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A Novel Erbium-Doped Fiber Laser Source (EDFL)

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Abstract

A novel configuration of a New Erbium Doped Fiber Laser (EDFL) is constructed and analyzed. It utilizes embedded fiber-loop mirrors, tunable filters with a linear laser oscillation. Implementing the Linear Cavity Fiber Loop (LCFL) as a new configuration using three circulators and two Tunable Band-pass Filters (TBF), the output power in the Single Wavelength (SW) laser was improved. The output power of the proposed laser system is more than 18 dBm at 1560nm. The Side Mode Suppression Ratio (SMSR) in the output power in this experiment was also high, greater than 64 dB. It is found that the double filtering technique in the proposed configuration enables the system to achieve higher power and lower Amplified Spontaneous Emission (ASE) noise levels.

I. INTRODUCTION

Tunable, narrow linewidth, single frequency erbium-doped fiber lasers (EDFLs) are important laser sources for Wavelength Division Multiplexing (WDM) transmission systems, optical switching systems and performance testing of optical components [1,2]. They are tunable over a large range of the EDFA spectrum. They have low threshold, high signal-to-noise radio, moderate effective linewidth (0.1~1.0 GHz), and excellent wavelength and power repeatability. Besides the wavelength tuning range, other parameters such as high Side Mode Suppression Ratio (SMSR) and flat output power response are also important. Various configurations have been suggested to achieve the best combination of these characteristics such as the ring cavity [3] and the linear cavity [4] configurations. 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 laser from the system is critical due to the presence of amplified spontaneous emission (ASE) in the output port. For efficient ASE filtering, the fused coupler is placed after the tunable filter [6]. However, inefficient filtering of the ASE can cause much noise at the output of the laser system even with two acousto-optic tunable filters. This leads to the deterioration of the SMSR which is critical for WDM transmission systems.

The novel configuration of EDFL reported here utilizes embedded fiber-loop mirrors with tunable filters in a linear laser oscillation. The new linear cavity fiber loop (LCFL) configuration using three circulators and two TBFs, the output power in the Single Wavelength (SW) laser was improved significantly. The output power is more than 18 dBm. The SMSR in the output power is greater than 64 dB. Therefore, the double filter technique results in higher power output and lower ASE noise level.

II. EXPERIMENTAL SETUP

Figure 1 shows the structure a new configuration for a laser system which consists of three circulators; one with four ports CIR1 and two CIR2 and CIR3 with three ports each. They are used as loop-back mirrors, which allow the output fiber coupler to be inserted. The tuning of the TBF is mechanical with a 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 of this TBF is limited to 40nm (1525nm to 1565nm). Both TBFs are tuned to the same wavelength in order to suppress the ASE efficiently for a selected wavelength, to stabilize the output power, to control the spectrum shape and to minimize the insertion loss. The linear laser cavity consists of a 10m length of the first erbium-doped fiber and a 15 m of the second erbium-doped fiber with Er^{3+}-ions concentration of 440ppm. The EDF is pumped by two 980nm laser diodes which have a pump power of 220mW maximum. A fused coupler with 95% coupling ratio 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 any back-reflection and to maintain a low cavity loss. The optical spectrum analyzer (OSA) with 0.01nm minimum resolution is a principal component in the in the measurement system.

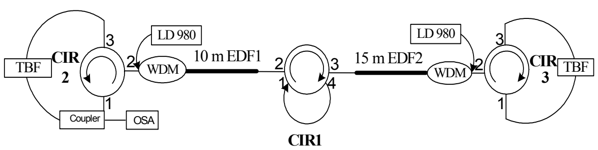


Figure 1: Architecture of erbium-doped fiber laser employing fiber loop mirrors embedded with a tunable bandpass filter.

III. RESULTS AND DISCUSSION

The effect of the pump power on the output is investigated by varying the power of the pump, which was provided by the two 980 nm laser diodes. The power of the first pump (P1) was fixed at 10 mW, while the power of second pump (P2) was varied from 10mW to 220mW in steps of 10mW. As the power of P2 reaches 220mW, the power of P1 was then raised similarly in steps of 10mW until it also reached 220mW. For the selected lasing wavelength of 1560nm, the output power of the laser system increases with increasing pump power until it becomes 18dBm, with an output coupling of 95%. Figure 2 illustrates the obtained laser outputs versus pump power of the two diodes.

