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SNR of 3-Stage Fiber Delay Lines Based on SOAs in Microwave Photonics Link

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***Abstract*—Signal to noise ratio (SNR) of multi-stage optical fiber delay lines based on semiconductor optical amplifiers (SOAs) is demonstrated with experiments by carrying 8 GHz microwave sinusoidal signal. We conclude that, higher input power of microwave source and the higher gain of SOAs will improve the performance of SNR. What's more, it is shown that more stages of optical fiber delay lines based on SOAs decrease the SNR.**

Keywords-component; signal to noise ratio, fiber delay line, SOA, microwave photonics

I. INTRODUCTION

Microwave photonics is attractive for analog signal procession [1, 2], particularly in the areas of the radio frequency wireless access networks, sensor networks, radar and satellite communications. Fiber delay lines used as microwave phase shifter has the advantages such as lower cost, light weight, ultra-wide band and low electromagnetic interference. In optical fiber delay lines, semiconductor optical amplifiers (SOAs) can be used multi-functionally as fast switch and power amplifier, which can compensate for the loss and enhance the programmability [3].

The main issues of microwave photonics links based on optical fiber delay lines is microwave phase noise and signal to noise ratio [4, 5]. It has been demonstrated that, setting the SOA just at the front of the photo-detector (PD) did not increase microwave phase noise in the OEO (optoelectronic oscillator) [6]. Multi-stage SOAs, assisted by optical filtering have been used to obtain continues RF phase shift (>360º) via slow and fast light effects [7]. The noise behavior of such links should be studied.

This paper presents an experimental study of 3 stage microwave shifter based on optical fiber delay lines and SOAs. The signal to noise ratio (SNR) was measured in different case of 1, 2 and 3 stages, respectively. It is shown that, higher input power of microwave source will benefit to enhance the SNR, and the higher gain of SOA will improve the performance of SNR. The experiment results also show that more stages of optical fiber delay lines based on SOAs decrease the SNR of the microwave link.

II. MICROWAVE LINK WITH OPTICAL FIBER DELAY LINES AND THE EXPERIMENTAL RESULTS

In an optical link of microwave photonics, the microwave source supply RF signal, which is modulated onto light wave with a high-speed modulator. The optical signals carrying microwave information transmit through fiber. At the end of the link, there is a PD, which converts the light wave back to the microwave signal.

Fig. 1 shows the microwave photonics link we used to assess the SNR. It consists of a microwave source (Agilent E8257D), tunable laser source (Anritsu, MG 9638A), electrical-optical modulator (EOM, Photline 0633), PD (Conquer, 10G PIN-TIA) and ESA (Anritsu MS2667C). The microwave is an 8 GHz sinusoidal wave.

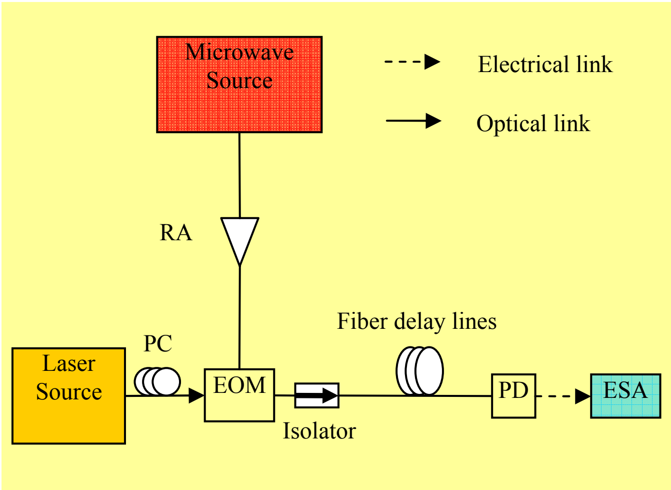

Figure 1. Microwave link with optical fiber delay lines

Fig. 2 shows the structure of fiber delay lines with SOAs. Each stage is composed of three arms and in each arm an SOA is used as switch and power gain supplier. In this figure, red point dash lines indicate "OFF" status of SOA during experiment.

We choose the 3^N optical fiber delay line structure based on SOAs for three reasons [3]:1) SOA acts as switch for the high speed, which help to program the delay amounts, 2) the gain of SOA can compensate the loss due to both microwave link and optical link, 3) we can use the least SOAs and delay lines to maintain the largest amount of delay.

As for Ref [3], the basic phase shift via this microwave photonic link can be calculated:

$$\varphi = 2\pi f \cdot \tau \qquad (1)$$

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where f is the frequency of the microwave and τ is the minimal true time delay in the fiber. In the fiber delay line structure shown as Fig. 2, amountτin series can be programmed according to applications.

