Lithographic scaling in silicon photonics: Is smaller better?

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Silicon has recently been used to build integrated optical and optoelectronic devices, using the same nanoscale fabrication processes used to make transistor-based electronic chips. Systems with thousands of optical components, in close proximity to integrated electronics, have been demonstrated, primarily for applications in data communications. Foundry processes and shared shuttle runs are just beginning to become available for simple photonic process flows, dramatically lowering the cost of entry in the field.

Convenient wavelengths for silicon photonics are in the near-infrared, so the feature sizes of devices have typically been in the hundreds of nanometers to microns. There is, however, enormous promise in creating truly nanostructured waveguides for applications in ultrafast nonlinear optics. Several recent developments have highlighted the benefits that smaller structures can provide. Slot waveguides have recently been shown to concentrate light below the diffraction limit, enabling an optical mode to be largely contained in gaps smaller than 50 nm. Even higher concentrations can be obtained through the use of plasmonic waveguides.

In several cases, devices based on these nanoscale waveguides exhibit performance that is inversely proportional to feature size. In particular, slot waveguide based electrooptic modulators have already shown order of magnitude improvements over conventional devices, solely on the basis of lithographic features. Slot waveguides have also been successfully used for all-optical signal processing on the basis of third-order optical nonlinearities.

This talk will review the state of the field and will discuss these results further. In many cases, we can expect dramatic further improvements in nanoscale photonic devices, as feature sizes grow even smaller.

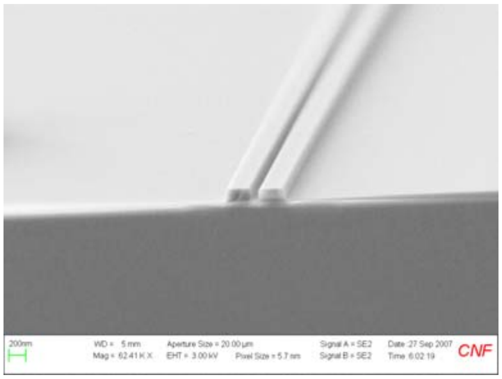

Fig. 1: Scanning electron micrograph of a cleaved slot waveguide in silicon-on-insulator.

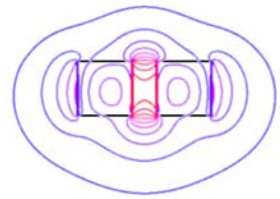

Fig. 3: Simulations of slot waveguides show high optical field confinement in the slot region.

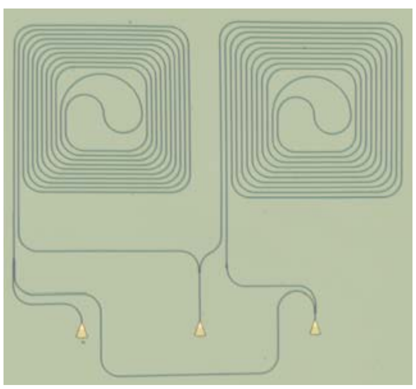

Fig. 2: Plan view image of a silicon-waveguide based all-optical modulator in sub-mm area.

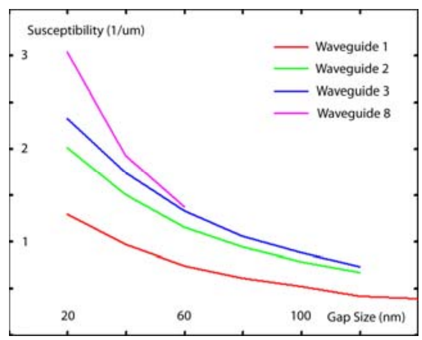

Fig. 5: Simulations of a variety of different slot waveguides show dramatically increased nonlinear performance as the slots become narrower.