12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

12C2-4

Active Birefringent Optical Loop Filter using an SOA as a Phase Shifter

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Abstract

Polarization-independent active birefringent optical fiber loop filters using a semiconductor optical amplifier (SOA) as a phase shifter are studied experimentally. By driving the SOA with DC/sinusoidal current, the SOA is operating as a phase shifter thus the active control of the periodic transmission/reflection properties of the loop filter are realized.

Introduction

Optical fiber loop filters with a birefringent fiber and a polarization controller (PC) were reported as periodic wavelength filters for applications in wavelength division multiplexing (WDM) or multi-wavelength fiber lasers [1,2]. Recently, active operation of the loop filters introducing a pair of phase modulators inside the loop has been reported [3]. However, the filter requires more complicated structure and the characteristic differences between the two phase modulators degrade the performance of the filter. In this paper, we report the polarization-independent, active birefringent fiber loop filters using a 1.3μm SOA as a phase shifter inside the loop. To our knowledge, this is the first experimental report of an active birefringent loop filter using an SOA inside the loop.

Experimental setup

Figure 1 shows the basic configuration of an active birefringent fiber loop filter with an SOA as a phase shifter. The loop filter consists of two polarization controllers (PC-A and PC-B), a 1.3μm SOA, polarization-maintaining (PM) fiber, and a PM 3dB fiber coupler. As light sources, an external cavity laser (ECL) and ASE light from an EDFA are combined together using a 7dB fiber coupler, and then introducing to the loop filter through a circulator which separates the reflected signal from the filter. The PC-A is set to produce a polarization rotation of 90 degrees and the PC-B is set to adjust the direction of the fast/slow axes of the PM fiber and the SOA since the SOA has ordinary single-mode pigtail fibers. The basic operating principle is the same as written in [3].

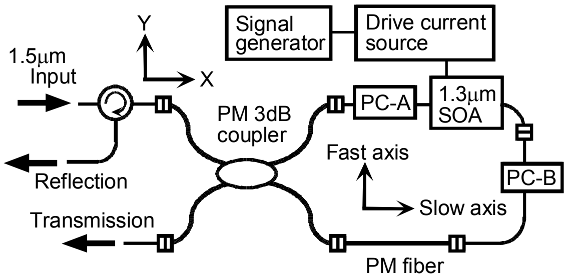

Fig.1 Experimental setup of SOA-introduced loop filter

Experimental results

In order to evaluate the polarization mode dispersion (PMD) of the SOA, we perform the polarization mode dispersion measurement of the SOA using a cross-connect method. Since the PMD of the SOA is estimated to be very small, it is hard to measure the value directly. So, we take the following steps. For simplicity, we assume the slow axis of the SOA is along with x-axis.

Step 1: By controlling both the PC-A and PC-B, we set the half-wave (HW) plate to completely flatten the transmission spectrum with minimum output power. This situation corresponds to the polarization rotation angle (PRA) at PC-A=0 degree and PC-B=0 degree.

Step 2: By rotating the HW plate of the PC-A, we create the periodic transmission spectrum with maximum extinction ratio. This corresponds to PRA at PC-A=90 degrees and PC-B=0 degree.

Step 3: Then rotating the HW plate of the PC-B, we create the flat spectrum again. This corresponds to PRA at PC-A=90 degrees and PC-B=90 degrees.

Step 4: Then rotating the HW plate of the PC-A to create the periodic transmission spectrum with maximum extinction ratio again. This corresponds to PRA at PC-A=0 degree and PC-B=90 degrees.

In case of step 2, the total PMD of the loop becomes $\Delta\tau_{PM} + \Delta\tau_{SOA}$, and in case of step 4, the total PMD becomes $\Delta\tau_{PM} - \Delta\tau_{SOA}$, where $\Delta\tau_{PM}$ and $\Delta\tau_{SOA}$ correspond to PMDs of the PM fiber and the SOA used in the loop, respectively. Figure 2 shows the measured results of transmission spectra corresponding to the “Step 2” and “Step 4” at 30mA driving current of SOA. In this measurement, a PM fiber with 1.43ps PMD is used. By calculating the total PMD for both spectra, PMD for the SOA is obtained as 0.036ps.

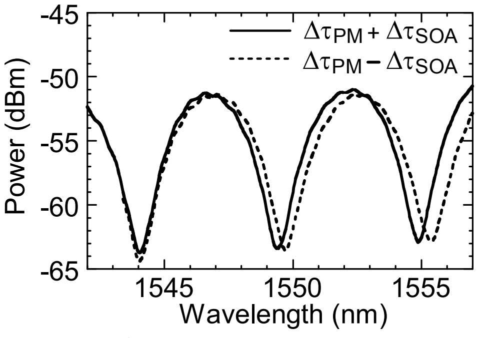

Fig.2 Measured transmission spectra using cross -connect method at 30mA driving current.

Figure 3 shows the measured results of the PMDs of SOA depending on driving current. It is clear that by increasing the driving current, the PMD of SOA is decreasing from approximately 37fs to 20fs. This means that by changing the driving current of the SOA, the PMD, i.e., the phase of the signal which passes through the SOA can be controlled by the current. Based on the above results, we perform the control of the transmission spectrum using DC driving current.