Figure 3 depicts the optical spectra of the output, using the OSA with a 0.1nm resolution. It shows that when the two pumps are operated at 220mW each with an output coupling of 95%, the laser output power at the 1560nm wavelength becomes 18mW, with a 64dB side mode suppression ratio (SMSR). Figure 3(a) shows a deformation at the bottom right-hand side of the output spectrum. However, it disappears with proper adjustment of the two TBFs to obtain the standard line shape, as in Figure 3(b).

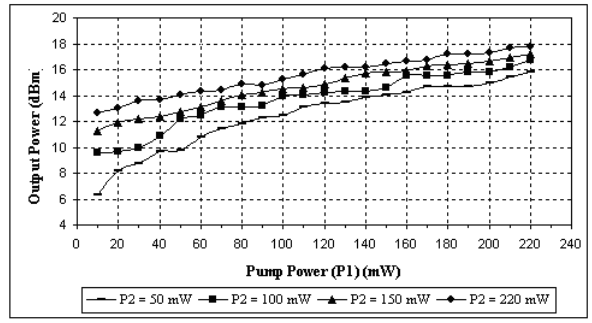
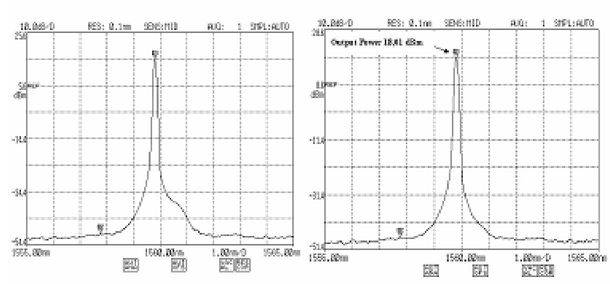


Figure 2: Experimental output power at 1560nm lasing wavelength against pump power2 at different pump powers1 per 980nm laser diode



(a) Before Adjustment (b) After adjustment

Figure 3: Output spectra of the laser system at 1560 nm (OSA resolution bandwidth of 0.1 nm)

It was observed that the location and the adjustment of the two TBFs have a significant effect on a number of parameters such as, ASE suppression, spectrum shape control and, the signal stability. Some previous work [7] has claimed that the shape of the laser signal cannot be controlled or changed. In this work, however, it has been demonstrated that it can. With good filtering of the ASE by placing the TBF before the output coupler leads, and proper adjustments, the lineshape can be adjusted and a good performance can be attained.

The laser spectrum with 0.01nm resolution and 0.5nm span is in depicted Figure 4. It proves that with the proposed laser system good stability of output optical spectrum can be achieved. Figure 5 shows the two spectra before and after the adjustment of the TBFs.

