USC Viterbi School of Engineering

Mork Family
Department of Chemical Engineering and Materials Science

2011 Student Research Symposium

Serpentine low loss trapezoidal silica waveguides on silicon

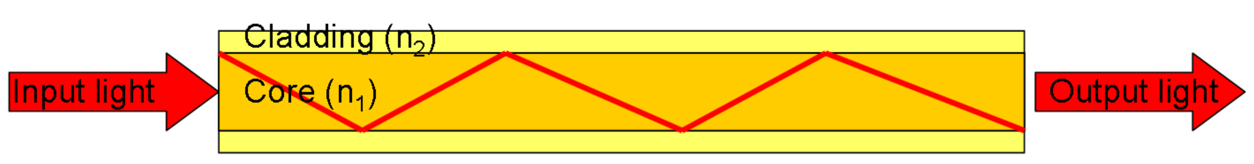
Audrey N. Harker, Mark C. Harrison, Xiaomin Zhang and Andrea M. Armani
Mork Family Department of Chemical Engineering and Materials Science

Abstract

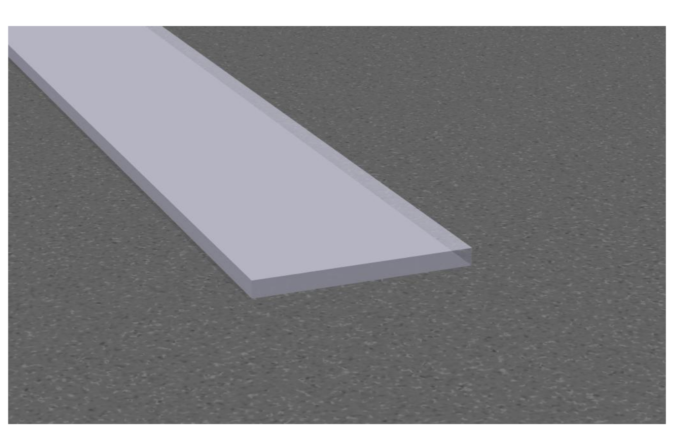
Optical waveguides have great potential for improving integrated devices in a variety of fields, including telecommunication, sensing and photonic integrated circuits. To benefit these applications, waveguides must be able to: 1) efficiently direct an electromagnetic field within a specific path and 2) they must be easily fabricated on-chip for integration with other components. Recently, the Armani Group invented a new silica waveguide integrated on a silicon wafer. To realize the full potential of this novel device (minimizing cost and maximizing functionality), it is necessary to increase the density of the devices on the silicon wafer. This project fabricated and tested a serpentine waveguide geometry and determined the bending loss as a function of bending radii.

Background

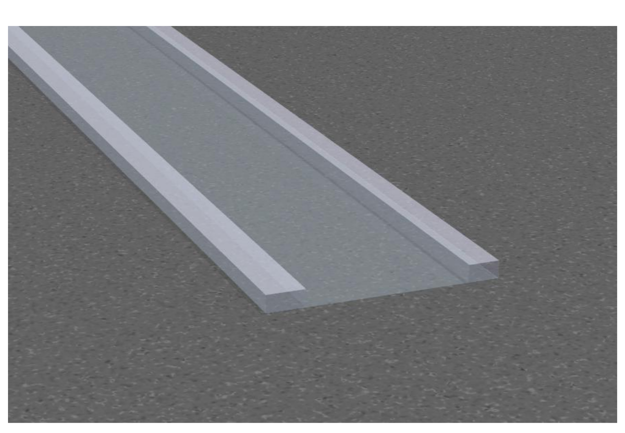
Optical waveguides allow electromagnetic waves, or light, to pass from one end to another via total internal refraction. A core, with a higher refractive index (n_1), is surrounded by a cladding of lower refractive index (n_2). The difference in refractive index allows for confinement of light within the waveguide device. A higher refractive index contrast between the core and cladding layer enables more efficient confinement of the optical field.



