Abstract of Dissertation

Unidirectional waveguide optical devices for InP-based photonic integrated circuits
（InP基板上光集積回路における一方向性導波路型光デバイスの研究）

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Abstract

Avoiding the problems caused by undesired reflections of light is a matter of great importance in photonic integrated circuits (PICs). For this purpose, this paper describes waveguide-based unidirectional devices that can be monolithically combined with other optoelectronic devices on a PIC. There are two promising ways of creating such devices. One is based on nonreciprocal propagation loss in an absorbing magneto-optic waveguide; the other is based on nonreciprocal polarization conversion in an asymmetric waveguide with a garnet layer.

(1) Nonreciprocal-loss waveguide optical isolator

The nonreciplocal loss is a phenomenon where—in an optical waveguide combined with an absorbing ferromagnetic material—the propagation loss of light is larger in backward than in forward propagation. Taking a 1.5-μm-band TM-mode isolator, we explained the theory, fabricating process, and operation of the device on the basis of our research. The isolator consists of an InGaAlAs/InP optical waveguide with a layer of ferromagnetic manganese pnictide (MnAs and MnSb) that is attached to the waveguide. The magnetized layer produces the magneto-optical Kerr effect, which induces the nonreciprocal loss in light traveling along the waveguide. Finally, an isolator with a MnSb layer we made had an isolation ratio of 12 dB/mm at a wavelength of 1.54 μm in the temperature range 20-70°C.

(2) Nonreciprocal polarization converter

We proposed a nonreciprocal TE-TM polarization converter that can be used to eliminate the disturbances caused by back reflection of light in InP-based photonic integrated circuits. Our device consists of an asymmetric InGaAsP waveguide combined with a ferrimagnetic Ce:YIG layer, making use of the magneto-optical transverse Kerr effect and the change in the state of polarization in the waveguide. We described the guiding principle to design the optimal structure of the device. We also confirmed the operation of nonreciprocal TE-TM conversion by means of electromagnetic simulation. The results showed that a nonreciprocal conversion efficiency of 93% could be obtained with a device length of 0.27 mm at 1.55-μm wavelength. Our device can be upgraded to a waveguide isolator simply by combining with a polarizer or mode splitter. Our nonreciprocal polarization converter should be useful in integrating variety of optical devices on a photonic integrated circuit.