A Thermally Tunable but Athermal Silicon MZI Filter

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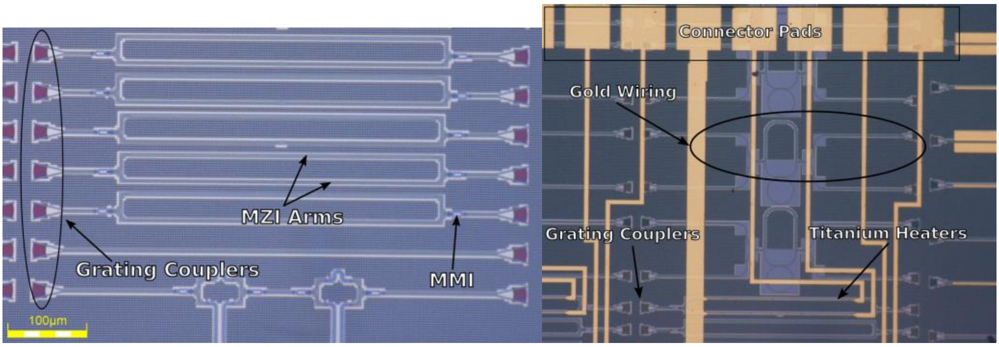
The very high refractive index from silicon enables the construction of waveguides, and therefore other devices, with very high index contrast, leading to micron-sized components and compact circuits. An important variable that has to be taken in account when adopting silicon is its high thermo-optic coefficient (1.8×10^{-4} K^{-1}). That characteristic of the material allows efficient tuning of wavelength filters with local integrated heaters. On the other hand, the high thermo-optic coefficient makes filters (and therefore the whole circuit) much more susceptible to ambient temperature variations.

The same local heaters that are used to tune the circuit can be used to dynamically compensate the change in temperature and maintain a fixed wavelength operation for the device [1]. However, this consumes power on top of the power needed to tune the filter to the correct wavelength. Alternatively, for a device such as a Mach-Zender Interferometer (MZI) it is also possible to obtain insensitivity to ambient temperature variations by carefully engineering the width and the length of the waveguides in the arms of the component [2]. Different widths of the waveguides will lead to different thermo-optic coefficients of the waveguide mode, which is directly dependent on the mode confinement in the silicon core. By choosing appropriate arm lengths the temperature dependence of both the arms can be made to cancel each other out.

We demonstrate a Mach-Zender interferometer that combines the technique of width and length engineering of the arms to obtain the athermal behavior with respect to ambient variations and at the same time use local heaters for tuning the wavelength response of the device. The MZI is based on the Silicon-On-insulator (SOI) platform of IMEC, Belgium, fabricated through the Europractice MPW service. The silicon waveguides are 220nm thick, and an additional 2 μm of oxide is deposited as a top cladding.

The MZIs are fabricated using 1x2 Multi Mode Interferometer (MMI) as splitters and combiners. The north and south waveguide width of the measured devices are, respectively, 1.1μm and 0.45μm. On top of these waveguides we processed simple titanium heaters with gold wiring using a liftoff process. The heater length is 325μm and its width is 2μm. The heater on top of the 1.1μm width waveguide was characterized and presented a phase shift efficiency of 0.22 Rad/mW. A microscope image of the processed heaters can be seen on Fig. 1b.



(a) **(b)**

Fig. 1. Microscope image of the integrated MZI (a). Microscope image of the circuit after the processing of the heaters (b).

The optical circuit was initially characterized for both 20°C and 50°C ambient conditions. As can be seen from figure 2, the operating point of the filter remains stable after a 30K difference in the operation temperature. A second measurement was performed when applying voltage to the heater on the 1.1µm width waveguide, shifting the operating point of the MZI. Again the transmission spectrum was measured for both 20°C and 50°C ambient conditions. As can be seen one more time from Fig. 2, the operating point of the MZI, once it is determined by tuning the heater, remains stable in different temperatures. With this we demonstrate that we can engineer an ambient athermal device that can still be thermally tuned by with local heaters.

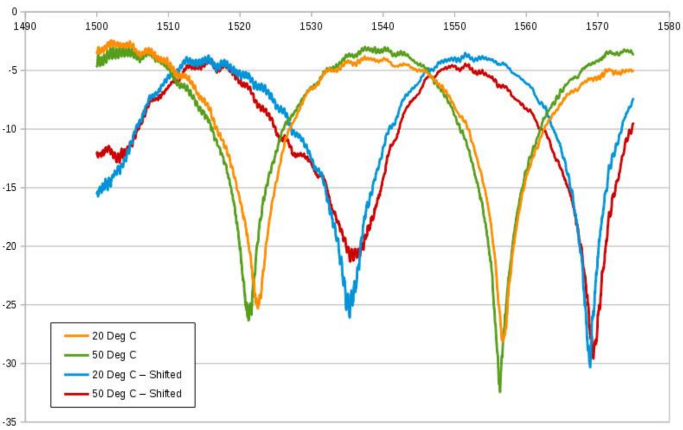


Fig. 2. Spectrum of the transmission of the MZI filter in two different ambient temperatures, 20°C and 50°C, with and without the use of the heaters to shift its operating point.

References

[1] *H. Yu, et al., Compact, thermally tunable silicon racetrack modulators based on an asymmetric waveguide, IEEE Photon. Technol. Lett., vol. 25, no. 2, pp. 159–162, Jan. 15, 2013.*

[2] *S. Dwivedi, et al., A compact all-silicon temperature insensitive filter for WDM and bio-sensing applications, IEEE Photonics Technology Letters , 25(22), p.2167 - 2170 (2013)*