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SOA-Based Fiber Ring Laser Use in a Photonic Radio-Frequency Phase Shifter[1]

F. M. Wu[a], P. C. Peng[b, *], J. Chen[a], C. T. Lin[c], and W. C. Kao[a]

[a] *Institute of Electro-Optical Engineering, National Chiao Tung University, Hsinchu, Taiwan, China*

[b] *Department of Electro-Optical Engineering, National Taipei University of Technology, Taipei, Taiwan, China*

[c] *Institute of Photonic System, National Chiao Tung University, Tainan, Taiwan, China*

*e-mail: pcpeng@ntut.edu.tw

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Abstract—This investigation demonstrates the feasibility of a semiconductor optical amplifier (SOA)—based fiber ring laser use in a photonic radio-frequency (RF) phase shifter. Experimental results indicate that a fiber ring laser can successfully replace an external pump laser in a photonic RF phase shifter. The RF phase shifter can be turned by adjusting the power of the fiber ring laser.

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1. INTRODUCTION

Recently, RF phase shifters that exploit photonic approaches have attracted considerable attention because of their potential use in microwave systems [1, 2]. Photonic devices have numerous advantages over conventional microwave systems that are based on purely electrical devices. These include flexible tunability, lightness of weight, and immunity to electromagnetic interference (EMI) [3–5]. These advantages have caused photonic RF phase shifter gradually to replace electronic shifters in microwave systems.

Of all photonic phase shifters, semiconducting devices are the most desirable because of their inherent compactness, ease of integration with other devices, and low power consumption, which enable the phase of an RF signal to be accurately and easily controlled for microwave photonic systems [5–7]. Recently, controllable time delay using population oscillation in a semiconductor optical amplifier (SOA) has been investigated [8]. The time delays can be controlled by varying the power of the external pump laser. However, this scheme depended on a highly stable and expensive external pump laser, and is difficult to implement.

Recently, fiber ring lasers have been the focus of considerable research, because fiber lasers are simply implemented, have a high output power, a high signal to noise ratio, and the potential to be incorporated into a fiber system [9–18]. This investigation proposes a novel photonic RF phase shifter that is based on a fiber ring laser. The fiber ring laser replaces the external laser source for the photonic RF phase shifter. It is constructed from an optical filter and optical circulators. The power of the fiber ring laser is controlled using a variable optical attenuator (VA). The time delay can be tuned by adjusting the power of the laser. A 1 GHz modulation signal with a tunable optical delay of 102 ps is presented. The relationship between the modulation frequencies of the probe signal and the time delay is also investigated.

2. EXPERIMENT SETUP AND RESULTS

Figure 1a present the experimental setup for measuring the tunable time delays in an SOA with an external pump laser source. A 1546.11-nm optical signal is generated by a tunable laser source and then modulated via a Mach–Zehender modulator (MZM). The optical circulator C_1 is used to connect the probe signal to the SOA, and C_2 is used to link the SOA to the pump laser source. The phase shifter can be tuned by adjusting the power of the pump laser. Figure 1b shows the experimental setup of the proposed system. The amplified spontaneous emission from the SOA circulates in the loop. This feedback continues to oscillate in the loop and create a laser beam. The direction of the feedback signal is counter-clockwise as determined by the optical circulator. The central wavelength of the fiber ring laser is determined by the optical filter, and is 1546.11 nm. The inset of Fig. 1b shows the optical spectrum. The variable optical attenuator is used to control the power of the fiber ring laser.