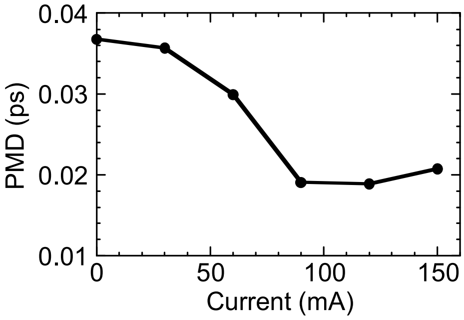

Fig. 3 The PMD dependency on the driving current.

Figure 4 shows the measured transmission spectra of the loop filter using the ASE and ECL light. In the experiment, PC-A is set to 0 and PC-B is set to 90 degrees, thus the injection current increases the phase shift inside the loop filter. In this figure, the driving current of SOA is set to 0mA, 50mA, 100mA and 150mA. By increasing the driving current, the peak of the periodic transmission spectrum (P_0) shifts to longer wavelength, and the transmission peak at 150mA (P_{150}) becomes at the reflection peak at 0mA. This means that the ECL signal which is set to the transmission peak at 0mA is switched from the transmission port to the reflection port in fig. 1. Also by increasing the driving current, the periodic spectrum intensity of the ASE is decreasing. The reason is that the loss of 1.5μm wavelength is increasing by increasing the drive current of the SOA.

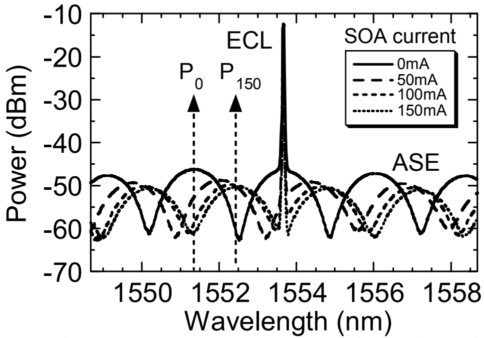

Fig. 4 The transmission spectra of the loop filter with different driving currents.

Figure 5 shows the modulated outputs at the transmission and reflection ports using a 10-kHz sinusoidal wave. The sinusoidal wave is connected to the external modulation port (Bandwidth: 300 kHz) of the drive current source. Both outputs are modulated at 10-kHz frequency but the waveforms are inverted because of the switching of the output port. As shown in the figure, the modulation amplitude at the reflection port is almost 50% of that of the transmission port. This is due to the loss of the 1.5μm wavelength at 150mA driving current as indicated in figure 4. Figure 5 indicates that the SOA-introduced birefringent loop filter can actively switch the input signal between the input and output ports by the driving current of the SOA.

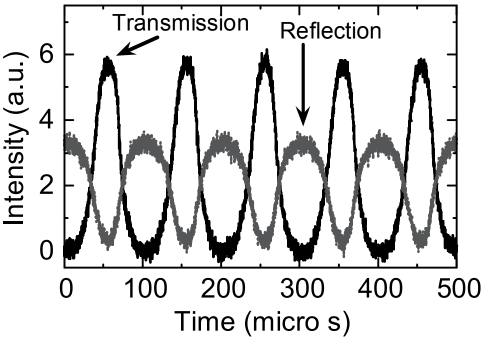

Fig.5 Modulation output from transmission/reflection port under 10-kHz sinusoidal modulation.

The rise and fall times of the loop filter are measured by using a rectangular waveform with ns-order rise and fall times. The measured rise and fall times of the loop filter are shown in fig. 6. From the figure, the rise and fall times are measured around 6μs and 1.5μs respectively. The main reason of this slow response is attributed to the small bandwidth (~ 300 kHz) of the external modulation port of the drive current source. Since the carrier lifetime of the SOA is around ns-order, it will be possible to operate the SOA-introduced active loop filter in the GHz operating region.

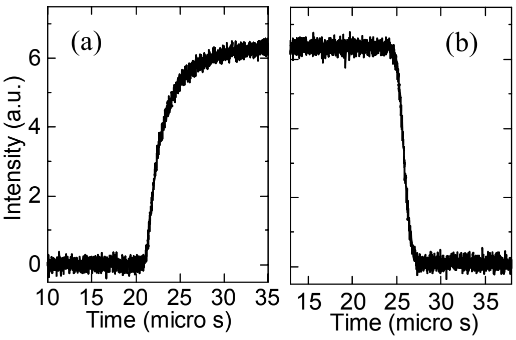

Fig. 6 Measured (a) rise time and (b) fall time of the loop filter

Conclusions

By using an SOA as a phase shifter, the active birefringent loop filter is realized. The periodic transmission/reflection characteristics can be shifted by the injection current to the SOA, and the signal switching between the transmission and reflection ports can be realized. By improving the drive electronics, the proposed filter can be operated in the GHz frequency region which is suitable for high-speed optical networks.

References

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