DESIGN AND PERFORMANCE EVALUATION OF NARROWBAND RECTANGULA OPTICAL FILTER BASED ON STIMULATED BRILLOUIN SCATTERING IN FIBER

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ABSTRACT

We propose a rectangular optical filter based on stimulated Brillouin scattering in fiber with tunable bandwidth from 50 MHz to 4 GHz at 15-MHz tuning resolution. The steep-edged rectangular shape of the filter is precisely controlled utilizing digital feedback revision of the pump light. The passband ripple is ~1 dB by nonlinearity management of the pump and using the fiber with a single Brillouin peak. The extinction ratio of the filter is further enhanced using the polarization characteristics of the Brillouin scattering. Based on this filter, we demonstrate a sub-band extraction of a multi-band orthogonal frequency division multiplexing signal, which shows the potential ability of the filter in the fields of optical and microwave signal processing.

Keywords: *Rectangular optical filter, stimulated Brillouin scattering*

1. INTRODUCTION

An ideal tunable passband filter has a rectangular response consisting of an ultra-flat passband and very steep edges which bring about many benefits. The flat passband will not distort the signal at all thus keeping high signal fidelity. The steep edges can suppress interference from adjacent bands at the extreme. And the tunability makes it more flexible and reusable to meet different requirements.Several methods have been proposed to implement such narrowband filters, including specially designed fiber Bragg gratings (FBG) [1], Fabry–Perot etalons [2], and Stimulated Brillouin scattering (SBS) [3-5],etc. Among all the above methods, SBS is considered as one of the most promising techniques. The wavelength of the SBS-based filter can be tuned easily by changing the wavelength of the pump. The filter bandwidth and the shape can be also flexibly changed by controlling the pump spectrum using external phase modulation [3], direct current modulation [4] and cascaded phase and intensity modulation [5]. However, it is very difficult to control the pump spectrum precisely in the previous works, therefore the exact flat top and steep edges as the ideal rectangular filter can be hardly achieved.

In this paper, we present a narrowband rectangular SBS filter with tunable bandwidth from 50 MHz to 4 GHz at 15-MHz tuning resolution. We use external amplitude and initial phase can be digitally controlled accurately. A feedback compensation process is proposed to revise the pump shape precisely. Some preliminary results have been presented in a previous paper [6] which shows the validity of the feedback method. On the foundation of the feedback process, we further propose the nonlinearity management to mitigate the four-wave mixing (FWM) effect and utilize a more suitable fiber with a single Brillouin gain peak to increase the filter flatness [7]. As a result, the in-band ripple is decreased to ~1 dB for all bandwidth cases while the unwanted out-of-band gain is further suppressed. To enlarge the filter extinction ratio we use the polarization characteristics of SBS [8] to separate the amplified signal from noises. Based on this filter, we demonstrate a sub-band extraction of a multi-band orthogonal frequency division multiplexing (OFDM) signal and prove the flexibility and validity of the filter.

2. EXPERIMENT

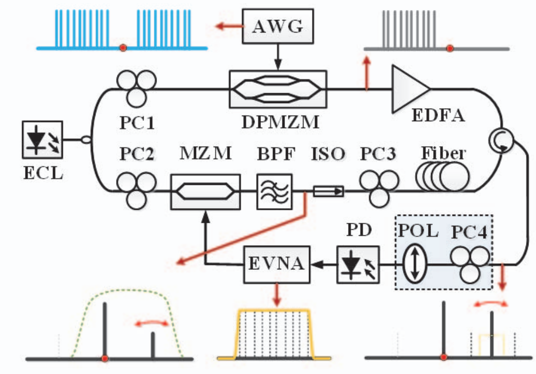

Fig. 1. Experimental setup

The experimental setup is shown in Fig. 1. An external cavity laser (ECL) operating at 1550 nm is split into two branches. In the upper branch, an AWG is used to generate the electrical spectral lines with random frequency interval within ±1-MHz deviation from the natural SBS bandwidth of 15 MHz, i.e. 14 MHz, 15 MHz and 16 MHz. Then it is modulated on the light to generate the SBS pump lines utilizing a dual-parallel Mach-Zehnder modulator (DPMZM). With proper phase control of the driving signals and bias control of the DPMZM, the optical carrier-suppressed single sideband (O-CS-SSB) modulation is achieved. The O-CS-SSB signal is then amplified by an erbium doped fiber amplifier (EDFA) and launched into the 12.5 km single-peak fiber through an optical circulator. In the lower branch, a sweeping signal covering the whole SBS gain region from an electrical vector network analyzer (EVNA) is modulated on the light to generate the probe signal. An optical bandpass filter (BPF) removes the left sideband of the probe signal for stable SBS gain measurement. Then the probe light goes through the single-peak fiber and is amplified once it sweeps within the SBS gain region. A polarization controller (PC3) is used to achieve the maximum SBS gain. After the SBS process, the probe signal is detected by a photodiode (PD) and then sent into the EVNA. If the polarization enhancement is proposed, an extra polarization controller adjusting the signal polarization state and a polarizer selecting the amplified polarization is used before the PD.

