Design and Measurement of Thermo-optics on Silicon
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The vision of optoelectronics started with the integration of optics and electronics on the same substrate. Various optical and electrical components on the same chip would have better performance and functionalities than the components taken alone. Electrical integrated circuits (IC) have been very successful on silicon substrate. Thus, silicon is one of the more desirable materials for optoelectronic devices. Silicon (Si) as well as silicon nitride (SiN) optical waveguides are becoming integral components for optical systems because of their advantages of high index contrast and compatibility with IC. Thermally tunable optical ring resonators made of SiN on silicon can be used as switches and filters. A small ring diameter (≈20 µm) allows a large free-spectral range. The temperature dependence of the refractive index (i.e., the thermo-optic effect of the core and cladding) is utilized to tune these ring resonators. Resistive heaters are designed to sit on top of the cladding for thermal tuning. One of the key aspects while designing the heaters is minimum power dissipation per GHz in terms of tuning flexibility. Figure 1 shows a thermal simulation for a heater over a two-ring filter.

Waveguides formed on silicon-on-insulator substrates can have sub-microsecond switching capabilities. These waveguides are heated by passing current through them; it is important to be able to study and measure the thermal characteristics of the device. Thermoreflectance spectroscopy is one of the many ways of measuring the temperature of the device. A temperature profile for a silicon-melt waveguide of 0.5 µm thickness is shown by measuring the reflectance changes due to modulating the current. Figure 2 shows the image of the melt waveguide along with temperature profile and the thermoreflectance image. The figure on the left inset shows the non-uniform temperature distribution within the waveguide. For the silicon melt waveguide, the measured thermo-optic coefficient (κ) was 1.1E⁻⁴/K, which is similar to the reported values for silicon for the specific wavelength (510 nm). Similar measurements can be done on SiN ring resonators to obtain the thermo-optic coefficient.

△ Figure 1: Temperature profile for the thermal tuning of ring resonators.

△ Figure 2: Silicon melt waveguide-thermal profile using the thermo-reflectance technique.