Double-Brillouin-Frequency Spaced Multiwavelength Fiber Laser using High Resolution OSA

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Abstract - We successfully demonstrate a double-frequency spaced multiwavelength Brillouin fiber laser (MWBFL) using a dispersion shifetd fiber (DSF) as the nonlinear medium. The spectrum of the MWBFL is observed by using a standard optical specrumanalyser (OSA) with a resolution of 0.02 nm. for comparison purpose, further verifcation of the double spacing spectrum is done by observing the spectrum using a high resolution OSA with the resolution of 0.16 pm. We realized that even thespacing between two consecutive of stokes is double-frequency shifted,however there are still hidden stokes wavelength spacing of 0.08 nm.From this observation it can be deduced that even-though the above described ring configuration should by all means only allow for double-spaced Stokes outputs, in reality both even and odd Stokes lines propagate in both directions in the laser cavity.

Keywords : BrillouinFiber Laser; Mutliwaelength; Double-frequency

1. INTRODUCTION

The demand for high usage of data volume in communication incredibly soaring especially in the internet supplication which is capable to be fullfil by wavelength-division-demultiplexing (WDM) systems [1]. WDM consider as a key technology where it is worth for enhancing the transmission capacity and sensor application[2]. Laser source is a part of WDM system that capable to be develop by utilizing multi-wavelength laser source. Multiwavelength fiber laser fascinate the attention due to their low cost [3], flat output and allow for utilisation of the large optical fiber bandwidth.

The DWDM system requires multi-wavelength laser sources and constant wavelength spacing for its operation.The realization of the nonlinear effect to generate muti-wavelength under various phenomenon such as Stimulated Brillouin scattering (SBS), Raman Scattering and nonlinear polarization effect [4]. Brillouin fiber laser (BFL) and hybrid brilloin-erbium fiber laser (BEFL) commonly achieve multiple stokes lines with a constant spacing of 0.08nm or 10 GHz in frequency domain.Simple structure and flexible wavelength tuning of BFLs exploit stimulated Brillouin scattering (SBS) in the optical fiber acting as a nonlinear gain medium gardener many attentions. Up to 11 Stokes and anti-Stokes lines with a 0.08-nm wavelength spacing is generated by BFL linear configution[5].However, the narrow spacing of BEFLs giving complexity in demultiplexing process which constrains their contributions in the system implementation.Most recently, multiwavelength BEFL with a 20-GHz wavelength spacing is realizedincorporated 4-port circulator, figure-of-eight configuration and photonic crystal fiber [3]. Double-spacing may be achieved by removing even-order or odd-order Stokes signals with the proposed configuration.

In this experimental observation, we demonstrate a double-frequency spaced multiwavelength Brillouin fiber laser (MWBFL) using a dispersion shifetd fiber (DSF) as the nonlinear medium. The spectrum of the

MWBFL is observed by using a standard Yokogawa optical specrum analyser (OSA) with aresolution of 0.02 nm. For comparison purpose, further verifcation of the double spacing spectrum is done by observing the spectrum using a high resolution OSA with the resolution of 0.16 pm. We realized that even thespacing between two consecutive of stokes is double-frequency shifted,however there are still hidden stokes wavelength spacing of 0.08 nm.From this observation it can be deduced that even-though the above described ring configuration should by all means only allow for double-spaced Stokes outputs, in reality both even and odd Stokes lines propagate in both directions in the laser cavity.

2. EXPERIMENTAL

Figure 1 shows the experimental setup for generation of double-frequency spaced multi-wavelength Brillouin constructed in simplest ring cavity geometry. 1.96 km dispersion-shifted fiber (DSF) with effective mode area (A_{eff}) of 12 μm^2 is used as a nonlinearity medium for longer amplifier spacingthrough Stimulated Brillouin Scattering (SBS). A tunable laser source (TLS) with the output power of 7.6 dBm at 1550 nm used as the Brillouin pump (BP)is injected into the Erbium-doped Fiber Amplifier (EDFA) to be amplified to an output power about 20 dBm. The amplified output channel through an optical isolator, which is connected to one of the 50% input ports of the 3 dB fused optical coupler. The optical isolator is used as a protection device as to avoid any reflected power that may damage the TLS. The 100% port of the coupler is connected to a DSF which functions as the medium for generating the Brillouin Stokes while the other end is connected to 90% port of 90/10 coupler. The 100% port 90/10 is then coupled to another 50% port of 1x2 3 dB coupler, thereby completing the ring cavity. The 10% port of the 90/10 coupler is fed into an ANDO AQ6370B optical spectrum analyzer (OSA) with a resolution of 0.02 nm. In generating the Brillouin Stokes, the process takes place when the optical power of the BP signal exceeds the threshold power for yielding a downshifted first Stokes signal (S1) through a nonlinear process The generated S1then travels from the DSF in the opposite direction of the BP signal, in a clockwise direction. The first Stokes signal, S1, is tapped out at 10% port of the fused coupler and the remaining 90 % power of the S1 is then used to generate the even Stokes line such as S2, as long as the signal power exceeds the threshold in the anti clockwise direction [6]. This process repeats until a point whereby the signal power is below the threshold of the subsequent Stokes lines. For comparison purpose of the output spectrum, the laser output is also measured by using a high resolution APEX AP2051A OSA with a resolution of 0.16 pm as to provide a more detailed analysis which has not been done before.