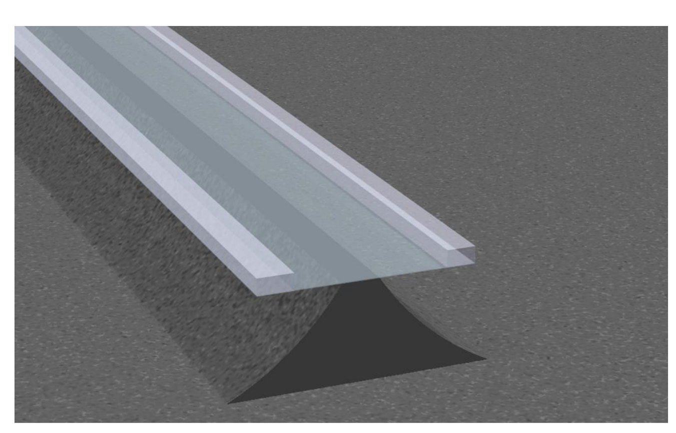
Fabrication Process



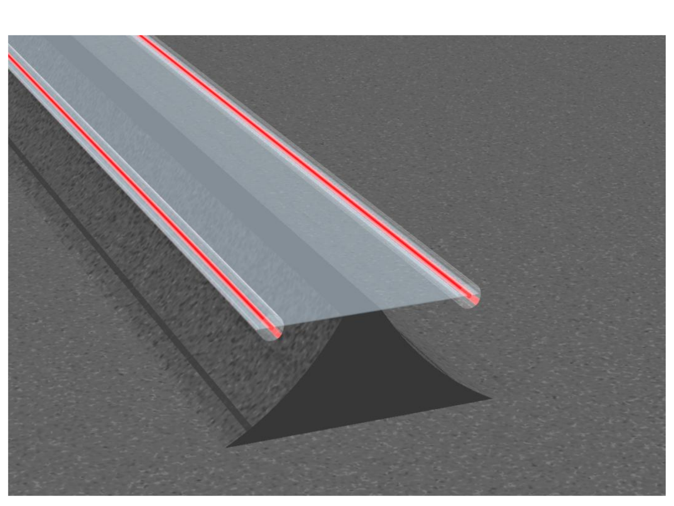
1. Transfer the waveguide pattern via photolithography and remove the uncovered silica using buffered oxide etchant (BOE)



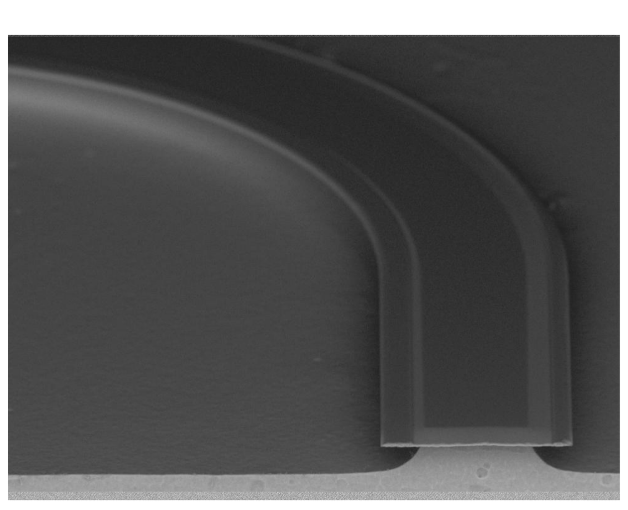
2. Perform a second photolithography in order to thin the membrane between the waveguides



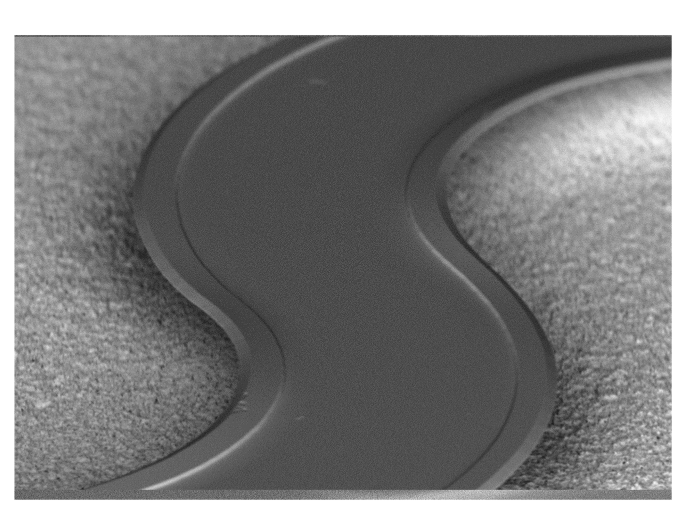
3. Isotropic etching via XeF_2 to elevate the waveguide above the silicon pillar



