Characteristics of Brillouin Fiber Laser Under Two Different Techniques

Mudhafer. H. Ali [1], Mohammed A. Saleh [2], Ali H. Abdulhadi[3]

[1] Network Engineering Department, College of Engineering, Al-Iraqia University, Baghdad, Iraq

[2] Physics Department, College of Education, Al-Iraqia University, Baghdad, Iraq

[3]Laser and Optoelectronics Engineering Department, University of Technology, Baghdad, Iraq

E-Mail englaser@yahoo.com

Mobile :07715582942

Abstract:

The effect of recycling transmitted Brillouin power (RTBP) ratio on the threshold of the single wavelength Brillouin fiber laser (SWBFL) utilizing a recycling technique (R-Technique) is investigated. Different single mode fiber (SMF) lengths are used as a gain medium for the proposed laser. The RTBP ratio is increased from 20 % to 100 % a steps of 20 % and compared within the conventional technique (C-Technique) for each gain medium length. The laser threshold within R-Technique is enhanced by 48.4 % for gain medium length of 5 km and by 28.29 % for gain medium length of 30 km as compared within the C-Technique. This reduction in the threshold ratio is attributed to the fact that at long SMF (>10 km) the effective gain medium length tends to be approximately constant.

Keywords: single wavelength Brillouin fiber laser, conventional technique, recycling technique

خصائص ليزر بريلوين الليفي تحت تقنيتين مختلفتين

ألخلاصة

تم التحقق من تاثير نسبة قدرة بريلوين المدورة على القيمة الحرجة لليزر بريلوين الليفي احادي الطول الموجي باستخدام تقنية التدوير. تم استخدام الياف بصرية احادية النمط باطوال مختلفة كوسط ربحي لليزر المقترح. اخذت نسبة قدرة بريلوين المتكررة المرسلة من 20% الى 100% ، بمقدار ثابت 20% ، وقورنت مع التقنية التقليدية لكل طول وسط ربحي. ان القيمة الحرجة لهذا الليزر مع تقنية التدوير تحسنت بقيمة 48.4% لوسط ربحي بطول 5كم و بقيمة 28.29% لوسط ربحي بطول 30كم بالمقارنة مع التقنية التقليدية. بالاضافة الى ذلك، وسط الربح المؤثر يميل للثبات للاطوال اكبر من 10كم. كنتيجة ذلك، لاطوال وسط ربحي اكبر من 10كم، تاثير نسبة قدرة بريلوين المدورة تنخفظ و يحدث اشباع في تحسين حد العتبة.

الكلمات المفتاحية: ليزر بريلوين الليفي احادي الطول الموجي، التقنية التقليدية، تقنية التدوي

Introduction

The main types of nonlinear scattering within optical fibers are stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) [1]. In optical fiber, the threshold power level for the SBS is quite lower than the SRS. It appears over the generation of a red shift backward Stokes signal that carries the most of pump power, once the input power reached the SBS threshold power level. As a result, the SBS determines the input power level in optical communication systems [1]. In contrast, this phenomenon can be used in numerous optoelectronics applications such as, optical sensors [2,3], optical amplifiers [4,5], single wavelength and multi wavelength laser sources [6–10].

In this context, achieving a lower threshold level is of utmost importance in most applications. Several approaches are proposed to obtain low SBS threshold. For instance, threshold reduction of SBS by Stokes seeds utilizing acousto-optic effect [11], core microstructuration in multifilament core fibers [12] and the bidirectional pumping methods have also been considered, in order to quicken the SBS establishment time [13]. In addition, both of recycling and laser techniques are proposed to reduce the SBS threshold to 48% [14] and 75% [15], respectively. Furthermore, modeling of SBS has been considered in order to predict the SBS Stokes and pump power along the fiber in conventional [16], recycling [17] and laser [18] technique.

In this paper, the performance of SWBFL within R-Technique is investigated under different RTBP ratios, namely, (20%, 40%, 60%, 80% and 100%) utilizing OptiSystem 10. The simulation results show that, the SBS threshold level depends strongly on RTBP ratio. In addition, the effective gain medium tends to be approximately constant for long SMF (>10 km). As a result, for longer gain medium length both of the RTBP ratio effect is reduced and threshold improvement is saturated.