The measured SBS spectra with 3-GHz bandwidth in different cases are shown in Fig. 2. The original SBS gain generated by the electrical spectral lines with equal amplitude and equal frequency interval are seriously affected by the FWM and nonlinear response of the electrical and optical components. As shown in Fig. 5 (a), the SBS gain is far from the rectangular shape. When implementing the feedback compensation as shown in (b), the ripple is still as high as 3.70 dB with large unwanted gain out of the passband. After utilizing the unequal interval spectral lines, the passband ripple in (c) is significantly reduced to 1.56 dB. By using the single-peak fiber, the ripple is further decreased to 1.00 dB shown in (d) and the gain at stop band is smaller than the previous cases.

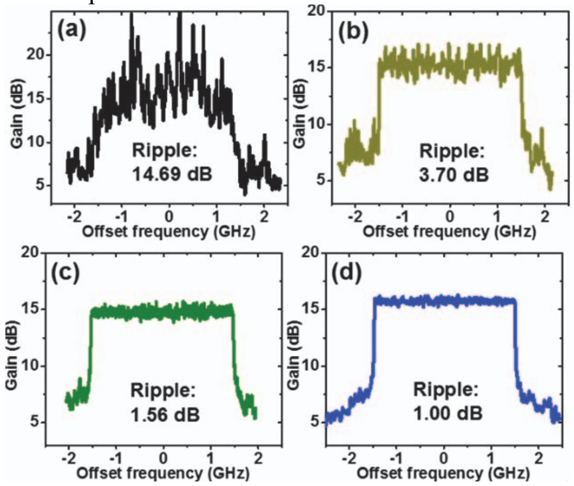

Fig. 2. The measured SBS spectra at different cases

The bandwidth of the proposed filter can be changed flexibly with a resolution of 15 MHz by changing the number of the electrical spectral lines generated by the AWG. The maximal rectangular SBS filter bandwidth is 4 GHz with 12-dB gain limited by the pump power. For the SBS filter shown in Fig. 3 (a) and (b) with 1-GHz bandwidth, the shape factor (SF_{15dB}) is 1.075 which was almost the ideal rectangular case. Based on this filter, we demonstrate a typical application of OFDM sub-band extraction as shown in Fig. 3 (c) and (d). We first generate a double-sideband OFDM signal containing 3 sub-bands. The bandwidth of each sub-band is 1 GHz and the band gap is as narrow as 100 MHz. Then we use the proposed filter to amplify only the middle sub-band by 25 dB. As shown in Fig. 3. (c), just small parts of the adjacent bands are amplified slightly thus making a ~21-dB distinction between the middle sub-band and the adjacent bands. After using the polarization enhancement shown in Fig. 3. (d), while the middle sub-band is amplified by 20 dB, adjacent bands are suppressed at the same time. The extraction can be quite flexible thanks to the filter flexibility of the bandwidth and wavelength.

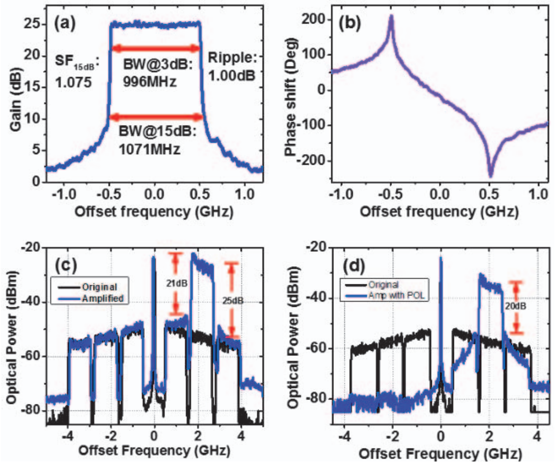

Fig. 3. The (a) amplitude and (b) phase response of 1-GHz filter, sub-band extraction using SBS filter (c) without and (d) with polarization enhancement

3. CONCLUSION

We have presented an ultra-flat rectangular optical filter based on stimulated Brillouin scattering and demonstrated a typical filter application of OFDM sub-band extraction. With flexible bandwidth from 50 MHz to 4 GHz and high tuning resolution of 15 MHz, the proposed steep-edged rectangular filter can find versatile applications in optical and microwave signal processing.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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