 1. The laser consists of piece of EDZF, a 1480/1550 nm wavelength-division multiplexer (WDM), the polarization maintaining fiber (PMF) that cascaded with the polarization–insensitive 3dB coupler as the wavelength-selective component of the fiber laser, a polarization controller (PC) and an optical isolator. The gain is provided by 2 m long EDZF, which was pumped through the WDM by a laser diode with maximum output of 120 mW at 1480 nm. The wavelength selective component is constructed by splicing together the outputs of a 3 dB coupler with a 3 m long PMF was inserted inside the loop. PC is used at the input of the component to rotate the polarization state and allows continuous adjustment of the birefringence within the cavity to balance the gain and loss. The isolator is used to ensure unidirectional operation of the fiber laser. The laser power is coupled out using a 90:10 coupler which provides 10% for the output and 90% for feedback inside the cavity.

The EDZF has been fabricated using in a ternary glass host, zirconia-yttria–aluminum codoped silica fiber through solution doping technique along with modified chemical vapor deposition (MCVD) [12]. With a combination of both Zr and Al, we could achieve the maximum erbium doping concentration of 4320 ppm wt in the glass host without any phase separations of rare-earths. Only a minor amount of Y_2O_3 is used in the perform to prevent cracking problem. A fiber of 125 micrometers in diameter is drawn from the fabricated preform at temperature of around 2000 ^{0}C using the conventional fibre drawing technique. The output laser is characterized using an optical spectrum analyser (OSA) with a resolution of 0.015 nm. In the ring cavity, the lasing wavelengths are defined by the transmitted peaks of the wavelength selective component. To obtain dual-wavelength laser emission, it is necessary to balance the cavity losses with the gain of EDZF for each one of the wavelengths. The wavelength interval depends on both the PMF and the PC. The side frequencies can be restrained by choosing appropriate length of the PMF.

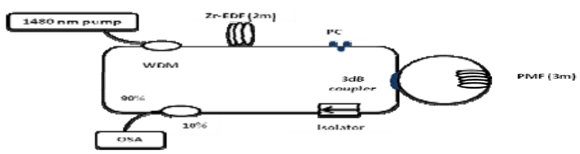

Fig. 1. Schematic diagram of the setup for dual wavelength ring laser utilized EDZF.

3. Results and discussion

We investigate the output power against the 1480 nm pump power characteristic of the laser using an OSA and the result is shown in Fig. 2. Inset of Fig. 2 shows the output spectrum of the laser emitting two simultaneous lasing lines at 1565.5 nm and 1567.2 nm with a wavelength separation of 1.7 nm at a maximum pump power of 120 mW. The optical signal to noise ratio (SNR) of each lasing lines is over 30 dB and the spectral width of each line is very small. As shown in Fig. 2, the output laser power of the lasers increases against pump power with slope efficiency of about 2% for each lasing lines. It is also observed that the threshold pump powers for lasing lines of 1565.5 nm and 1567.2 nm are obtained at 30 mW and 29 mW, respectively. At the maximum pump power of 120 mW, the output powers of 0.17 mW and 0.18 mW are obtained at 1565.5 nm and 1567.2 nm, respectively. The amplitude different among the two lasing lines is less than 0.3 dB which indicates an excellent equilibrium in the dual-wavelength oscillation.