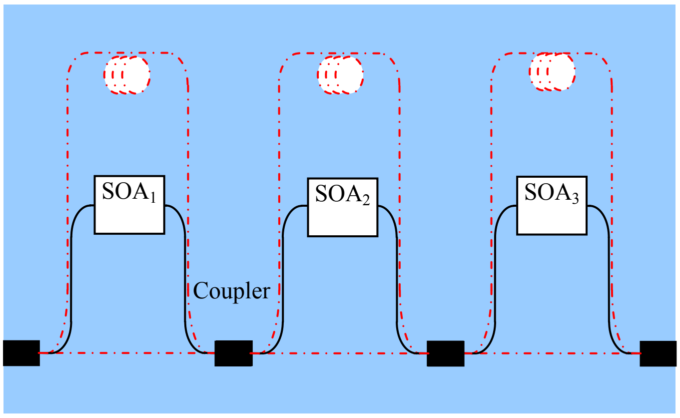

Figure 2. Structure of fiber delay lines with SOAs

Fig. 3 shows the measured SNR as a function of the power of input microwave for different stages. In the 1 stage SOA experiment, we set the SOA gain so as to produce an output of -3.0dBm and -17.75dBm, respectively. As for the 2 stages, we set the two SOAs with nearly the same drive current, and then measure the total optical power output of the link as -3.0dBm and -11.38dBm. In the 3 stage experiment, the total optical power outputs are -3.0dBm and -9.3dBm, respectively, with each SOA contributing nearly the same drive current.

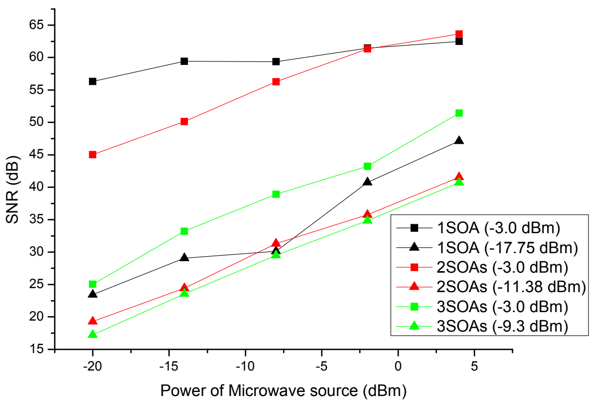

Figure 3. SNR with input power of microwave source

Fig. 4 shows the SNR as the function of power gain of SOA. We regard the fiber delay structure with SOA(s) as one optical component to calculate the total gain. In some sense, we take the multi-stage fiber delay line structure based on SOA as one amplifier, so we chose the total gain as a parameter of the microwave photonics link. For the 2 or 3-stage situations, each SOA is set to provide nearly the same drive current. The microwave input is set at -2dBm.

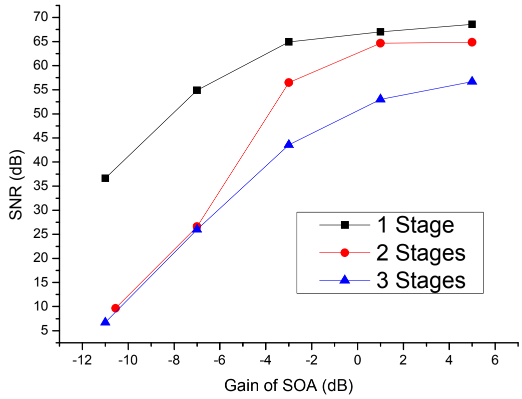

Figure 4. SNR with gain of SOA

From the above results, it can be seen that increasing the microwave input power will improve the SNR of the microwave photonic link. In the experiment of the same optical output power with -3dBm, the SNR of the microwave photonics link with 3SOAs dramatically turn down, otherwise, when the optical power output of SOAs become smaller, the SNR of the microwave photonic link decreases, and the SNR of 2 stages is very close to the 3 stages for the weak optical power output. As for the function of SNR and the gain of SOA(s), we can find that more stages of SOA will deduce the decreasing of the SNR. However, when the gain of SOA(s) increases to the high level, the SNR becomes stable.

III. CONSLUSION

The SNR of optical fiber delay line based on SOAs with different stages are measured. It is shown that, higher microwave input power will increase the SNR, and meanwhile the higher gain of SOA will improve the SNR. It is also shown that more stages of optical fiber delay lines based on SOAs result in the decrease of the SNR.

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