2018 IEEE 7th International Conference on Photonics (ICP)

Multiwavelength Brillouin-erbium Fiber Laser in Linear Cavity

Mirsa Nurfarhan Mohd Azhan, Noran Azizan Cholan, and Rahmat Talib
Faculty of Electrical and Electronics Engineering
Universiti Tun Hussein Onn Malaysia
86400 Parit Raja, Batu Pahat, Johor, Malaysia.
mirsa.nurfarhan@gmail.com, noran@uthm.edu.my, rahmat@uthm.edu.my

Abdul Hadi Sulaiman
Institute of Power Engineering,
Universiti Tenaga Nasional,
Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia.
hadisulaiman4@gmail.com

***Abstract*—A multiwavelength Brillouin-erbium fiber laser (BEFL) is proposed in this work. The proposed multiwavelength BEFL utilizes a virtual mirror in the linear cavity. The virtual mirror comes from the effect of backward stimulated Brillouin scattering of a 20 km single mode fiber. With this design, five laser lines can be obtained at the pump power of 165 mW. The multiwavelength BEFL has wide tunability from 1530 nm to 1565 nm. It also has low threshold pump power of 20 mW.**

Keywords—fiber laser; stimulated Brillouin scattering; fiber non-linearity.

I. Introduction

Fiber lasers have developed rapidly in recent years as a result of the advancement of laser diode and optical fiber technologies. Consequently, fiber lasers have been applied in many areas such as in security, medicine, defense, industry and communication systems [1]. In fact, more fiber laser applications is expected to be discovered in the near future. Fiber lasers can be realized with many techniques. Among them are Raman fiber laser [2], fiber optical parametric oscillator [3], erbium-doped fiber laser [4], Brillouin fiber laser [5] and Brillouin-erbium fiber laser (BEFL) [6]-[13]. BEFLs have the advantages over the others in that they have low threshold pump power and narrow laser linewidth.

Multiwavelength BEFL consists of many Stokes lines with a wavelength spacing of 0.08 nm (10 GHz). The first demonstration of multiwavelength BEFL was reported by Cowle [6]. Since then, many technologies or techniques have been developed to improve the performances such as the number of laser lines, tunability, stability, linewidth, compactness, flatness and design complexity. Among the techniques reported are utilizing Sagnac loop filter [7], ring cavity [8], self-seeded design [9]-[11], four wave mixing [12] and composite cavity [13]. In this work, a multiwavelength BEFL with a virtual mirror in a linear cavity is presented. With this proposed design, as many as five laser lines with wide tunabilty can be obtained at the pump power of 165 mW.

II. Methodology

The experimental setup to generate a multiwavelength BEFL is shown in Fig. 1. The multiwavelength BEFL is a type of a linear cavity where the one end is formed by a three-port circulator that acts as a mirror, while the other end is provided by a 20 km SMF that behaves as a virtual mirror. Oscillating signals in the laser cavity obtain C-band amplification from an erbium-doped fiber amplifier (EDFA) in which a 980 nm laser is pumped into a 10 m erbium-doped fiber. A tunable laser source that can be tuned over the C-band serves as the Brillouin pump (BP).

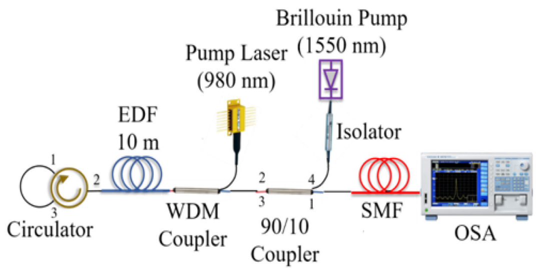

Fig. 1. Experimental setup of multiwavelength BEFL.

The mechanism for the multiwavelength BEFL is as follows; at first, the BP signal is injected into the cavity and it travels back and forth provided that it has sufficient gain for the oscillation. When the BP power goes beyond the threshold power of the SMF, the first order Brillouin Stokes (BS1) signal appears and oscillates. With the increase of pump power, BS1 is then capable to overcome the SMF threshold power, thus triggering the second order Brillouin Stokes (BS2) signal. The similar process occur for the higher-order Stokes signal.

III. Results and Discussion

Firsly, the behavior of the laser output power as the EDF pump power increases from 0 to 165 mW is investigated as shown in Fig. 2. In this case, the BP power and wavelength are set at 8 dBm and 1550 nm respectively. It can be observed that there is no or little output power for low EDF pump power. However, once the pump power goes beyond the value of 20 mW which is the laser threshold power, the laser output power increases exponentially. The reason for no or little output power below the laser threshold power is that the dominance of spontaneous emission over stimulated emission. However,

978-1-5386-1187-6/18/$31.00 ©2018 IEEE

when the pump power exceeds the threshold power, stimulated emission dominates over spontaneous emission, thus triggering signal oscillation in the laser cavity.

