A Hybrid Optical Integrated Circuit Module for High-Accuracy Optical Modulation

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Abstract

A hybrid optical integrated circuit module featuring a built-in $LiNbO_3$ modulator, 3dB optical coupler and wide-bandwidth photo diode was prototyped for its use in high accurate modulated signal generator. By this integration, the phase fluctuation of modulated optical signals in the $LiNbO_3$ modulator was monitored with high accuracy.

Introduction

Recent active research and development of the dense wavelength division multiplexing (DWDM) technologies based on 10Gbit/s per wavelength successfully opened practical Tbit/s optical networks era. The next technological target is the 40Gbit/s per wavelength and total capacity of 10Tbit/s DWDM, which strongly demand of the performance characterization for the optical components with high accuracy and resolution.

The $LiNbO_3$ modulator has been widely used for not only high-speed optical transmission systems [1,2] but also optical measurement, because of its

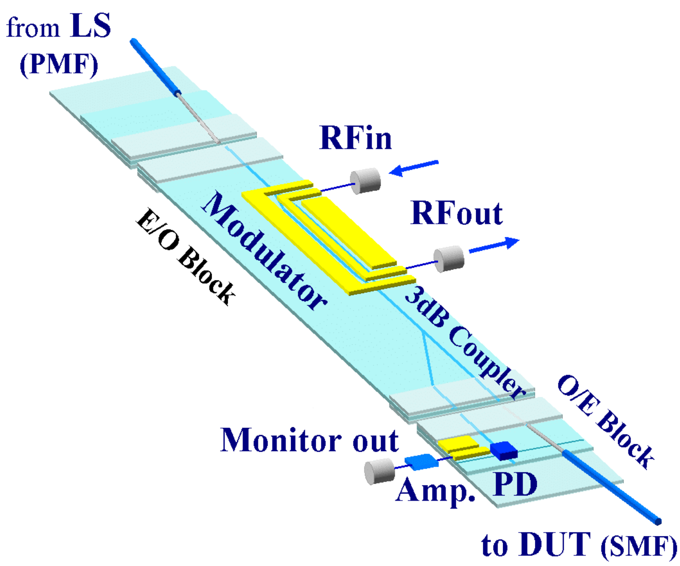


Fig.1 Construction of Monitored Modulation Unit

high-speed and low chirping characteristics. When this $LiNbO_3$ modulator is used for high accuracy optical modulation, it is important to monitor the phase fluctuation in the modulator at very close to one. Therefore, we integrated $LiNbO_3$ modulator with the wide-bandwidth photo diode using flip chip mounting technology.

In this paper, we demonstrate a hybrid optical integrated circuit using a $LiNbO_3$ waveguide, with build-in modulator and monitor photo diode for its applications in the high accurate modulated signal generator.

Fabrication of A Monitored Modulation Unit

Fig.1 shows the construction of our hybrid optical integrated circuit module (called Monitored Modulation Unit). The block of the Electro-Optic conversion (E/O block) and the block of the Opto-Electric conversion (O/E block) are separated. Both of these blocks are fabricated on $LiNbO_3$ substrate.

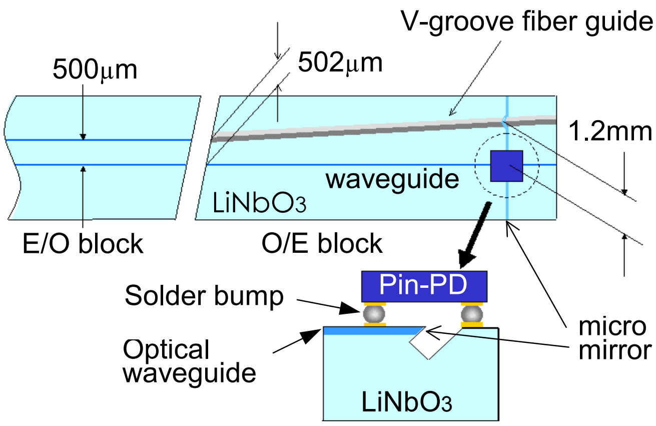
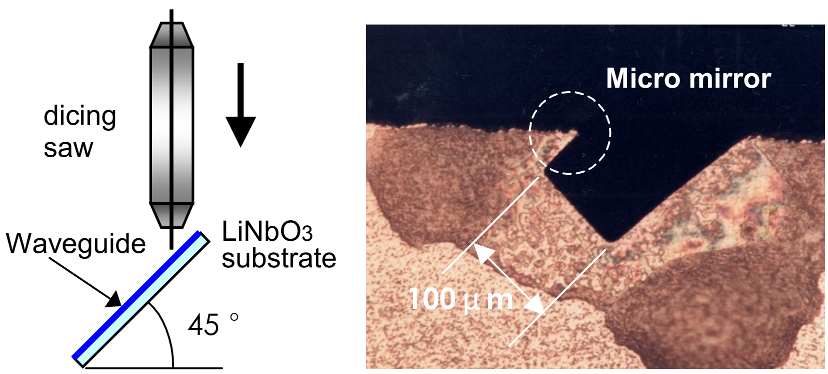


Fig.2 Schematic diagram of the O/E block

E/O block; The Mach-Zehnder modulator and 3dB coupler were fabricated in x-cut $LiNbO_3$ substrate by indifusing 900Å thick and 6μm wide Ti at 990°C for 16 hours. The total length and the total optical loss of the E/O block were 60mm and 7dB, respectively. The length of traveling-wave type electrode was 20mm. The modulation bandwidth and half wavelength voltage at DC were 3.6GHz and 6.8V, respectively.