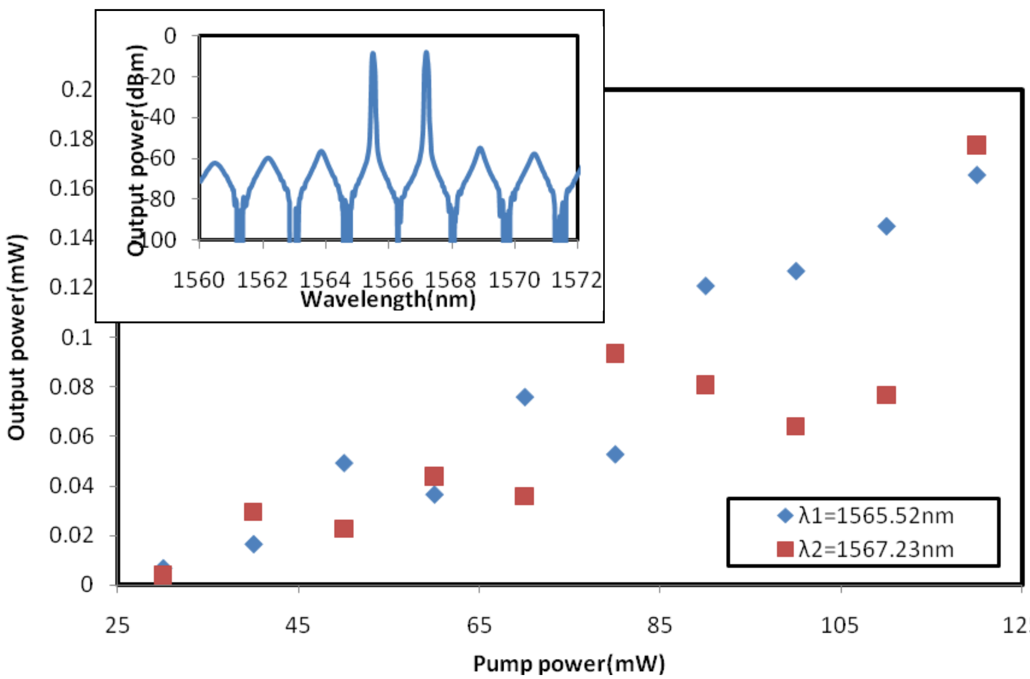

Fig. 2. The output laser power against 1480 nm pump power for both lasing lines. Inset shows the output spectrum of the dual-wavelength laser at 120 mW pump power.

Fig. 3 shows the output spectra of the dual wavelength EDZF laser with fourteen times repeated scans at 5 minutes intervals in nearly one and half hour. As shown in the figure, the stability of the dual-wavelength operation of the laser at room temperature was very good and no significant drift in wavelength or variation was discovered under invariant pump power. The multi-wavelength BFL lases stably with the fluctuation of wavelength and peak power is less than 0.1 nm and 0.1 dB over 1.5 hours. Temperature variations and mechanical vibrations were small as the experiment was conducted in a laboratory; thus the drift of the spectral profile was minimal. These results show that the proposed configuration is suitable for the dual-wavelength applications in sensor and optical communication networks.

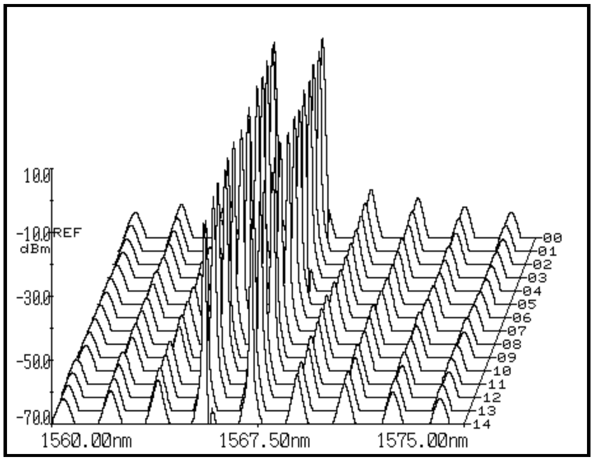

Fig. 3. Spectral evolutions of the proposed dual-wavelength EDZF laser against time. (The laser spectrum was scanned at every 5 minutes).

4. Conclusion

A dual wavelength fiber ring laser has been demonstrated experimentally using a fabricated EDZF in conjunction with a PMF-based wavelength-selective filter. The laser operates at simultaneous wavelengths of 1565.5 nm and 1567.2 with peak powers of 0.17 mW and 0.18 mW respectively at the maximum pump power of 120 mW. Both lasing lines have a signal to noise ratio of more than 30 dB and threshold pump power of about 30 mW. The stability of the proposed laser is very excellent where fluctuation of wavelength and peak power is less than 0.1 nm and 0.1 dB over 1.5 hours.

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*Corresponding author: swharun@um.edu.my