Demonstration of Mach-Zehnder interferometer optical switch with InGaAsP/Si hybrid MOS optical phase shifter

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【Introduction】In Si photonic devices, the free-carrier plasma dispersion effect is generally adopted for phase modulation owing to its capability of efficient and high-speed modulation with moderate power consumption. However, the coexisting free-carrier absorption unavoidably results in significant power imbalance between the two arms of Mach-Zehnder interferometer (MZI), leading to deteriorated crosstalk for optical switch. In this work, we have presented a MZI optical switch with InGaAsP/Si hybrid metal-oxide-semiconductor (MOS) optical phase shifter. Owing to the efficient phase modulation and low optical absorption in InGaAsP [1,2], as well as the small leakage current of the hybrid MOS structure, low-crosstalk and low-power optical switching was successfully demonstrated.

【Device structure】Figure 1(a) shows a schematic of the MZI optical switch with InGaAsP/Si hybrid MOS optical phase shifters. An n-type InGaAsP layer is bonded on a p-type Si waveguide by wafer bonding. With applied voltage between the InGaAsP and Si layers, electrons accumulate at the InGaAsP MOS interface, modulating the refractive index. The microscope image of the fabricated MZI optical switch is shown in Fig. 1(b). A III-V taper is used to ensure smooth optical mode transition from Si waveguide into the InGaAsP/Si hybrid MOS phase shifter.

【Result and Discussion】Figure 2(a) shows the switching characteristics of the MZI optical switch at 1565 nm wavelength. The cross state was established at V_g of 0.4 V due to unavoidable initial phase. The bar state was obtained at V_g of 1.8 V with a low crosstalk of -28.6 dB which was attributed to small power imbalance between two MZI arms owing to the weak free-carrier absorption in InGaAsP. Figure 2(b) presents the benchmark of MZI optical switches on Si photonics platform based on free-carrier injection and hybrid InGaAsP/Si MOS phase shifter. The power consumption is dominated by the leakage current of the hybrid MOS capacitor. Since the leakage current was negligibly small, the power consumption was maintained below 1.3 nW. Consequently, we have significantly improved the crosstalk and power consumption of optical switch simultaneously.

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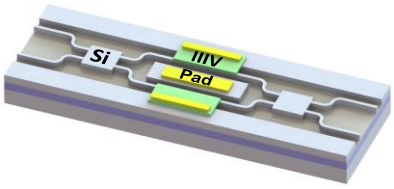
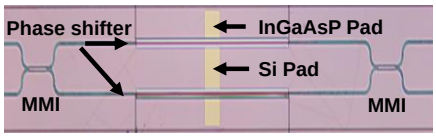
[1] J. Han, F. Boeuf, J. Fujikata, S. Takahashi, S. Takagi, and M. Takenaka, Nat. Photon., vol. 11, no. 8, pp. 486–490, Jul. 2017.
[2] J. H. Han, M. Takenaka and S. Takagi, *IEEE International Electron Devices Meeting (IEDM)*, 25.5, 2016.

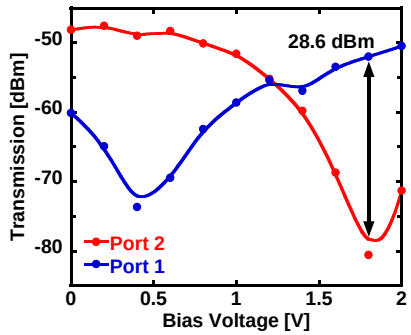


(a)

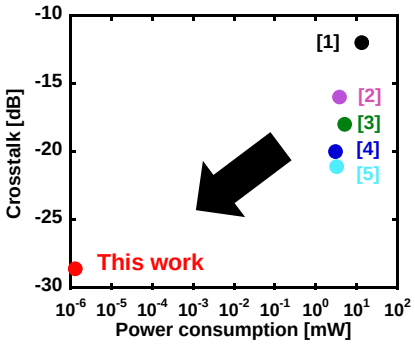


(b)

Fig. 1 (a) Device schematic and (b) plan-view photo of Si MZI switch with InGaAsP/Si hybrid phase shifters.



(a)



(b)

Fig. 2 (a) Measured switching characteristics of InGaAsP/Si hybrid MOS optical switch and (b) benchmark of optical switches on Si photonics platform.