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論 文 要 旨

THESIS SUMMARY

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

With the rapid growth of global IP traffic, people are seeking ways for higher speed, lower cost and lower power data communication. Optical communication systems have attracted broad research interests as an effective mean. Since optical switches have great potential in optical communication networks, this dissertation proposed the idea of a novel remotely controllable time division multiplexing passive optical network (TDM-PON) system utilizing all-optical thermo-optic (TO) switches, which could have much better performance than the conventional TDM-PON system.

Starting from introducing the significance of photonics integrated circuits (PICs) and the important role of silicon photonics for PICs, we then discussed about motivations of all-optical TO switches. Based on utilizing all-optical TO switches, we proposed the idea as well as described the prospective performance of a remotely controllable TDM-PON system in which efficient dynamic burst switching process can be realized by remote control from the base-station without any power supply or digital-to-analog converters in the fields that conventional electrically controlled TO switches needed. In our proposed system, bit rate can be expected to increase over tenfold compared to the conventional TDM-PON system. Therefore, the objective of this dissertation was determined to propose and demonstrate a high-performance remotely controllable all-optical TO switch that can be applied in the proposed system.

As the operation principle of the all-optical TO switch, the basic theory of TO effect on a silicon-on-insulator (SOI) platform was analyzed by calculating the properties of a conventional silicon-based TO phase shifter, and furthermore, this dissertation discussed in detail the principle of TO effect induced by the metal heater and inferred that TO effect dominated the change of refractive index of silicon waveguide rather than non-linear effects when a high-intensity pump light was induced. We then simulated the thermal responses of all-optical TO phase shifters with a titanium (Ti) layer above the structures of a single silicon waveguide as well as two adjacent silicon waveguides and also analyzed the parameters about the metal layer through simulations, which were the preparations of designing the microring resonator (MRR)-based as well as the Mach-Zehnder interferometer (MZI)-based all-optical TO switches.

For the demonstration of MRR-based all-optical TO switch, we proposed the device with TE-mode-polarized light for the input signal while the induced pump light was in TM-mode polarization that could remotely control the switching status of the output signal due to TO effect, which could effectively reduce the insertion loss and enhance the extinction ratio of the switch compared to the switch using TM-mode-polarized light for the input signal. The proposed device performed at 10-90 % switching times of 0.71 μs for the rising time and 2.66 μs for the falling time in the temporal response measurement. Moreover, it performed an on/off switching ratio of 7.3 dB at the through port and 7.2 dB at the drop port, respectively, with a peak pump power of 16.8 mW in the burst switching measurement. Therefore, from the performance of the MRR-based switch the effective all-optical switching process has been confirmed utilizing a TM-mode-polarized pump light to control the TE-mode-polarized signal light.

For the demonstration of MZI-based all-optical TO switch, we proposed a 1×2 switch as well as a 1×8 switch with broadband switching that could be applied in the remotely controllable TDM-PON system, utilizing the pump lights in TM-mode polarization and the signal lights in TE-mode polarization. Two adjacent silicon waveguides with an embedded metal layer above were used to design the all-optical TO phase shifter of the MZI-based switch. By considering the parameters of the all-

optical TO phase shifter through simulation, we designed the all-optical TO switch with low insertion loss as well as high extinction ratio, and thus, the proposed device with the determined parameters were fabricated on SOI wafers. Consequently, as the results of experimentally characterization of the fabricated device by measurement, we proposed and demonstrated the remotely controllable 1×8 MZI-based all-optical TO switch on a silicon platform, exhibiting a lowest extinction ratio of 15.2 dB among the C-band wavelength range (λ = 1530-1565 nm) for all output ports, while the measured minimum insertion loss was 5.0 dB. The elementary unit of this device, a 1×2 MZI-based all-optical TO switch, yielded a π-phase-shift power P_π of 46.2 mW with switching times of 1.7 μs and 4.4 μs for 10%-90% rising time and 90%-10% falling time, respectively. Our proposed 1×8 switch was a great step to achieve the prospective performance of the remotely controllable TDM-PON system.

As a summary, this dissertation successfully proposed and experimentally demonstrated all-optical remotely controllable TO switches on SOI platforms, including MRR-based switch, 1×2 and 1×8 MZI-based switches. The 1×8 MZI-based all-optical TO switch has achieved broadband switching with a reasonable power consumption, exhibiting a low insertion loss as well as a high extinction ratio, which could be applied to the remotely controllable TDM-PON system. Our proposed device would contribute to the establishment of all-optical remote control of signal processing in PON systems in the future.