CONTINUOUSLY TUNABLE ERBIUM-DOPED FIBER RING LASER USING FIBER BRAGG GRATING

S. W. Harun and H. Ahmad

Department of Physics, Faculty of Science, University Malaya, 50603 Kuala Lumpur

P. Poopalan

Telekom Malaysia Photonics Research Center, University Malaya, 50603 Kuala Lumpur
E-mail: wadi72@yahoo.com

ABSTRACT: An efficient tunable erbium-doped fiber (EDF) ring laser utilizing a single fiber Bragg grating (FBG) and an optical circulator is investigated. The laser demonstrates a threshold of 3.43 mW and a slope efficiency of 12.5%. Tunability of the fiber laser is obtained by thermal tuning of the FBG. Simultaneous temperature tuning demonstrates a 0.01 nm/^{o}C variation in laser wavelength.

KEY WORDS: Fiber Bragg grating, fiber laser, tunable laser, ring laser, thermal tuning

1. INTRODUCTION

Continuous-wave wavelength tunable erbium-doped fiber (EDF) ring lasers operating in the 1550 nm band have important applications in wavelength-division multiplexing systems and sensor technology. The two main ingredients of a laser are a gain medium that provides amplification and a suitable cavity that provides positive optical feedback [1]. So far various unidirectional ring or loop configurations have been developed. Ring-structure EDF laser with transmission-type filters, such as compound-ring resonator [2], Fabry-Perot filter [3], or Mach-Zehnder interferometer [4] have been demonstrated. EDF lasers using fiber Bragg grating (FBG) in a short linear Fabry-Perot cavity with excellent results were also obtained [5], [6]. However, in a traveling wave fiber ring laser cavity, it is easier to achieve single longitudinal mode operation with a high output power [7]. In this paper, a tunable EDF ring laser using an FBG, which is incorporated into the fiber ring laser with an optical circulator, is reported.

2. EXPERIMENT

The experimental set up of the tunable EDF ring fiber laser is shown in Fig. 1. It consists of a section of an EDF, a 980/1550-nm wavelength-division multiplexer (WDM) coupler, a four-port optical circulator, a 3-dB wide band coupler (WBC) and an FBG. A 980-nm diode laser pump is coupled into the EDF via the WDM coupler. The FBG is connected to port 2 of the circulator, and reflection from the FBG is routed to port 3. The light is split to half by the 3-dB coupler. One half of the light propagates through the WDM to initiate laser oscillation. Output is obtained from the other port of the coupler. The FBG has a reflectivity of 97.4% at the center wavelength of 1553.4 nm and a 3-dB bandwidth of 0.32 nm. It has been fabricated in high germania boron co-doped fiber with a 244-nm argon ion laser and a phase mask [8]. Tunability of the EDF laser is obtained by thermal tuning of the FBG. The tuning operation can be achieved by tuning the Bragg wavelength of the FBG [9], given by $\lambda = 2n_{eff}\Lambda$, where n_{eff} is the effective refractive index and Λ is the period of the FBG. An electric oven is used to subject the FBG to temperature variation.

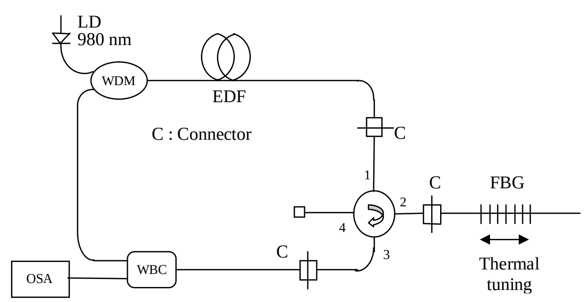

Fig. 1 Setup of a tunable EDF ring laser

3. RESULT AND DISCUSSION

The output power against the coupled-in pump power at the lasing wavelength of 1553.3 nm is shown in Fig. 2. It has a measured lasing threshold of 3.43 mW and a slope efficiency of 12.5%. A typical output spectrum of the tunable EDF ring laser is shown in Fig. 3. It has a stable output with an extinction ratio of 85 dB with respect to ground and an output spectralwidth of 0.02 nm limited by the optical spectrum analyzer resolution. The laser wavelength against temperature is shown in Fig. 4. Simultaneous temperature tuning demonstrates a 0.01 nm/°C variation in the laser wavelength. A continuous tuning range of 0.9 nm is obtained by varying the fiber temperature from 39 to 126°C, as observed from an optical spectrum analyzer (OSA).

