Characterization of nonlinear nonreciprocal propagation in semiconductor amplifying waveguide optical isolators

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[**INTRODUCTION**] Semiconductor waveguide optical isolators based on nonreciprocal loss are composed of an SOA covered with a ferromagnetic metal. They have the advantage of monolithic integration with semiconductor lasers compared to conventional free space optical isolators. So far, demonstrations of nonreciprocal propagation have been reported for TE and TM mode operation [1,2]. Since optical gain of the SOA compensates the propagation loss from the ferromagnetic metal in these waveguide optical isolators, it is important to characterize the amplifying waveguide optical isolators as SOA as such for full understanding of their performance. One of the important issues is gain saturation of the amplifier. Here we report on the nonlinear nonreciprocal propagation characteristics in TM mode 1285nm transparent semiconductor amplifying waveguide optical isolators.

[**CHARACTERIZATION**] We measured saturation effects in InGaAlAs MQW TM mode semiconductor waveguide optical isolators with $Co_{50}Fe_{50}$ as the ferromagnetic metal [2]. The device is 2mm-long, AR-coated, and has gain peak at $\lambda = 1285$nm. The device becomes transparent for forward propagating light at a bias current of 200mA, and shows 7.5dB isolation for 0dBm input light from an external cavity tunable laser. In this work, we fixed the input wavelength at 1285nm and the bias current at 200mA. We changed the input light intensity between -10dBm and 10dBm, and characterized the optical gain and isolation.

[**MEASUREMENT RESULTS**] Fig. 1 shows the measurement result. The fiber to chip coupling loss equals 10dB per facet. We calibrated the optical power of the output light intensity. With increasing the input light intensity, the device shows saturation at -5dBm for the backward and -2dBm for the forward propagating light. As a result, the isolation increases with increasing the input light intensity.

[**DISCUSSION**] The measurement result of Fig. 1 shows that the amplifying waveguide optical isolator has higher propagation loss for larger backward optical intensity. In general, ferromagnetic metals such as $Co_{50}Fe_{50}$ have a large carrier density, hence do not show saturation absorption below 10dBm input light. Therefore, the observed nonlinear nonreciprocal propagation effect results from gain saturation of the InGaAlAs MQW amplifying layers. In conclusion, in amplifying waveguide optical isolator it is necessary to consider saturation effects for forward and backward propagating light.

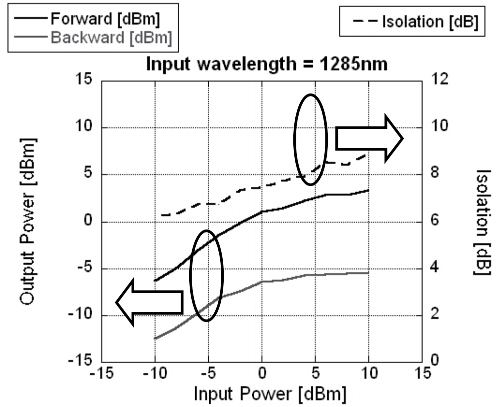

Fig. 1 Nonlinear nonreciprocal propagation measurement results. The input light is 1285nm TM mode. The measurement temperature is 20deg. A 1kG magnetic field was applied by a permanent magnet.

[1] H. Shimizu et al., J. Lightwave Tech. **24**, 38, (2006). [2] W. Van Parys et al., Appl. Phys. Lett., **88**, 071115, (2006).