論　文　要　旨
Thesis Abstract

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主論文題名　（Title）

Study of waveguide optical isolator employing nonreciprocal radiation mode conversion for Si photonics

内容の要旨　（Abstract）

An optical isolator is an indispensable device in optical communication systems since it can protect active photonic devices from unwanted reflected light. Magnetic garnet crystals are necessary to construct the optical isolator owing to their large magneto-optic coefficient and low absorption loss in the near infrared region. In decade ago, optical isolators with a Si guiding layer have been researched widely. The author has investigated two types of the optical isolator with the Si guiding layer, employing a nonreciprocal guided-radiation mode conversion. First, the optical isolator utilizes a magneto-optic waveguide with a crystalline Si guiding layer. The magneto-optic waveguide is fabricated by bonding technique between a magnetic garnet and silicon-on-insulator (SOI) structure. Last, the optical isolator consists of an amorphous Si guiding layer deposited on a magnetic garnet cladding layer. Therefore, in both cases, the optical isolator is composed of a magneto-optic waveguide with the Si guiding layer and the magnetic garnet cladding layer.

In order to realize the magneto-optic waveguide with a crystalline Si guiding layer, surface activated bonding and adhesive bonding were considered. By using these techniques, Si and a magnetic garnet can be connected with each other at low temperature. The optical isolator employing the nonreciprocal guided-radiation mode conversion was designed at a wavelength of 1.55 μm. The nonreciprocal phase shift was calculated in the magneto-optic waveguide with a magnetic garnet / Si / SiO_2 structure. It was confirmed that the largest nonreciprocal phase shift was obtained when the thickness of the Si guiding layer is 200 nm. The relationship of waveguide parameters for isolator operation was investigated.

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By using bonding technique, there is concern over a gap generated between the Si guiding layer and the magnetic garnet cladding layer. The nonreciprocal phase shift was calculated when the gap existed in the magneto-optic waveguide and the relationship of waveguide parameters were clarified for various gaps. The magneto-optic waveguides were fabricated by surface activated bonding and adhesive bonding.

In the optical isolator with a hydrogenated amorphous Si (a-Si:H) guiding layer, the magneto-optic waveguide has a structure of air/ a-Si:H/ magnetic garnet. Since the a-Si:H guiding layer is deposited directly on the magnetic garnet cladding layer, there are no gaps between the a-Si:H and the magnetic garnet. The nonreciprocal phase shift was calculated at a wavelength of 1.55 μm and the relationship of waveguide parameters were clarified. The isolation ratio of the optical isolator was calculated by simulating the electric field of TM guided mode and that of TE radiation mode. The magneto-optic waveguide with a-Si:H guiding layer was fabricated and evaluated.

The temperature dependence of the optical isolator employing a nonreciprocal guided-radiation mode conversion was investigated. The optical isolator consists of a rib-type magneto-optic waveguide with a-Si:H guiding layer. The relationship of rib height and rib width for the isolator operation was clarified for various operating temperatures. Refractive indices of layers in the magneto-optic waveguide were considered since proper refractive indices can circumvent deviation of the waveguide parameters due to the temperature shift. The results show that athermal operation can be achieved by the negative temperature dependence of the refractive index of the upper cladding layer, and the relationship of waveguide parameters varies only slightly with the selected upper cladding layer. As for the candidate of the upper cladding layer of the magneto-optic waveguide, TiO_2 and $C_6H_{11}CH_3$ compound were proposed for athermal operation of the optical isolator.

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