Simulation Setup

The simulation setup of the SWBFL utilizing both of the conventional and recycling technique is illustrated in Fig.1 A and B, respectively. The Brillouin pump power (BPP) is obtained from a laser source (LS) with a line width of 10 MHz, wavelength of 1550 nm and maximum power of 24 mW. In this setup, the BPP is injected through port 1 of the optical circulator (OC1) then propagated through a 3-dB coupler before inserting into the gain medium, and the laser architecture operates as an SWBFL with C-Technique.

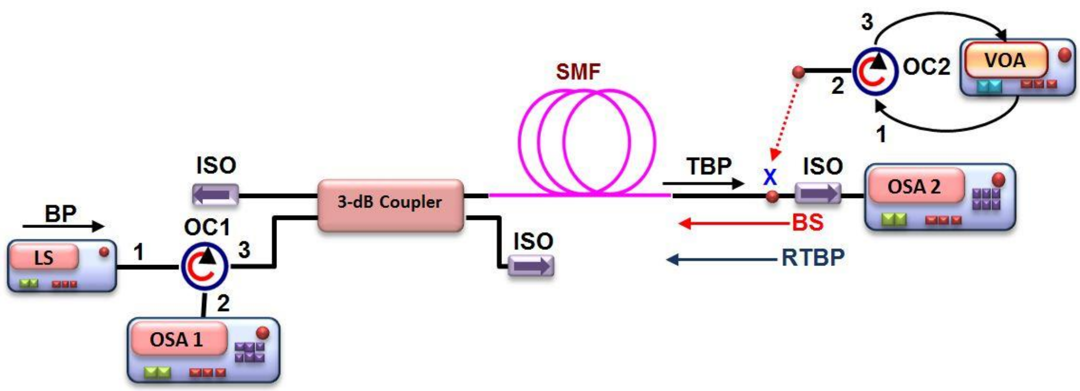

Figure 1: Simulation setup of SWBFL (configuration A) conventional technique; and (configuration B) recycling technique, with optical circulator and VOA connected to point X.

In order to reinsert the TBP inside the gain medium, another optical circulator (OC2) is connected to point X through port 2. In addition, a variable optical attenuator (VOA) is connected between port 3 and port 1 in order to control the ratio of the RTBP as depicted in Fig.1 B. The laser output power (Stokes signal) is measured through port 3 of the (OC1) via an optical spectrum analyzer OSA1 for both configurations, while the RTBP and TBP are measured via OSA1 and OSA2, respectively.

Results and Discussion

The behavior of both the Stokes power and TBP versus the BPP utilizing C-Technique are depicted in Fig.2 (a) and (b) for gain medium length 5 km and 30 km, respectively. In general, for both gain medium lengths, the increment in the pump power led to increase the TBP linearly, while the Stokes power is still close to zero. Then after a certain pump power (SBS threshold) the behavior of both the Stokes power and TBP are changed, the Stokes power is increased rapidly while the TBP is closed to saturate. This can be attributed as follow; at first the pump power was lower than the SBS threshold and the optical system work within the spontaneous Brillouin scattering. While the laser (Stokes signal) is appeared when the pump power is becoming greater than the SBS threshold as well as those caused the saturation in the TBP. In addition, when the gain medium length is increased from 5 km to 30 km, the laser threshold power is decreased from 18.76 mW to 6.19 mW, respectively. While the laser output power has increased from 4.4 mW for SMF of 5 km to 17,12 mW for SMF of 30 km at pump power of 24 mW.

The effect of the RTBP ratio on the proposed laser performance is investigated for different gain medium length. The R-Technique are compared with the C-Technique results on the same gain medium length. The results of 5 km and 30 km are illustrated in Figure (a) and (b), respectively. According to the results in Figure (a), the laser threshold within RTBP ratio of 0 % C-Technique and 100 % R-Technique is about 18.76 mW and 9.681 mW, respectively. This represents a 48.4 % improvement in the laser threshold, as well as shows good agreement with the results in [14][15], which confirm the validity of our model. For gain medium length of 30 km as depicted in Figure b), the laser threshold level is enhanced from 6.19 mW within C-Technique to 4.43 mW within the R-Technique, which represents a 28.29 % improvement in the laser threshold.

In order to clarify the effect of the RTBP ratio on the laser threshold for different gain medium length, the threshold power as a function of the RTBP ratio is depicted in Figure(4). The results show that the improvement in the threshold level of the shorter gain medium length is higher than it in the longer gain medium length as well as this improvement is saturates at gain medium length (>10 km). This can be attributed to the fact that, the effective gain medium length tends to be constant (approximately $1/\alpha$), as well as this improvement boundary shows good agreement with the results in [14,15].