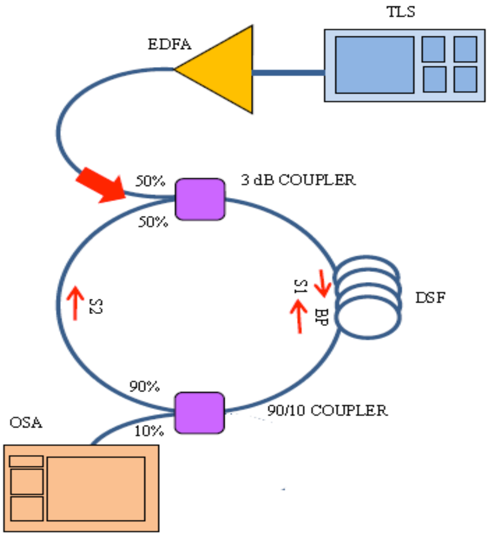

Fig. 1. Schematic diagram of the proposed double-spaced multi-wavelength Brillouin fiber laser.

3. RESULTS & DISCUSSION

Figure 2 shows the obtained spectrum from the proposed fiber laser. The BP is set at an operating wavelength of 1550 nm, with a peak power of 20 dBm after EDFA amplification. The spectrum of backward Brillouinscattering is obtained using the OSA with the 0.2 nmresolution is shown in Figure 2(a). Using this OSA, three Brillouin Stokes lines and two anti-stokes are observed, which Brillouin-frequency multi-wavelength spaced measured is 0.16 nm or 20 GHz in frequency domain. Based on figure 2(a), peak power for 1st stokes, 2nd stokes and 3rd stokes is -6.75 dBm, -11.81 dBm and -44.24 dBm respectively. By increasing the BP power, more Brillouin stokes may generate because of the cascaded SBS process. In order to get a more accurate measurement of Brillouin spectrum, the output port is fed into the 0.16 pm of high resolutionand plotted in figure 2(b).

(a)

(b)