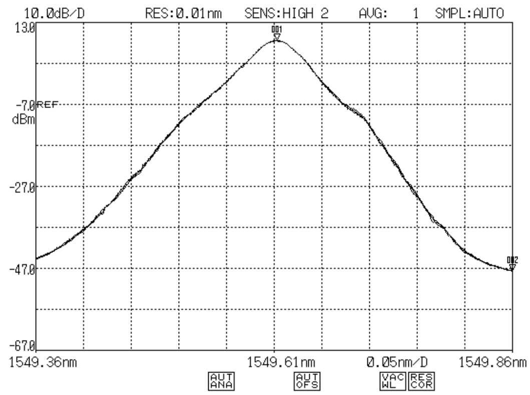


Figure 4: The stability of output optical spectra

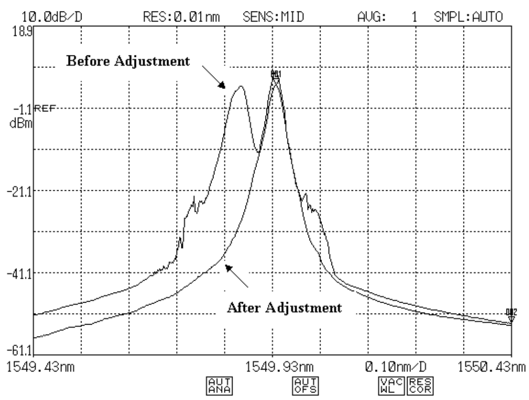


Figure 5: Controlling in form of output optical spectra

As mentioned earlier, there are two pumps (980nm). The first supplies the10m EDF and the second the 15m EDF. The output spectrum of the proposed system at 1560nm is depicted in Figure 6, for the condition when the first pump is switched off and the second varied from 10mW to 220mW. This is obtained by the OSA at a resolution of 0.1nm. It shows that the laser power is 12.32 dBm with a SMSR of more than 63 dB. However, when the second pump is switch off and the first is varied from 10mW to 220mW, the output spectrum is as shown in Figure 7. The laser power is 15.02dBm. Hence the 10m EDF gave higher output power than other. This shows the effect of fiber length on laser output is that the shorter the EDF, the higher is the output power. The distributed power along the EDF boosts up the optical ions to the excited state wit a higher probability, whereas a longer EDF consumes a bigger portion of the pump power.

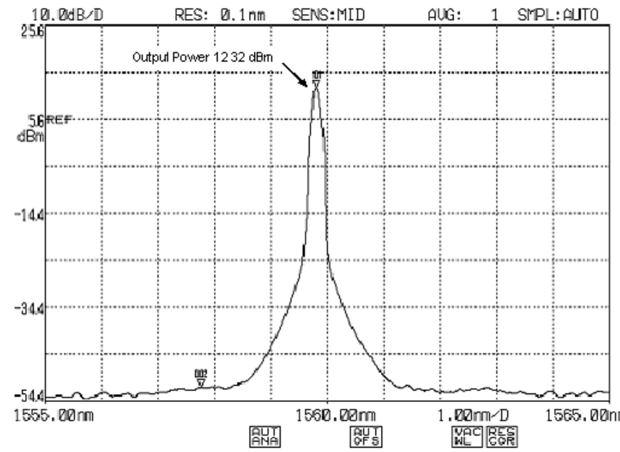


Figure 6: The output spectra of the proposed laser system at 1560nm when the first pump power is switched off

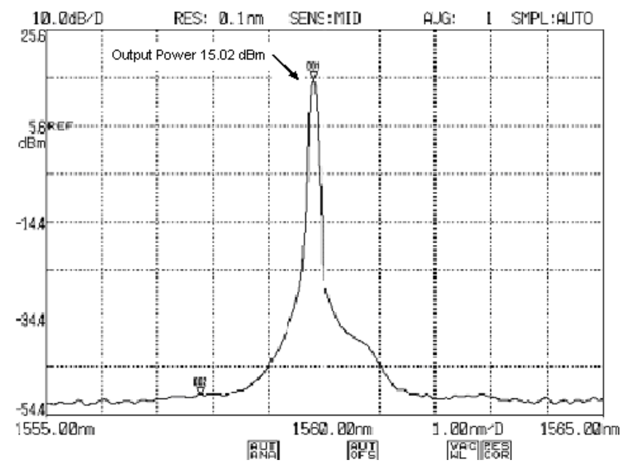


Figure 7: The output spectra of the proposed laser system at 1560nm when the second pump power is switched off

IV. CONCLUSION

The investigation demonstrated that the proposed laser configuration of the EDFL gives a high laser output power with a high Side Mode Suppression Ratio (SMSR). This is achieved by feeding the output signal of the Dual Stage Quadruple Pass (DSQP) to the input of the Dual Stage Linear Cavity (DSLC). The measurements also show that efficient noise suppression of in the linear cavity of the erbium-doped fiber laser has been successfully demonstrated in the DSLC. The two tunable filters used in this experiment to select a narrow lasing mode also suppress the other unwanted modes effectively. The coupling of 95% is selected for an optimized experimental output, in which a laser output power of more than 18 dBm with a reasonably high stability and a side mode suppression ratio of 64 dB were achieved. It is also shown that the shape of the laser signal of the erbium-doped fiber can be controlled by proper tuning the TBF at both ends.

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