Comparison of the Effect Structure on Ring and Linear Cavity Lasers of Er-Doped Optical Fibers

Sellami Ali[1], Khalid A. S. Al-Khateeb[2], and Belloui Bouzid[3]
[1]Department of Computational and Theoretical Sciences
Faculty of Science, International Islamic University Malaysia
[2]Electrical and Computer Engineering Department
Kulliyyah of Engineering, International Islamic University Malaysia
[3]P.Box: 1803. Hafr Al-batin Community College (HBCC), 31991 Saudi Arabia
sellami2003@hotmail.com, khalid@iiu.edu.my

Abstract

Two Erbium Doped Fiber Laser configurations are conceived and constructed; A Ring Fiber Laser and a Linear Cavity Fiber Loop Laser. A comparative investigation tests were carried out. It is found that both the output power and the side mode suppression ratio (SMSR) for the two structures were significantly different. The measured laser power and the side mode suppression ratio (SMSR) of 11mW and 75dB respectively were higher for the Linear Cavity configuration. A lower output power and SMSR of 3mW and 61.5 dB respectively were obtained with the Ring laser configuration. Both lasers were pumped with a 90mW pump power, and had a reflectivity of 90 %.

I. INTRODUCTION

Tunable single-frequency lasers in the wavelength region of 1550nm are of much interest in a variety of applications such as WDM optical communications, spectroscopy, and fiber sensors [1,2]. The potential advantage of these lasers lies in their narrow line-width and low intensity noise. They represent a natural source for optical fiber communications. The light is generated in the fiber itself, which can be spliced directly to other system parts. Other advantages may include high side mode suppression ratio (SMSR), low threshold, and a flat output power response. These are important design parameters in this type of lasers. Various configurations may be proposed aimed at achieving suitable combination of these characteristics. Mainly, they different types of ring cavity [3] and linear cavity [4] structures. The suggested tuning range in the conventional-band (C-band) and long-band (L-band) is reported to be 80nm [5]. The placement of the fused coupler for tapping the output from the system is critical due to the presence of amplified spontaneous emission (ASE) in the laser output. For efficient ASE filtering, the fused coupler is placed after the tunable filter [6]. Inefficient filtering can lead to the deterioration of the SMSR value, which is critical for WDM transmission.

In this paper, we report two EDFL configurations, ring cavity and linear cavity lasers. A thorough investigation of the behavioral trends regarding laser power and high side mode suppression ratio (SMSR) vs pump power for different reflectivity values were carried out. The results are interpreted to show the effect of the configuration on the power output, the SMSR, and the efficiency associated with each configuration.

II. EXPERIMENTAL SETUP

The cavity with a tunable filter is shown in Figure 1. The ring laser cavity is a loop of an erbium-doped fiber. A wavelength division multiplexing (WDM) method is used to combine the pump and the circulating laser light. The pump power 980nm is provided by a laser diode. The length of the EDF is 10m, and the core diameter is 2μm. The Er concentration in the core is 440ppm, which is co-doped with Ge and Al. The output is coupled out by a coupler of different coupling ratios, which followed the EDF. The ring is completed by closing the loop with TBF of 40 nm tuning range and an isolator. These are both necessary to ensure the wavelength selectivity of the ring cavity.

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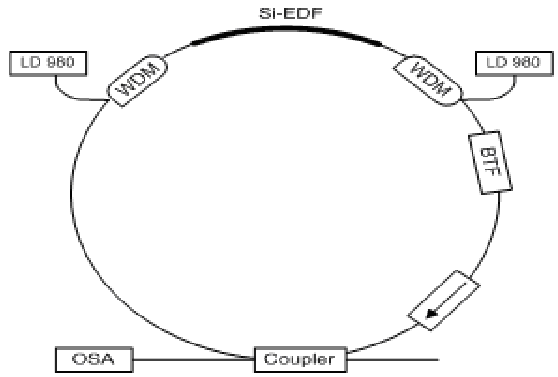

