Boosting Output Power of Multiwavelength Fiber Laser with Lyot Filter utilizing Hybrid Amplifier

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***Abstract*—This paper presented an investigation on the effect of hybrid amplifier to multiwavelength fiber laser (MWFL) with in-cavity Lyot filter. The hybrid amplifier comprising semiconductor optical amplifier (SOA) and erbium doped fiber amplifier (EDFA) was used to boost the lasing output peak power. The multiwavelength lasing output has improved by 20 dB, while the extinction ratio (ER) increased to 4 dB when hybrid amplifier was used. The lasing lines remain stable, with a maximum 2.94 dB of power dithering within 100 minutes of observation.**

***Index Terms*—multiwavelength fiber laser, Lyot filter, semiconductor optical amplifier, erbium doped fiber amplifier**

I. Introduction

MWFL is one of the main choice as laser source for dense wavelength division multiplexing, optical sensing and also fiber link monitoring [1]. One of the common gain medium use is SOA where it inhomogeneity can be exploited to produce high number of lasing lines and flat spectrum because mode competition is minimal [2]. EDFA is another popular gain medium were it is homogeneous in nature, thus has the advantages of low threshold, high gain, and broad bandwidth [3]. However, EDFA suffers from power instability among lasing lines because of long gain competition, thus reducing the number of lasing lines compared to SOA.

Therefore, it is possible to combine both gain media to make hybrid amplifier and incorporate them into one ring cavity fiber laser to capitalize on their advantages. Many works were realized using a hybrid amplifier, such as Raman amplifier and EDFA [4] and SOA and EDFA [5]–[7]. This paper presented a MWFL design based on the hybrid amplifier together with Lyot filter to produce multiwavelength lasing output. Hybrid amplifier has improved the laser performance of ER and peak power of multiwavelength spectrum compared to utilizing SOA only.

II. Experimental Setup

The experimental design is as depicted in Fig. 1. In this experiment, the hybrid amplifier consists a combination of SOA and EDFA. The SOA is manufactured from Qphotonics, model number Q1550, with maximum current and wavelength range of 325 mA and 1500 to 1560 nm, respectively. EDFA used was a C-band amplifier manufactured by Keopsys (model: CEFA-C-PB-HP). Polarization maintaining fiber (PMF) is a birefringence device which can produce two lights; ordinary and extraordinary lights. Subsequently, a combination of a section of PMF and polarization controller 1 (PC1) forms a Lyot filter. A polarizer is formed by PC2 and polarization dependent isolator (PDI) used to induce nonlinear polarization rotation (NPR) effect to flatten the output spectrum. Small portion of lasing output was split by a 5/95 splitter into optical spectrum analyzer (OSA) set to high resolution setting (0.02nm) for analysis.

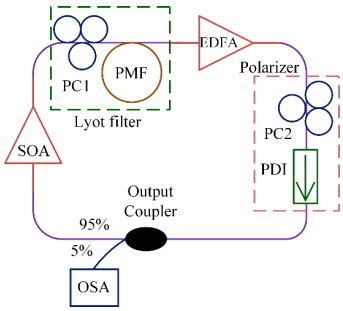

Fig. 1. The experimental setup of MWFL based on SOA and EDFA.

The multiwavelength spectrum was generated by constructive interference occurring in Lyot filter. The two lights, ordinary and extraordinary were produced in PMF provided that the polarization direction of the incoming light is 45° in between the axes of PMF. The constructive interference occurred between two lights propagating at the same phase and amplitude before recombining at the end of the PMF. SOA in the cavity not only provide gain but also became a medium for NPR effect. The effect induces the mechanism of intensity dependent loss (IDL) and intensity dependent transmission depending on polarization state change. In this work, IDL mechanism contributed to the flat and stable multiwavelength output.

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III. Results and Discussions

The erbium gain module was inserted into the cavity to increase the lasing output power. Fig. 2 depicts the comparison of multiwavelength output spectrum using hybrid amplifier with SOA current at 325 mA and EDFA output of 0 dBm. The spectra are compared fairly at similar wavelength span of 15 nm. It is clear that by adding EDFA into the cavity, the peak lasing output increases to -13 dBm while with only SOA, the peak is only at -33 dBm. This 20 dB improvement is due to higher gain produced by EDFA. Apart from that, ER of the laser has also improved by 4 dB. One trade-off from this hybrid amplifier is that the number of lasing line reduces by almost half from 79 to 40 compared to SOA gain only.

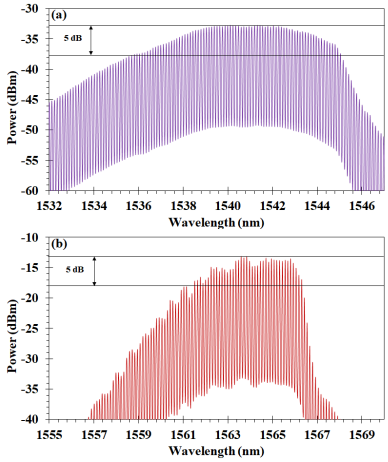

Fig. 2. Comparison of multiwavelength spectra based on (a) SOA only and (b) hybrid amplifier in the setup.

Interestingly, the multiwavelength output range has shifted toward the end of C-band region, as shown in Fig. 2(b). To investigate further, the SOA current was reduced and the lasing line was reduced, while EDFA power was fixed at 0 dBm. The number of lasing lines were decreased, from 25 to 16, with lower SOA current but the output peak power was not affected much (refer Fig. 3). Therefore, it can be said that EDFA provides power boosting to the laser and number lasing lines is controlled by SOA.

The MWFL stability was observed for 5 lasing lines, around the center of the output spectrum (1560.5 nm - 1560.9 nm), for 100 minutes as illustrated in Fig. 4. The highest power dithering of 2.94 dB was observed at 1560.8 nm and the lowest power dithering is 1.98 dB found at 1560.9 nm.

IV. Conclusion

We have demonstrated an output power boost by inserting hybrid amplifier into ring cavity of multiwavelength fiber laser with Lyot filter. The peak output power was boosted by 20 dB. The extinction ratio was also increase by 4 dB. However, the lasing output was reduced to 40 from 79 for fiber laser with SOA only. Further investigation is necessary to evaluate the full impact of hybrid amplification in the MWFL with Lyot filter.

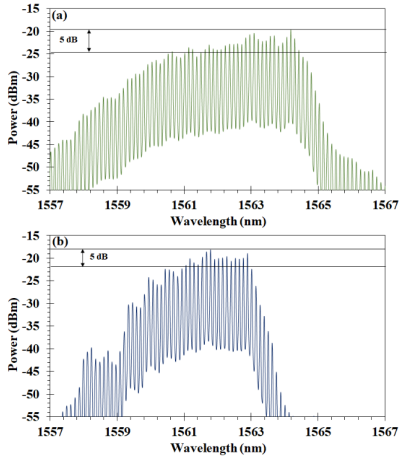

Fig. 3. The MWFL spectrum at fixed EDFA power of 0 dBm, with SOA current settings of (a) 225 mA and (b) 125 mA.

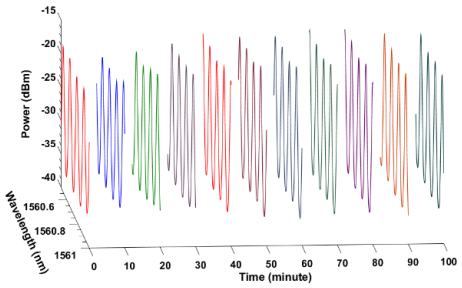

Fig. 4. The stability test of peak power based on the hybrid amplifier.

Acknowledgment

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