Influence of amplifier spontaneous emission noise on distributed acoustic monitoring systems

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Abstract: Erbium Doped Fiber Amplifier (EDFA) is an indispensable part of the distributed acoustic monitoring system. It plays an important role in improving the transmission distance and the signal-to-noise ratio of the demodulation signal. However, the presence of the EDFAs will bring Amplifier Spontaneous Emission (ASE) noise generated by different EDFAs on the whole system. Using a filter with a bandwidth of 0.2 nm, the influence of ASE noise on the demodulation signal was observed. The ASE noise generated by the power-EDFA has no effect on the SNR of the demodulation signal. However, the ASE noise generated by the pre-EDFA will greatly affect the SNR of the demodulation signal. After adding a filter after the pre-EDFA with center wavelength of 1 550.12 nm and bandwidth of 0.2 nm, the signal-to-noise ratio of the demodulation signal was increased from about 20 dB to 60 dB.

Key words: optical fiber sensor; distributed acoustic monitoring system; erbium doped fiber amplifier; amplifier spontaneous emission noise; signal-to-noise ratio

CLC number: TP212.9 **Document code:** A **DOI:** 10.3788/IRLA201746.S122005

放大器自发辐射噪声对分布式声波监测系统的影响

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摘 要: 掺铒光纤放大器(Erbium Doped Fiber Amplifier, EDFA)是分布式声波监测系统的重要组成部分,对于提高信号光的传输距离和系统解调信号的信噪比至关重要。但 EDFA 的引入也不可避免地带来了放大器自发辐射(Amplifier Spontaneous Emission, ASE)噪声。利用一个分布式声波监测系统,分别研究了不同位置的 EDFA 产生的 ASE 噪声对系统解调信号的影响。结果表明,功率 EDFA 产生的 ASE 噪声对于系统解调信号的信噪比基本没有影响。而前置 EDFA 产生的 ASE 噪声会对系统解调信号的信噪比产生很大的影响,在系统中加入一个中心波长为 1 550.12 nm,带宽为 0.2 nm 的滤波器后,系统解调信号的信噪比从大约 20 dB 增加到 60 dB。

关键词: 光纤传感器; 分布式声波监测系统; 掺铒光纤放大器; 放大器自发辐射噪声; 信噪比

收稿日期: 2018-02-10; **修订日期:** 2018-05-20

基金项目: 国家自然科学基金(61605101);山东省自然科学基金(ZR2016FM33);山东省重点研发计划(2016GGX101040)

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0 Introduction

Compared with other sensors, optical fiber sensor has many unique advantages, such as small size, light weight, high sensitivity, high speed responsibility, anti-electromagnetic interference, multi-parameter measurement, easy integration and so on. So, in recent decades, the optical fiber sensor technology was developed more and more rapidly and played an important role in the fields of aerospace, petrochemical industry, electronic power, civil engineering, biomedicine, etc [1-7]. In the optical fiber sensing technology, acoustic wave monitoring technology attracted lots of researchers′attention[8-12]. Compared with traditional video surveillance recognition technology, optical fiber acoustic monitoring technology has great advantages in measurement reliability, dynamic measurement characteristics and measurement accuracy and so on.

Erbium Doped Fiber Amplifier (EDFA) was an integral component in optical fiber acoustic monitoring system. According to the function or position of the EDFA in the system, it is mainly divided into two categories. One is after the acousto-optic modulator, it can amplify the power of the signal light and improve the transmission distance. Usually, this EDFA was called power-EDFA. The other type is used to amplify the scattered light of the signal light before the demodulation system. It can improve the intensity of the scattered light, which was called the pre-EDFA. It can be said that EDFA plays an important role in the development of optical fiber sensing technology, especially in the improvement of the signal-to-noise ratio of the demodulation signal. However, the EDFAs also added the extra noise to the whole system. In the extra noise, the Amplifier Spontaneous Emission (ASE) noise was the main one.

In this paper, a distributed acoustic monitoring system based on Rayleigh scattering was used to study the influence of ASE noise generated by different EDFAs. The experimental results showed that the ASE noise of the power-EDFA has no influence on the demodulation signal. It is mainly because that the Rayleigh scattering intensity generated by this ASE noise was very low and will be buried in the system. However, the ASE noise of the pre-EDFA had a great influence on the demodulation signal. After adding a 0.2 nm filter, the signal-to-noise ratio of the demodulation signal was increased from about 20 dB to about 60 dB. The main reason for this phenomenon is that the ASE noise generated by the pre-EDFA directly entered into the demodulation system to participate in the demodulation. In addition, the amplified Rayleigh scattering light intensity is relatively low, so the ASE noise of the pre-EDFA can seriously affect the demodulation result.

1 Experimental setup

The experimental setup of the influence of ASE noise on distributed acoustic monitoring system was shown in Fig.1. The laser source was a distributed feedback narrow-line laser with a center wavelength of 1 550.12 nm, a linewidth of 3 kHz and an output power of 20 mW. Acousto-optic modulator (AOM) and driver were manufactured by Gooch & Housego Co. Ltd. Their serial numbers were Fiber-Q and 1200-DINA-2.5 HCR, respectively. After the power-EDFA, we added a filter with a center wavelength of 1 550.12 nm and a bandwidth of 0.2 nm. It was used