Figure 1: Experimental setup for the Er-doped fiber ring laser

The configuration of the EDFL utilizing fiber loop mirrors is illustrated in Figure 2. The fiber loop mirror is constructed using a circulator. In each fiber loop mirror there is a mechanically tunable bandpass filter, which has a 3dB passband of 1nm. The insertion loss of the tunable bandpass filter is around 1.5dB at the center wavelength of the passband. The tuning range is limited to 40nm (1525nm to 1565nm). Both tunable filters must be tuned to the same wavelength in order to suppress the ASE efficiently. The linear laser cavity consists of a 10m long erbium-doped fiber with Er^{3+}-ion concentration of 440ppm. The bidirectional pumping of the EDF is effected by two 980nm laser diodes, each of which has a pump power of 90mW maximum. A fused coupler with different coupling ratios is placed after the tunable filter in one of the fiber loop mirrors to act as an output port. All connections are fusion spliced to minimize back-reflections and to achieve a low cavity loss. An optical spectrum analyzer (OSA) with 0.01nm resolution is a principal component of the equipment used in the measurements.

III. RESULTS AND DISCUSSION

The impact of reflectivity (R%) on the performance of the laser output is investigated by giving different values to the coupling ratio of the fused fiber coupler; 40% , 50%, and 90%. The pump power from the 980nm laser diode is varied up to its maximum value of 90mW. The output power for different coupling ratios of the fiber laser is shown in Figure 3 for the ring configuration. Figure 4 is for linear cavity configuration. The interesting feature of the proposed laser systems is the low threshold power. For the ring laser system, the threshold was measured to be 3.8 mW and for linear cavity system, the threshold was between 2.5mW and 3mW, for all the reflectivity values. These values are lower than other values reported previously. It is thought that this is due to the higher gains of the selected mode in the double-pass amplification in the EDF. Furthermore, the tunable filters suppress the oscillation of the unwanted ASE in both directions. Therefore, the competition between the modes in the lasing process has been reduced effectively. The effect of reflectivity on the threshold pump power is not very significant. However, the output power and the slope

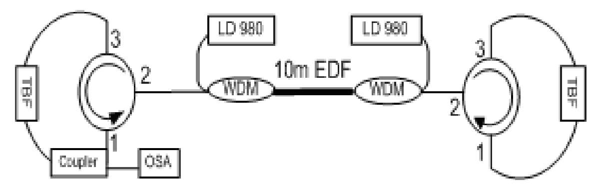

Figure 2: Architecture of erbium-doped fiber laser employing fiber loop mirrors embedded with a tunable bandpass filter.

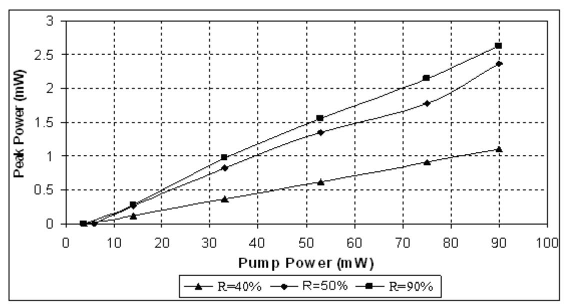

Figure 3: Output power against peak power using different coupling ratio values For Er-doped fiber ring laser system

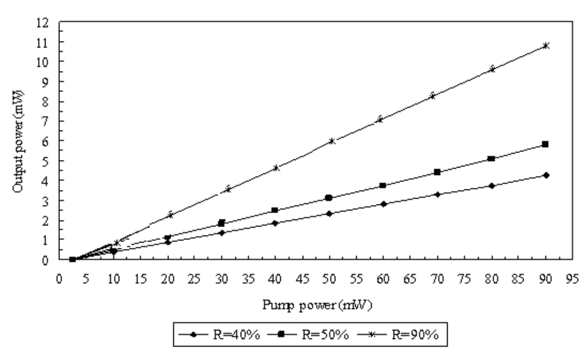

Figure 4: Measured output power against pump power for different reflectivity values at 1550nm lasing wavelength for linear cavity system.

efficiency of the proposed lasers increase in tandem with the reflectivity. For the ring laser system, the maximum output power was 3mW and for linear cavity system, the maximum output power was 11mW. Both were measured at a reflectivity of 90% and a pump power of 90mW. The conversion efficiency was then calculated from the experimental results as shown in the inset of Figures 3 and 4. This parameter is defined as the efficiency of the fiber laser to convert pump energy into lasing signal energy. The highest conversion efficiency achieved was about 12% at 90% reflectivity for the linear cavity system and for the ring laser system was about 2.85 % at 90% reflectivity.