Figure 2 plots the waveforms of the probe signal at various powers of the external pump laser and the fiber ring laser, respectively. The laser powers are used to control the time delay in the SOA. The laser power is varied from –20 to 8 dBm, and the driving current of the SOA is 300 mA. Figure 3 plots the measured time delays at different laser powers. The time delay in the SOA increases with the laser power. Finally, the time

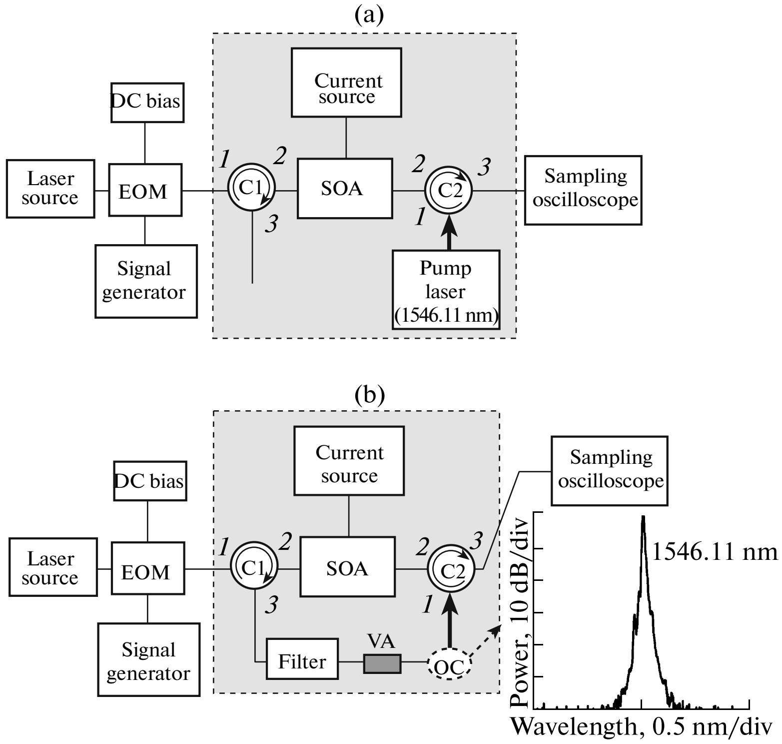

Fig. 1. Experimental setup for measuring tunable time delays in SOA (EOM: electro-optic modulator, C: optical circulator, SOA: semiconductor optical amplifier, VA: variable attenuator, OC: optical coupler).

delay in the SOA with an external pump laser yield similar results as that of the SOA with the fiber ring laser. The fiber ring laser can therefore replace the external pump laser source.

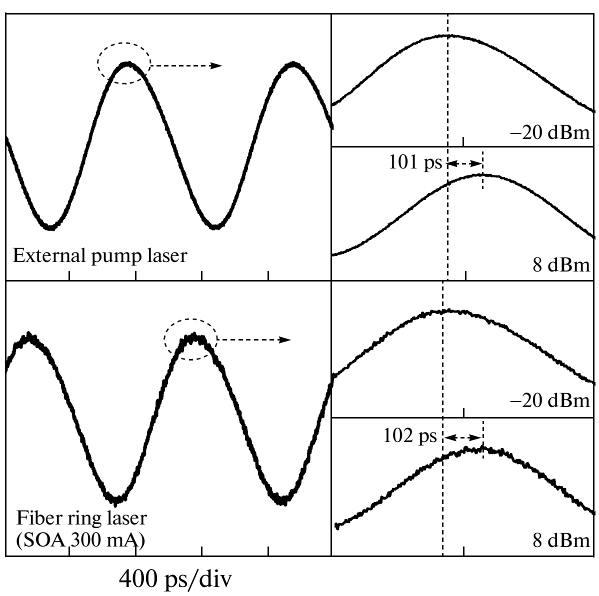

Fig. 2. Waveforms at various powers of probe signal.

The time delay is also measured at different driving currents of the SOA. Figure 4 plots the measurements of time delay for the 1 GHz probe signal at various powers of the fiber ring laser. The maximum time delays are 99 and 52 ps at bias currents of 200 and 100 mA, respectively. Moreover, Fig. 5 plots the time delay against the power of the fiber ring laser and the driving current of SOA. The time delay increases with the optical power of the fiber ring laser.