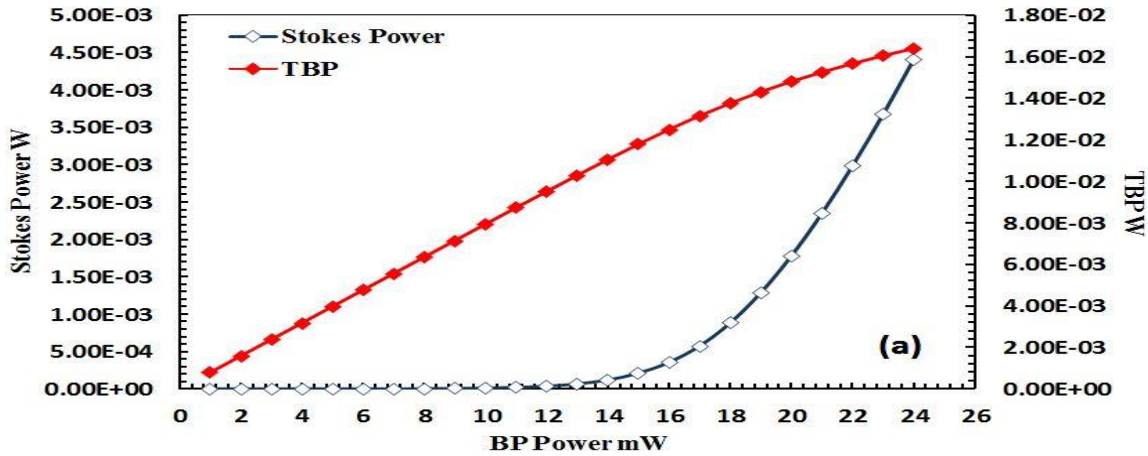

Figure 2-a: Stokes Power and TBP versus BPP for gain medium length: (a) 5 km, (b) 30 km.

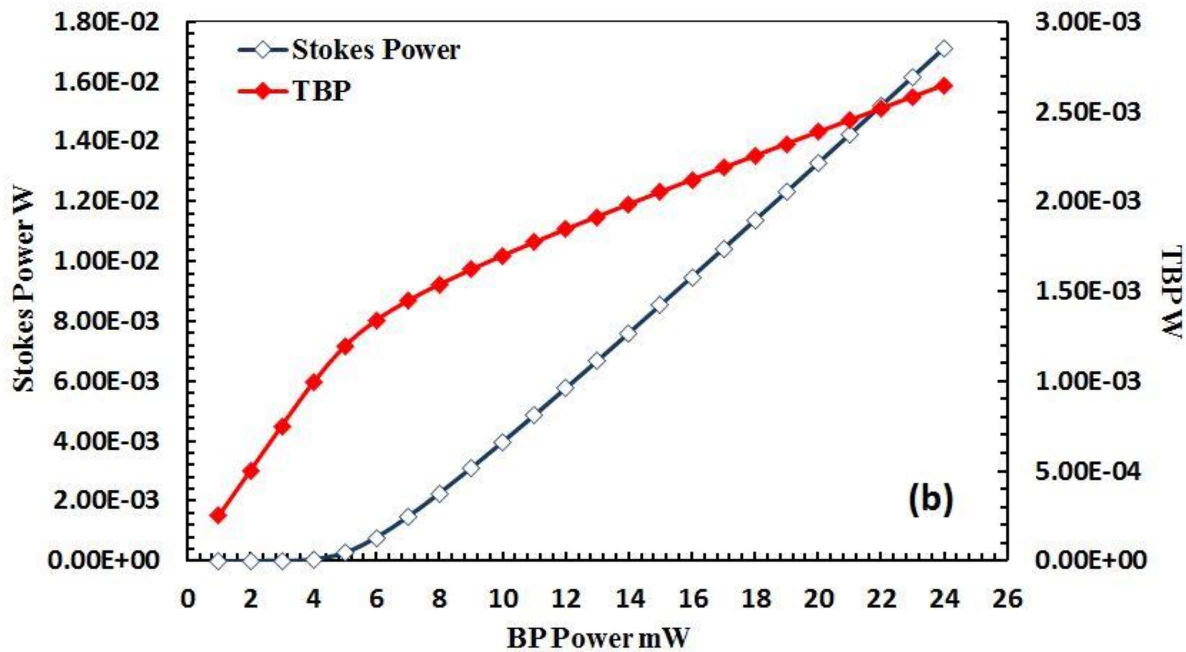

Figure 3-b: Stokes Power and TBP versus BPP for gain medium length: (a) 5 km, (b) 30 km.