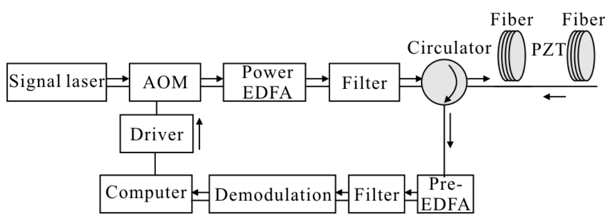

Fig.1 Experimental setup of the influence of ASE noise on distributed acoustic monitoring system

to observe the power–EDFA ASE noise on the demodulation signal. The amplified signal light entered into the sensing fiber through the circulator, and the backward Rayleigh scattering light was output through the circulator. After the pre–EDFA and the filter, the Rayleigh scattering light entered into the demodulation system. This filter was used to observe the effect of ASE noise from the pre–EDFA on the demodulation signal. Demodulation system was based on 3×3 fiber coupler signal demodulation technology. This demodulation method was suitable for both micro and strong vibration signals, and the demodulation result was accurate, fast and had a large dynamic range. A weak fiber grating at each end of the piezoelectric ceramic (PZT) was used to enhance the signal intensity. The control signal of the PZT came from a signal generator, the signal was a 1 kHz sine wave of amplitude 1 V. In order to ensure the accuracy of the experimental results, we made the whole system in the same environment and took several measurements at different time during the experiments.

2 Experimental results and analysis

2.1 Influence of power–EDFA ASE noise on the system

First of all, we observed the effect of ASE noise caused by power–EDFA on the demodulation signal. The result was shown in Fig.2. When observing the effect of ASE noise from the power–EDFA, a filter with a center wavelength of 1 550.12 nm and a bandwidth of 0.2 nm was inserted after pre–EDFA. Figure 2(a) showed the demodulation signal without a filter in the system. The local noise was between 0–10 dB and the signal intensity was about 70 dB. Figure 2(b) was the demodulation signal with a filter in the system. We found that the demodulation signal was the same regardless of whether the filter was present or not. The main reason for this phenomenon was that although the total power of ASE noise produced by this EDFA was comparable to that of signal light, the bandwidth of ASE was wide, typically 40 nm, so the average power to a single wavelength was very low. In this case, the Rayleigh scattering signal generated by a single wavelength of ASE noise will be very weak and annihilated by other noise in the system. Therefore, the ASE noise generated by the power–EDFA had no effect on the demodulation signal.

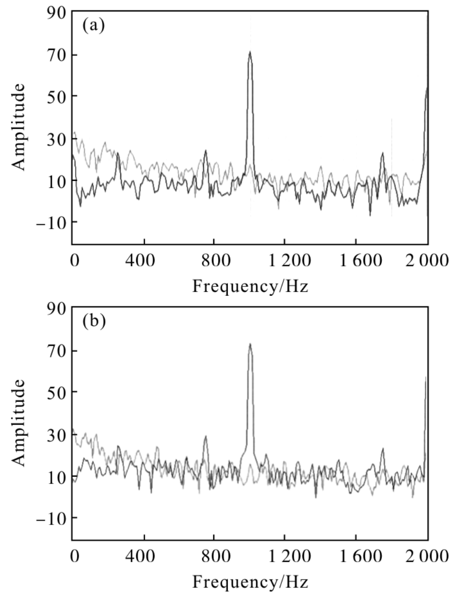

Fig.2 Demodulation results

2.2 Influence of pre–EDFA ASE noise on the system

Because the ASE noise of the power–EDFA had no effect on the demodulation signal, when testing the influence of pre–EDFA ASE noise, there was no filter after the power–EDFA. The results of the system demodulation were shown in Fig.3. From Fig.3, we can clearly see that after the filter was added after the pre–EDFA, the demodulation signal–to–noise ratio was greatly improved. The intensity of the demodulated signal was improved from about 30 dB to 70 dB. The main reason for this phenomenon was that the ASE noise generated by the pre–EDFA directly entered the demodulation system. And the signal received by the demodulation system was relatively weak. Thus, the ASE noise can greatly affect the system demodulation. In addition, we also selected the filter with a bandwidth of 0.1 nm in the experiment, and the result of the demodulation had no significant improvement. This phenomenon proved that the influence of ASE noise at this time has almost no effect on the demodulation result.

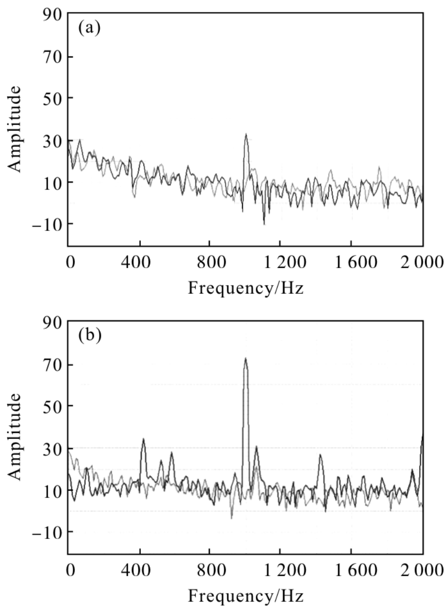

Fig.3 Demodulation results whether the filter is present after the pre-EDFA: (a) without a filter, (b) with a filter

3 Conclusion

In conclusion, a distributed optical fiber acoustic monitoring system based on Rayleigh scattering was used to study the influence of ASE noise generated by EDFAs at different positions. The experimental results showed that the ASE noise of power-EDFA had no effect on the demodulation signal. However, the ASE noise of the pre-EDFA had a great effect on the system. When a filter with a bandwidth of 0.2 nm was added after the pre-EDFA, the signal-to-noise ratio of the demodulation signal was improved from about 20 dB to 60 dB. The signal-to-noise ratio of the demodulation signal is an important parameter of optical fiber sensing system. The research content of this paper is of great significance to the design and optimization of optical fiber sensing system.

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