The laser threshold is extremely low since it takes very little pump power to almost fully invert the Er^{3+} ions. The FBG slope efficiency can be improved by increasing the EDF length, using higher erbium concentration EDF and reducing the cavity loss. The laser operates as a three level laser system when excited by a 980 nm pump laser so that a length of unpumped fiber absorbs strongly at the lasing wavelength. For a given fiber length, lasing can occur only if the gain available from the bleached section equals, or exceeds, the loss of the remaining length. The use of high concentration EDF will increase the absorption per unit length and it can reduce the EDF length requirement. The low cavity loss increases the oscillating laser power in the cavity.

Wavelength tuning in the fiber laser is achieved by heating the FBG. The laser oscillates at particular wavelength, corresponding to the center wavelength of the FBG. The variation in Bragg wavelength with respect to thermal variation is generally dependent on the fiber thermal expansion and thermo-optic effects. It is given by [10], [11]

$$\Delta\lambda / \lambda = (\alpha + \xi) \Delta T$$

where α is the thermal expansion coefficient and ξ is the thermo-optic coefficient.

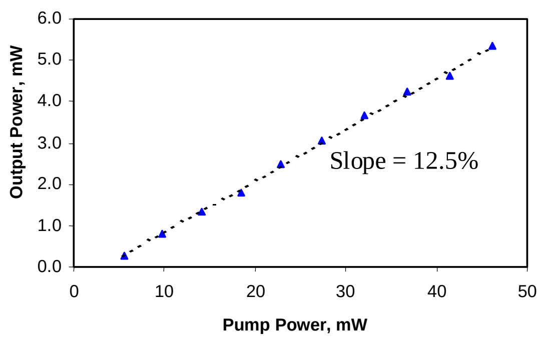

Fig. 2 Output power as a function of coupled in pump power

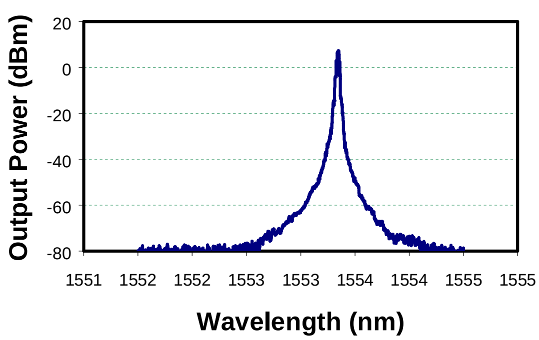

Fig. 3 Spectrum of laser output measured by optical spectrum analyzer

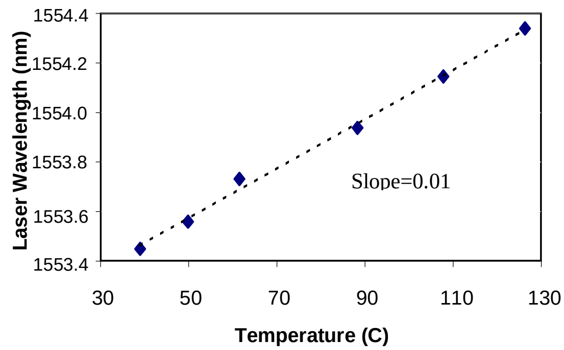

Fig. 4 Fiber laser wavelength against applied temperature

4. CONCLUSIONS

Tunable EDF ring laser using a high reflectivity FBG incorporated into the laser cavity by an optical circulator is investigated. Efficient lasing with a laser threshold of 3.43 mW and a slope efficiency of 12.5% is obtained. A tunability of 0.9 nm is obtained by varying the fiber temperature from 39 ~ 126°C. It is expected that an improved tuning range and tuning response would be found using a grating stretcher/compressor.

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BIOGRAPHIES

Sulaiman Wadi Harun received his B. Eng in electrical and electronic system engineering from Nagaoka University of Technology, Japan in 1996. Currently he is studying for his M.Sc. in Department of Physics, University of Malaya.

Prabakaran Poopalan received his B.Sc. and M.Sc from University of Malaya in 1994 and 1996, respectively. He is a researcher with Telekom Malaysia R & D and is involved in Fiber Bragg Grating Project.

Harith Ahmad is a professor at Physic department, Faculty of Science, University of Malaya. He obtained his Ph.D from University of Swansea (U.K) in Laser Technology, 1983 and has been involved in laser related research the past 15 years. He has numerous research papers published both local and international journals.