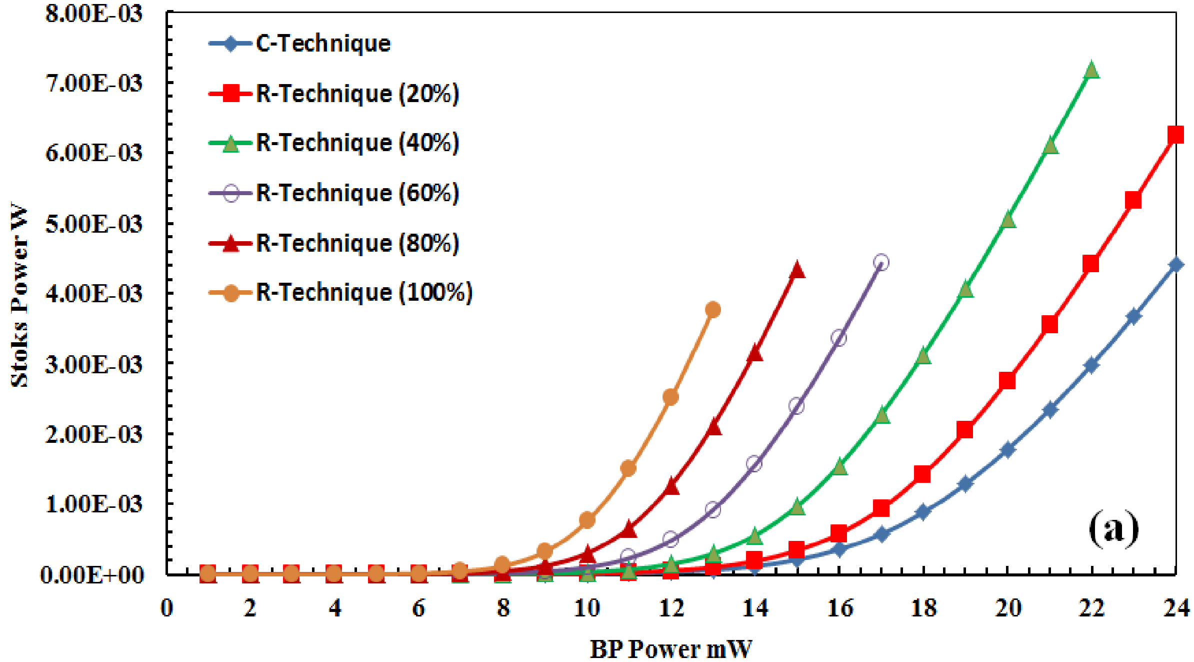

Figure 3-a: Stokes power versus BP power for gain medium length: (a) 5 km SMF, (b) 30 km

