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Efficient Phase Tuning of Silicon Photonic Devices Using Alignment Assisted Liquid Crystal Tuners

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In recent decades, the domain of silicon photonics (SiP) has emerged as a mature technology for photonic integrated circuits (PICs). The maturity in device and process technology has motivated the development of programmable circuits as a general-purpose system. One of the key elements in such a programmable circuit is the phase tuner. A low-power tuning scheme is essential to achieve large circuity with acceptable power dissipation. The widely used thermal phase shifters suffer from thermal crosstalk and power dissipation. In this regard, liquid crystal (LC) has seen immense interest due to its low power consumption and large anisotropy in its optical and electro-optic properties that can be stimulated by an external electric field [1-3].

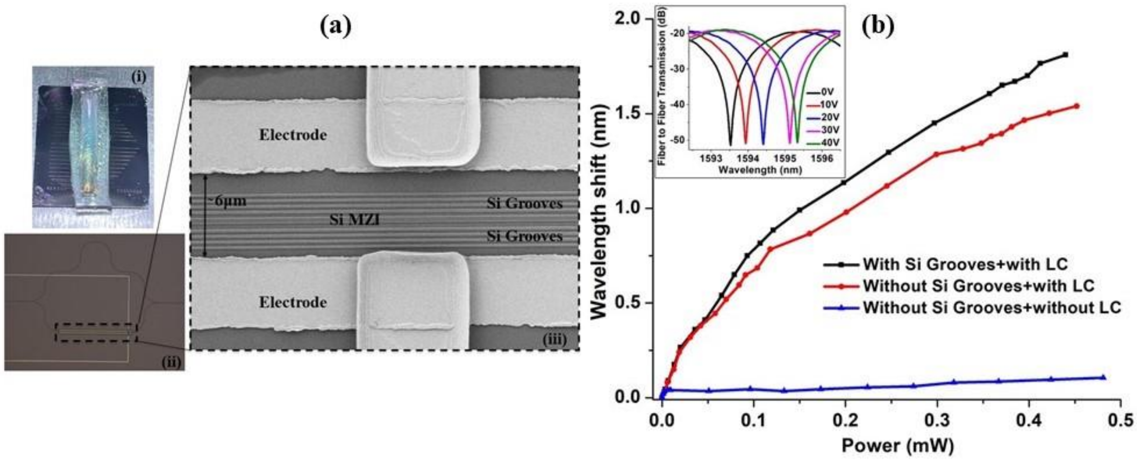

Fig. 1(a) Fabricated device (i) photograph, (ii) microscope and (iii) SEM image. (b) shift of resonance wavelength as a function of applied power (inset shows the zoomed response of MZI having silicon grooves and LC).

In this work, we propose and demonstrate the tuning efficiency improvement through silicon (Si) grooves parallel to the waveguides, yet optically isolated. An unbalanced Mach-Zehnder interferometer (MZI) is used as a test device. The orientation of LC molecules can be altered by incorporating Si grooves in one of the arms of MZI, which influences the switching voltage and resonance tuning of the proposed device. The MZI is designed with a shallow-etch silicon waveguide having a width of 550 nm and an etch depth of 70 nm in a 220 nm device layer thickness in the silicon-on-insulator (SOI) substrate. The length of MZI, the gap between silicon grooves-MZI and electrode-to-electrode distance have been taken as 350 μm, 400 nm and 6 μm, respectively. The proposed structure is fabricated using electron-beam lithography followed by etching, PECVD, optical lithography, sputtering and lift-off processes. The liquid crystal (LC) is confined over the device using an oxide window and PDMS reservoir. 4-Cyano-4'-pentylbiphenyl (5CB) is used as the LC tuner. The fabricated device is shown in Fig. 1(a). Fig. 1(b) shows the spectral tuning of the proposed device with an applied external field. The presence of LC along with Si grooves shows the tuning efficiency of 49 pm/V or 2.25π/mW against 36pm/V or 1.7π/mW for a device without Si grooves. Through this, we demonstrate that the Si grooves improve the tuning efficiency. The efficiency could be further improved by reducing the gap between the electrodes and using wire waveguides for better light-matter interaction. We shall present the effect of groove orientation and proximity on the optical and electro-optic response of the devices. The proposed phase tuning technique will be suitable for PICs, programmable photonic circuits and quantum computing applications.

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