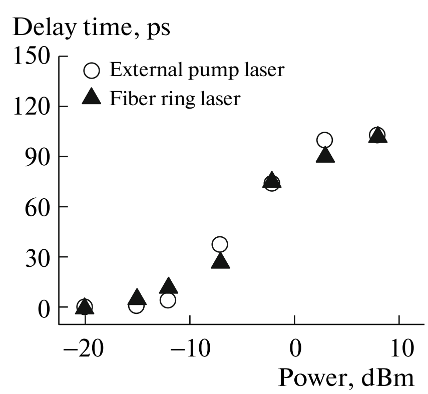

Fig. 3. Time delay against optical power of external pump laser and fiber ring laser.

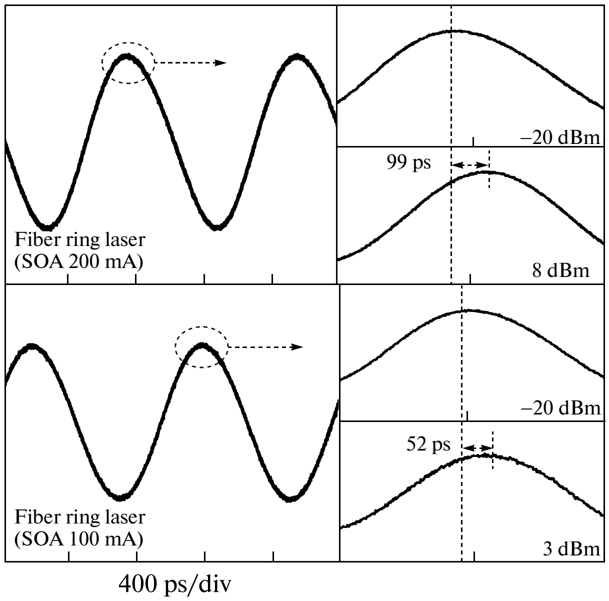

Fig. 4. Waveforms at various powers of probe signal.

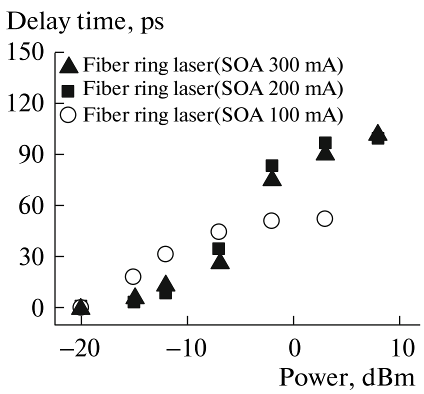

Fig. 5. Time delay against optical power of fiber ring laser and driving current of SOA.

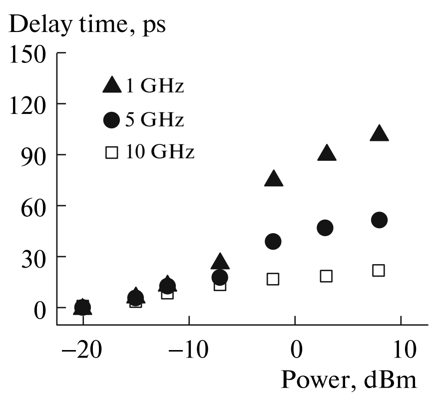

Fig. 6. Time delay against optical power of fiber ring laser and modulation frequency.

Figure 6 plots the time delay against the power of the fiber ring laser and the modulation frequency of the probe signal. The laser power is varied from –20 to 8 dBm, and the driving current of SOA is set to at 300 mA. The maximum time delays are 102, 51, and 21 ps at modulation frequencies are 1, 5, and 10 GHz, respectively. The time delay increases as the modulation frequency declines.

3. CONCLUSIONS

This investigation experimentally demonstrates a fiber ring laser, including an SOA, for application in a photonic RF phase shifter. A fiber ring laser can successfully replace the highly stable and expensive external pump laser. It is compact and can therefore be use in a phase shifter. The photonic phase shifter can be tuned by adjusting the power of the fiber ring laser. This phase shifter has the potential to reduce the size and cost of microwave photonic systems. Moreover, the fiber ring laser could apply to wavelength-division multiplexing systems by using an all-fiber birefringent filter in the ring cavity [19].

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