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著者(和文)	Shuyuan Liu
Author(English)	Shuyuan Liu
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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	Shuyuan Liu	審査員主査： Chief Examiner	Yuya Shoji

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

To achieve silicon-based high-performance integration of magneto-optical (MO) nonreciprocal devices, this dissertation based on the wafer bonding technology approach, by designing high-efficiency mode converters and mode couplers based on mode evolution, successfully realized low-insertion-loss (IL) broadband and narrowband integrated TE mode MO devices; and proposed and demonstrated the first silicon-based integrated polarization-independent MO isolator.

Starting from the reported silicon-based integrated MO nonreciprocal devices, this dissertation analyzed and summarized the challenges we facing now: on the one hand, the performance of TE mode devices was lower than that of TM mode devices, which was due to the MO materials sidewall deposition or serial polarization rotators to achieve TE mode isolation, which would introduce additional IL; on the other hand, the performance of devices prepared by wafer bonding was lower than that of monolithic integration technology, because the bonded MO material chip tended to cover a larger on-chip area resulting in additional MO absorption losses. To solve the above problems, we demonstrated the feasibility of employing the nonreciprocal phase shift (NRPS) of TM mode to achieve TE mode isolation operation by half-mode conversion idea; and proposed the mode evolution design to achieve high efficiency, large fabrication tolerance, and wide bandwidth mode-converting components to realize low-IL TE-mode nonreciprocal devices.

For broadband TE mode MO isolators, we propose a novel design based on asymmetric directional couplers. The device was composed of two parallel waveguides with different widths, and the device presents a quasi-one-dimensional structure, which was suitable for high-density PICs design. The incident TE mode light was converted into the equal-energy TE_0 and TM_0 modes in the nonreciprocal phase shifter by a half-mode converter based on mode evolution, and the NRPS was accumulated from the hybrid mode during the mode conversion process. The device exhibited a 15-dB isolation ratio (IR) and 5-dB IL after experimental processing. Compared with the previously reported work, the IL was greatly reduced, but the IR of the device was constrained due to the unbalanced intermode loss. If the precision of wafer bonding was improved in the future, the device was expected to achieve IL and IR were 3.56 dB and 17.8 dB respectively. At the same time, this design was also expected to achieve polarization-independent operation, but due to the limitation of the waveguide height, only three eigenmodes were supported in the nonreciprocal phase shifter under the current structural parameters. So, under a thicker core layer design, the design was expected to realize the isolation operation under TE and TM mode input simultaneously.

For narrowband TE mode MO isolators, we proposed a novel MRR-type device design based on asymmetric microring. Due to the asymmetric design, only one side of the microring transmitted the TM_0 mode and accumulated the NRPS, so the device could work under a unidirectional magnetic field. At the same time, the device combined the mode conversion process with the coupling section of the MRR, avoiding the design of an additional series of polarization rotators. The device exhibited an ultra-high performance of 22-dB IR and 4.3-dB IL in the experiments and was expected to reduce IL to 1.4 dB after the bonding accuracy was further improved. To verify the possibility and compatibility of the back-end integration of the device under the CMOS process, we prepared the device again by external-

fab and realized the back-end integration of the MO material by reserving the material integration window. The device finally showed an IR of 28 dB and an IL of 6.9 dB.

Inspired by the above two device designs, we proposed a polarization-independent optical isolator design based on a polarization-independent half-mode converter. By designing polarization-independent 3-dB couplers and polarization rotation couplers, the incident TE- and TM-polarized light would be converted into equal-energy TE_0 and TM_0 modes and accumulate NRPS in the nonreciprocal phase shifters. And the device had a fully planar structure, did not require an anisotropic etching scheme, and was therefore compatible with CMOS processing. The isolator finally exhibited 20-dB IR and 4.6-dB IL under TE-polarized input; 12-dB IR and 8.2-dB IL under TM-polarized input. If μ-transfer printing or monolithic integration technology was used in the future so that the MO material only covers the nonreciprocal phase shifters, the ideal IL of 1.2 dB and IR of 24 dB under both TE- and TM-polarized input will be achieved. The proposed configuration was a milestone as the first silicon-based integrated polarization-independent optical isolator.

Overall, the proposed configuration in terms of IL represents a certain improvement over other reported TE-mode integrated MO devices. In terms of IR, although half-mode-conversion-type devices were slightly inferior to MZI-type devices and MRR-type devices due to the unbalanced intermode loss, they still had novel properties such as quasi-one-dimensional structure or polarization-independent operation. This dissertation had made achievements in the performance optimization of silicon-based integrated TE mode MO nonreciprocal devices and the realization of polarization-independent MO nonreciprocal devices.