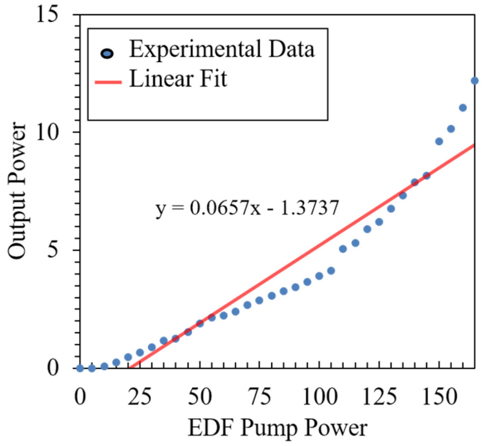

Fig. 2. Evolution of laser output power with EDF pump power.

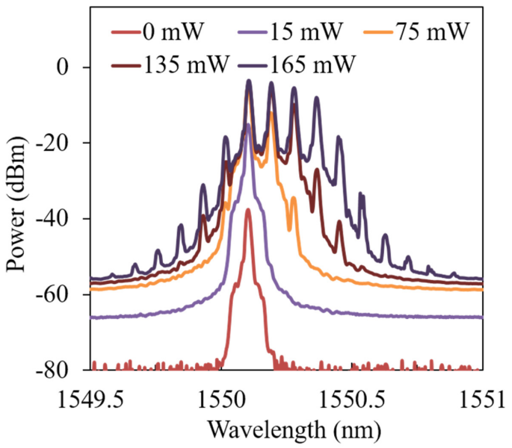

Fig. 3. Spectra of Stokes evolution as EDF pump power increases.

The evolution of the laser output spectrum as the EDF pump power increases is then investigated. The laser output spectra for the pump powers of 0 mW, 15 mW, 75 mW, 135 mW and 165 mWare plotted in Fig.3. In this case, the BP power and wavelength are set at 8 dBm and 1550 nm respectively. At 0 mW and 15 mW, only BP line exists as the EDF pump power is not high enough to trigger SBS effect. However at 75 mW, two laser lines which are BP and BS1 present in the spectrum. This illustrates that the EDF pump power is high enough to overcome the SBS threshold power of the 20 km SMF. At the EDF pump power of 135 mW and 165 mW, as many as three and five Stokes lines correspondingly are generated, as shown in Fig. 3. This suggests that a larger number of Stokes lines can be generated when the EDF pump power increases.

The tunability of the multiwavelength BEFL is afterwards monitored. Figure 4 shows the tunabilty spectra as the BP wavelength varies from 1530 nm to 1565 nm. In this case, the BP and EDF pump power are set at 8 dBm and 165 mW respectively. As seen from Fig. 8, there is no self-lasing cavity modes present in the spectrum. This illustrates the wide tunability of the proposed multiwavelength BEFL.

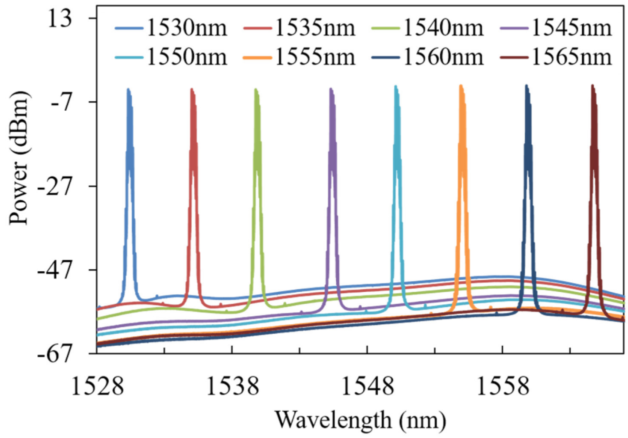

Fig. 4. Tunability of multiwavelength BEFL as a function of BP wavelength.

IV. Conclusion

A multiwavelength BEFL with a virtual mirror in the linear cavity is presented. With the pump power of 165 mW, as many as five laser lines can be generated. The multiwavelength BEFL has wide tunability from 1530 nm to 1565 nm. It also has low threshold power of 20 mW.

Acknowledgment

This work was supported in part by the Ministry of Higher Education (MOHE) Malaysia under Fundamental Research Grant Scheme (FRGS) FRGS/1/2015/TK04/UTHM/03/5 Vot 1537 and by the Universiti Tun Hussein Onn Malaysia (UTHM) under Post-Graduate Research Grant (GPPS) Vot U591.

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