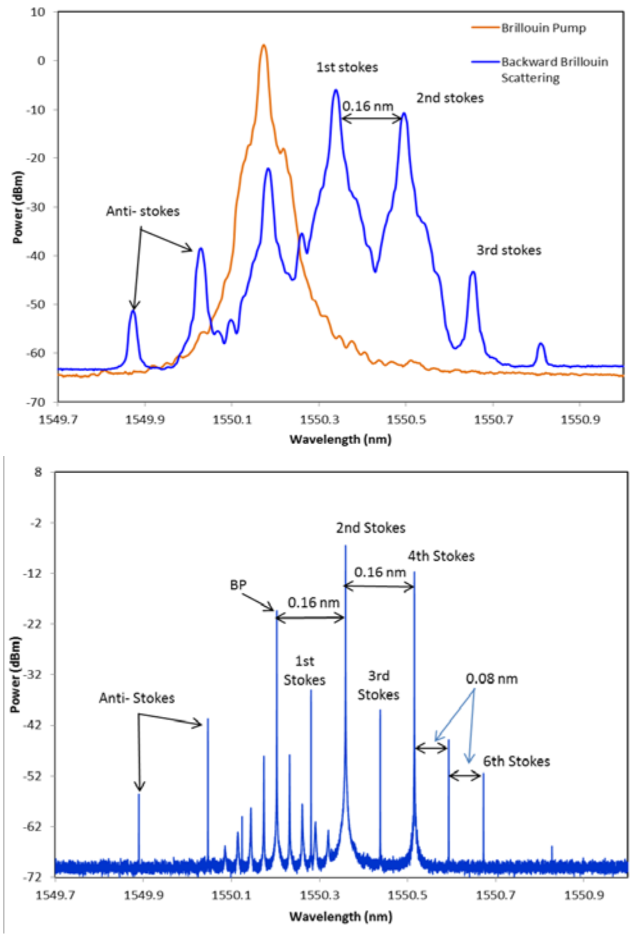

Fig. 2. Spectrum of BP and backward Brillouin scattering of double frequency spaced Brillouin stokes when BP is 8.5 dBm at 1550 nm wavelength using **(a)** 0.02 nm resolution OSA, **(b)** 0.16 pm resolution OSA.

An important observation is made, as referred to figure 2(b).It is very interesting to note that under the higher resolution, the spectrum obtained indicates the presence of the Stokes between 0.16 nm wavelength spaced. We realized that even in figure 2(a), thespacing between two consecutiveof stokes is double-frequency shifted,however there are still hidden stokes wavelength spacing of 0.08 nm.Indications of higher-ordered odd Stokes are also observed, though the power of these peaks are low enough that they blend in with the noise floor. From this observation it can be deduced that even-though the above described ring configuration should by all means only allow for double-spaced Stokes outputs, in reality both even and odd Stokes lines propagate in both directions in the laser cavity. In this regard, previous reports of double-spaced Brillouin fiber lasers such as those in the references [7–9] may be misleading, although this would have resulted from the limited resolution of the OSAs used, as opposed to a misinterpretation of data.

Further observation of even and odd stokes lines that exist is investigated by analysis signal-to-noise ratio (SNR) which compared the highest peak power and the noise floor at different BP. In this study, the BP varies from -2.5 dBto 23.2 dB as shown in figure 3.

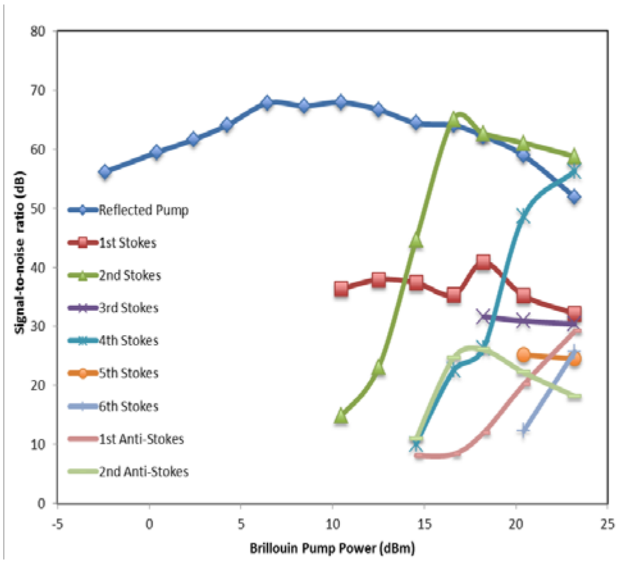

Fig.3. The measured SNR with a variation of injected BP

From the graph, the increases the BP power supplied attribute to the generation of the new stokes. On the other hand,as we increased the BP power, the SNR of odd-stokes show depletion while SNR for even-stokes increased exponentially.Optical signal-to-noise ratio (OSNR) is a key optical performance indicator, and monitoring the OSNR evolution of an optical transmission link can provide vital information about its performance. We significantly want to highlight that the odd-stokes that may not appear clearly in regular OSA which caused by limitation of resolution virtually has SNR level that cannot be ignored. We observed the highest SNR values for unseen stokes in 0.02 nm resolution OSA (odd-stokes) which is 40.84 dB while the lowest one is 24.5 dB.

4. CONCLUSION

We successfully demonstrate a double-frequency spaced multiwavelength Brillouin fiber laser (MWBFL) using a dispersion shifetd fiber (DSF) as the nonlinear medium An important observation is made, that under the higher resolution, the spectrum obtained indicates the presence of the Stokes between 0.16 nm wavelength spaced.by observing the spectrum using a high resolution OSA with the resolution of 0.16 pm. We realized that even thespacing between two consecutive of stokes is double-frequency shifted,however there are still hidden stokes wavelength spacing of 0.08 nm.From this observation it can be deduced that even-though the above described ring configuration should by all means only allow for double-spaced Stokes outputs, in reality both even and odd Stokes lines propagate in both directions in the laser cavity.

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