4. Device reflow using a CO_2 laser

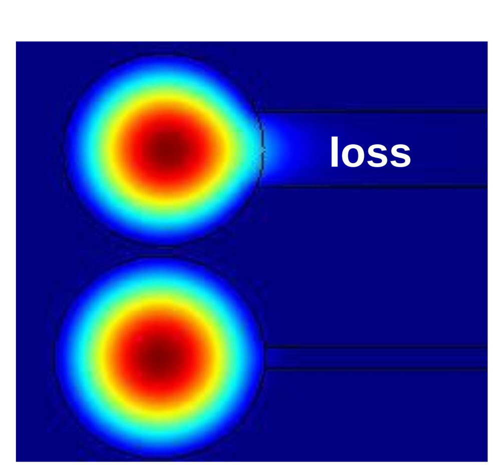


SEM of a cleaved waveguide end, where light is coupled into the device



SEM of the serpentine geometry

Waveguide fabrication is completed in four main steps. In devices that have a single photolithography, there is some optical loss into the silicon pillar (COMSOL simulation). When a second photolithography step is added to the fabrication, process a thinner membrane can be created, thus reducing the total optical loss. Fabrication was completed in the USC Photonics Cleanroom.

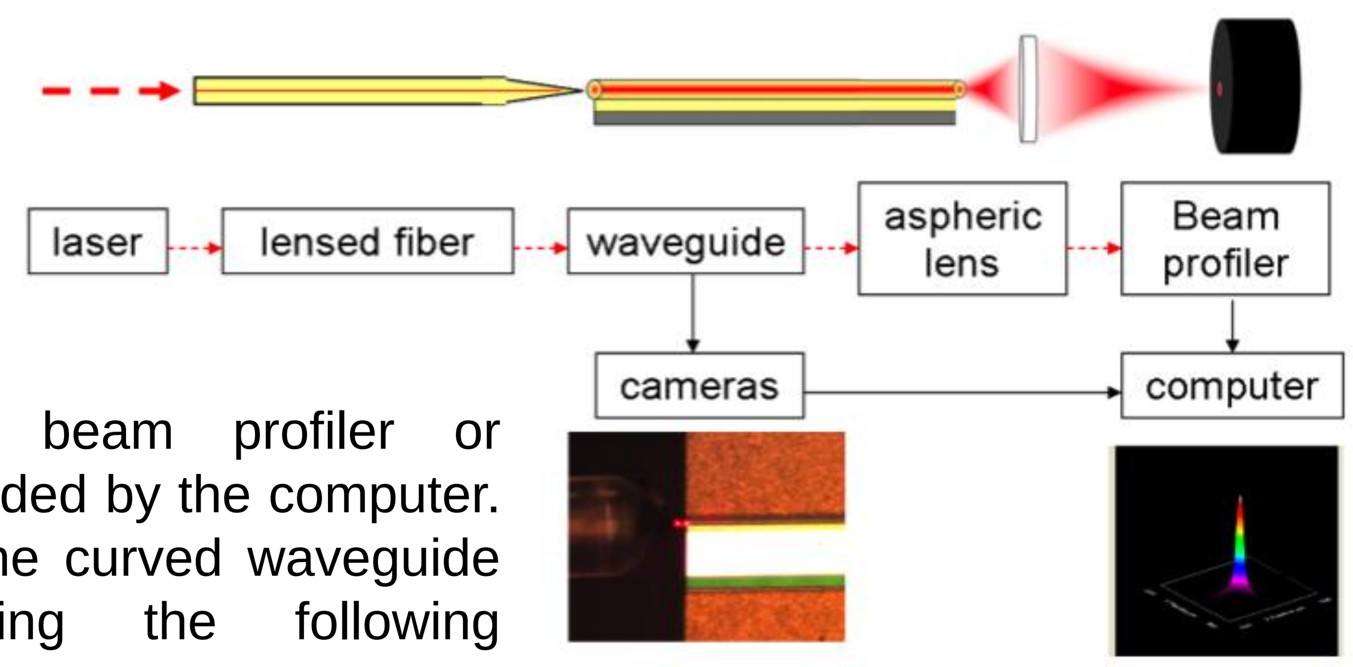


Acknowledgements

ONR
USC | wise Women in Science and Engineering
USC Viterbi Merit Research Program