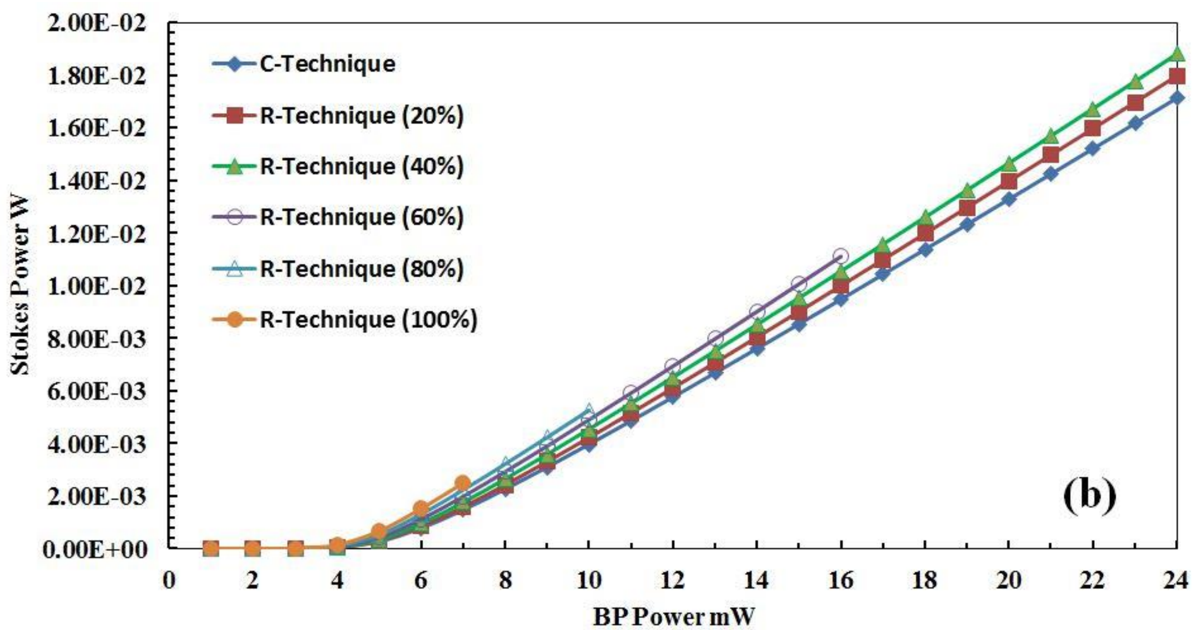

Figure 3-b: Stokes power versus BP power for gain medium length: (a) 5 km SMF, (b) 30 km SMF.

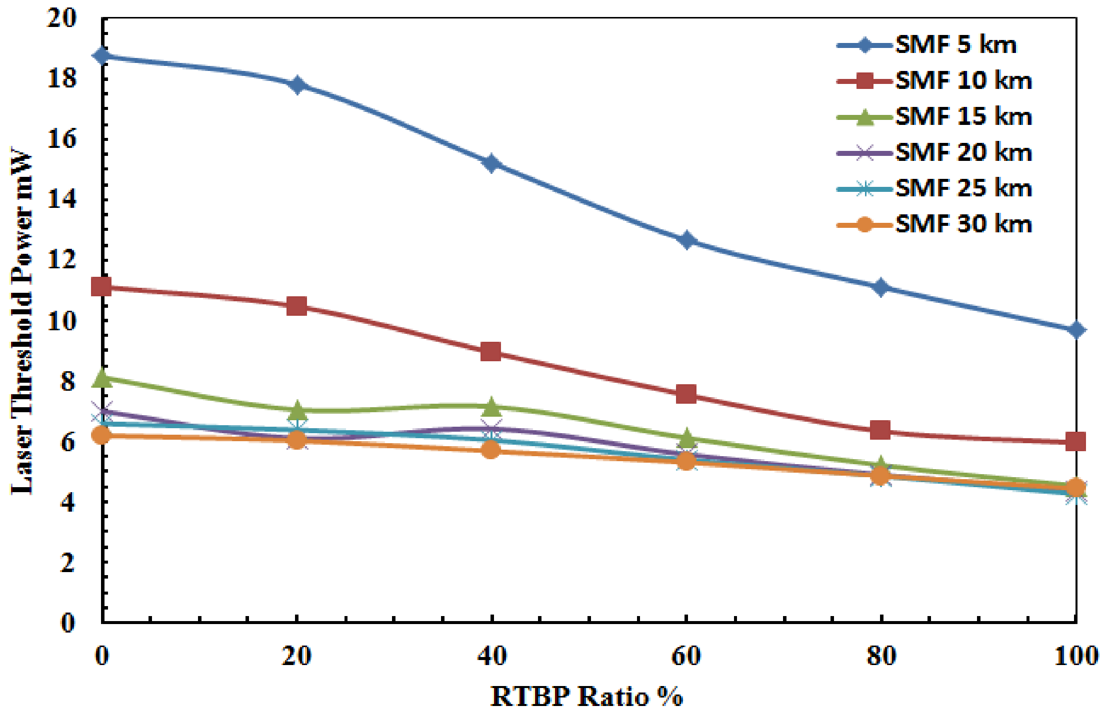

Figure 4: Laser threshold power versus the RTBP ratio %.

Conclusions

We theoretically investigated the effect of the RTBP ratio on the threshold of SWBFL via recycling technique. The laser threshold depends strongly on the RTBP ratio, and improved as the RTBP ratio is increased. The effect of the RTBP ratio on the laser threshold is reduced as the gain medium is increased, as well as the threshold improvement is saturated for long gain medium length (>10 km).

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