O/E block; The schematic diagram of the O/E block is shown in Fig.2. An



a) b)

Fig. 3 Fabrication of the micro-mirror by using a dicing technique.
a) Fabrication setup b) Microscope photograph of the micro-mirror

optical coupling with the photodiode is achieved by the micro-mirror, which was fabricated on the waveguide. As shown in Fig.3-a, the micro-mirror was fabricated by angled slit of 45 degree by using the dicing saw. The microscope photograph of the micro-mirror is shown in Fig.3-b. The reflection loss of the micro-mirror was 2.54dB, this is caused by the light scattering at the rough mirror surface. The InGaAs/InP pin-PD chip (band width ~5GHz) with the diameter of light sensitive area 75μm was mounted on the $LiNbO_3$ substrate by using a solder-bump technique, which had a self-align effect with the accuracy of alignment better than 1μm. The V- groove fiber guide is used to mount the single mode fiber that was made by dicing technique with the V shaped blade. In order to minimize a coupling loss between the E/O block and the O/E block, it is necessary to improve the processing location accuracy of V-groove to less than 1μm.

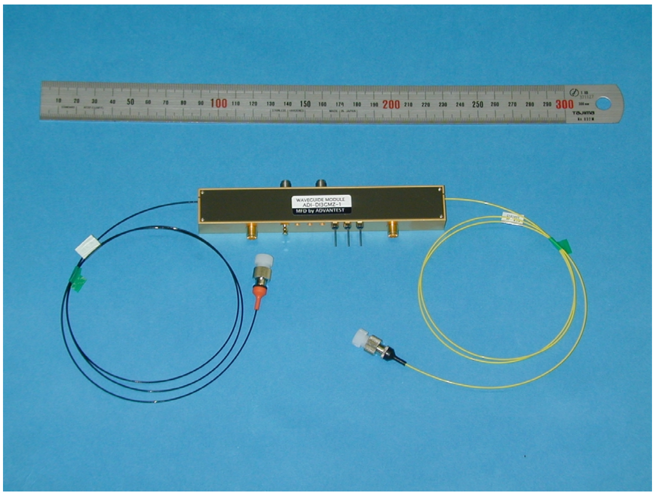


Fig.4 Photograph of the Monitored Modulation Unit

After aligning the light axes of the E/O block and the O/E block, UV cured bonding was done. The device is then put into a metallic case, and connectors for input and output signals are mounted. A photograph of the Monitored Modulation Unit is shown in Fig.4.

Experimental Setup and Results

The Monitored Modulation Unit is employed to measure the group delay by using the phase shift technique [3]. The measurement setup is shown in Fig.5. The input light from the DFB laser (λ = 1550nm) into the Monitored Modulation Unit is modulated by the Mach-Zehnder modulator and divided into two parts. One of these was converted into electric signal by the monitor PD of the O/E block, while the another was introduced from the SMF into the fiber-coupled

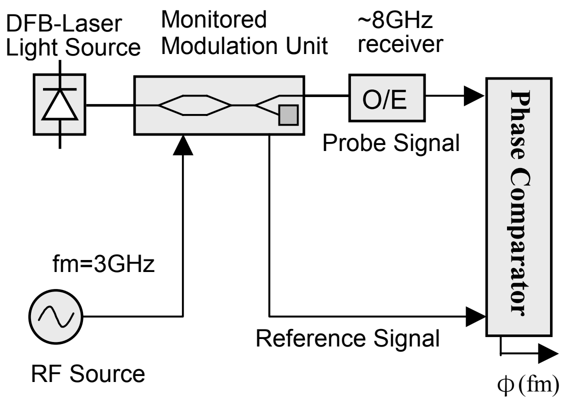


Fig. 5 Experimental setup for group delay measurement

receiver. The phases of these signals was compared with the phase comparator, and converted into the group delay. The measurement results are shown in Fig.6. The group delay of the Monitored Modulation Unit was 15.3ns. And, by monitoring and canceling the phase fluctuation of the $LiNbO_3$ modulator, the fluctuations of the group delay for five minutes were reduced to less than 0.05ps p-p .

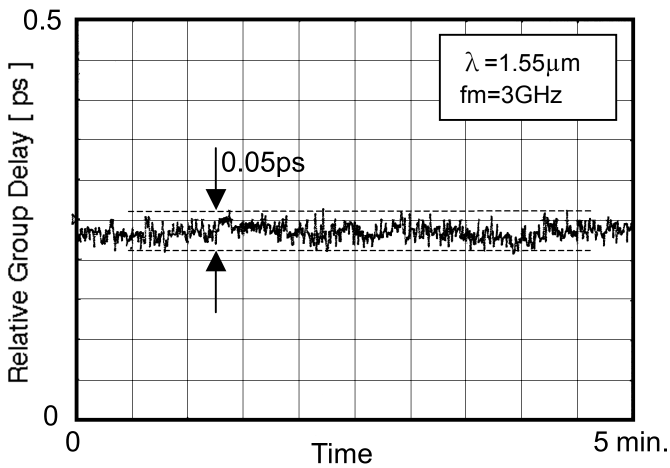


Fig.6 Measurement results of group delay

Conclusion

A prototype of Monitored Modulation Unit, consisting of an integrated $LiNbO_3$ modulator, 3dB optical coupler and a photo diode, is reported with its improved performance and reduced fluctuations in group delay.

Acknowledgement

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