Measuring Waveguide Loss

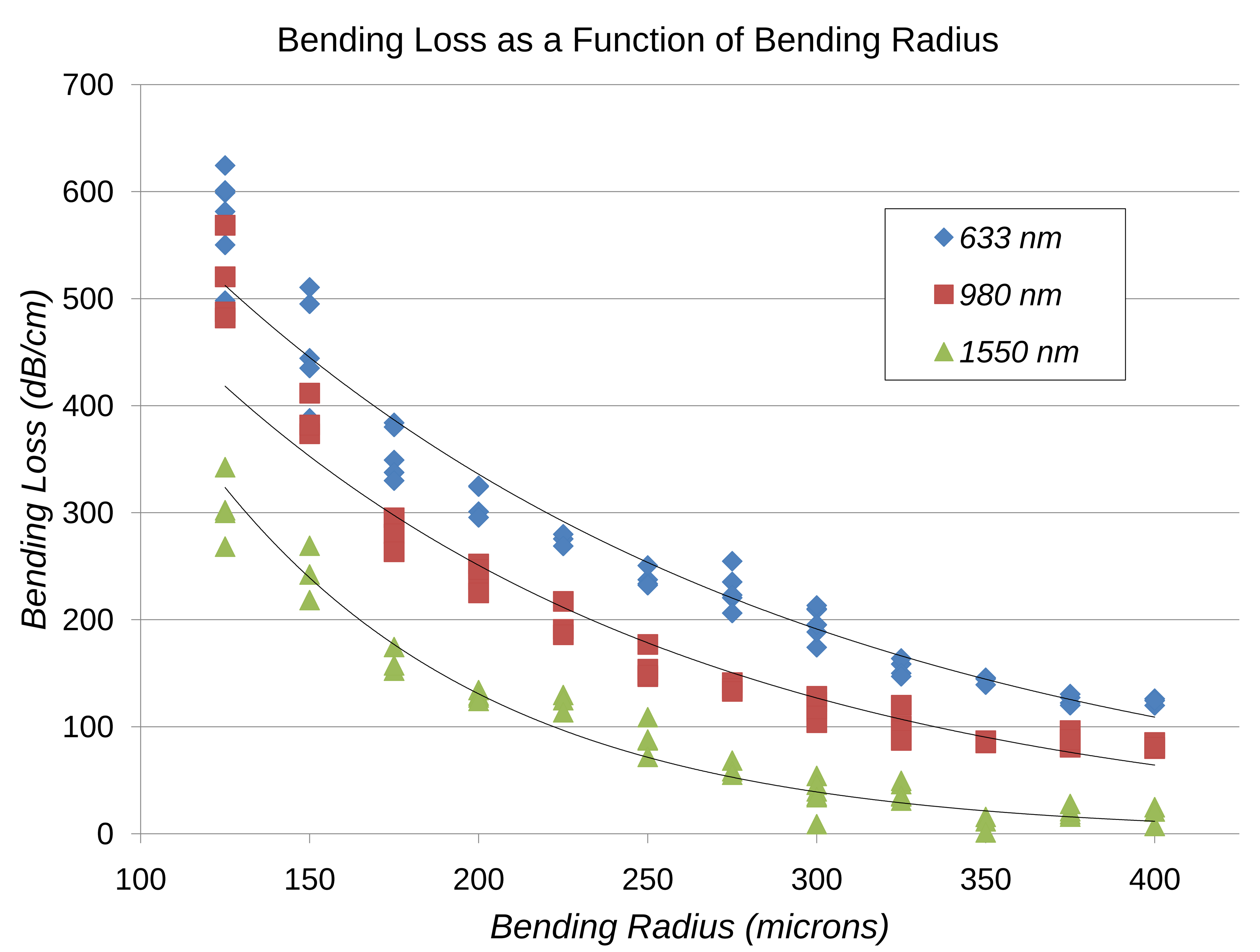
To determine the bending loss, laser light is focused into the waveguide using an optical lensed fiber. The output light is focused onto a beam profiler or detector, which is recorded by the computer. The bending loss of the curved waveguide was calculated using the following relationship:



$$\alpha_{total} = \alpha_{length} + \alpha_{system} + \alpha_{bend}$$

Where α_{total} is the total measured loss of the devices, α_{length} is the loss due to waveguide length, α_{system} is a constant that consists primarily of coupling loss, and α_{bend} is the bending loss. The total loss is found by finding the difference between the input and output power. Losses due to length (α_{length}) are found by measuring the length of the device and multiplying by propagation losses (found by another team member). To account for length differences, the loss was normalized by dividing the measured loss in dB by the arc-length of the waveguide bends. The length loss and the system loss are then subtracted from the total loss to yield the bending loss of the serpentine devices.

Results



This graph shows the bending loss as a function of bending radius using 633, 980 and 1550 nm lasers. Each point represents a unique device (N>3 for each radius). For all three wavelengths, the loss follows an exponential curve. One can see that the exponential fits are very similar, with the shorter wavelengths exhibiting more loss. This occurs because at shorter wavelengths, the light more easily leaks into the silica membrane and is therefore more easily lost into the silicon pillar. The critical bending radius has a slight wavelength dependence, and is below 375 microns for all wavelengths. This data was compared to theoretical simulations of our devices (using LUMERICAL), which also followed a similar exponential trend. Additional experiments and simulations were performed by other group members and combined with these bending loss experiments into a manuscript with the same title as this project, which is currently under review.