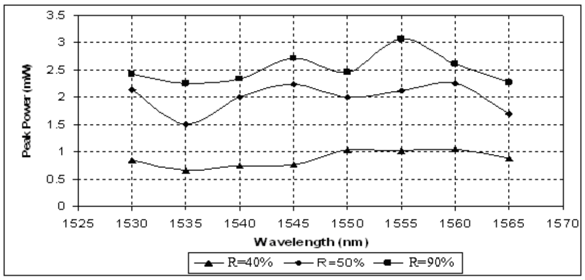

Figure 5: Output power and SMSR as function of lasing wavelength at different reflectivity For Er-doped fiber ring laser system

The tuning characteristics of the proposed system were also investigated for different reflectivity values. The SMSR and the peak laser power were also measured. The results are shown in Figures (5, 6, and 7). The pump power was set at 90mW and the lasing wavelength awa tuned from 1525nm to 1565nm with 5nm steps. The SMSR is defined as the difference between peak laser power and the noise level at 1nm away from the center of the lasing wavelength with an OSA resolution of 0.1nm. The SMSR increment is proportional to the increment in the reflectivity. The highest obtained SMSR value in the 40nm tuning range was more than 71dB. It was found that the SMSR increases from 71dB to 75dB as the lasing wavelength increases from 1525nm to 1565nm for the

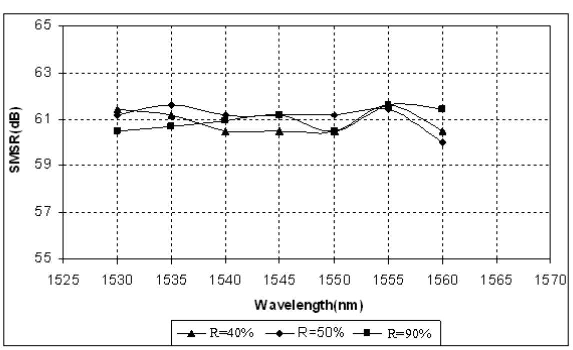

Figure 6 Experimental results of SMSR against wavelength using different reflectivity for Er-doped fiber ring laser system.

linear cavity system. As for ring laser system, the highest value for the SMSR was 61dB. The variation in the peak power for both systems was less than 1.6dB for all reflectivity values. The smallest peak power was at the low wavelength of 1525nm. The operation of the proposed fiber laser is under a deep saturation regime where the population inversion is very low.

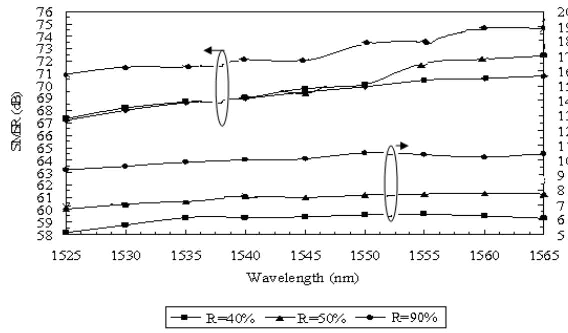

Figure 7: Output power and SMSR as function of lasing wavelength at different reflectivity for linear cavity system.

IV. CONCLUSION

Characterizing and investigating the Si-EDF is demonstrated using novel amplifier configurations. The types of EDFL structures, which were implemented and experimentally tested, are the ring and the linear cavity. The effect of the configuration on the behavioral trends of the power and the SMSR was investigated. The study demonstrated in this paper shows that on one hand, the highest laser power and SMSR were obtained by linear cavity fiber loop configurations, and on the other, the lowest power and SMSR were obtained with the ring laser configuration.

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