

Silicon photonics is of topical interest because of the possibility of building on the large investments and technological advances already made for microelectronics processing. Although silicon has found many applications for passive optical devices, the development of active (the ability to amplify or generate light) devices using silicon has been a major challenge that has prompted much research. Optical amplification from stimulated Raman scattering in silicon-on-insulator (SOI) waveguides is an attractive possibility. The large Raman coefficient of silicon and small optical mode field profile in planar waveguides make it possible to build amplifiers in lengths short enough to be of practical interest.

In this thesis we first studied the inter-relationship between nonlinear absorption (two-photon absorption and free-carrier absorption) and spontaneous Raman scattering in SOI waveguides. The non-degenerate two-photon absorption coefficient of silicon was measured using a picosecond pump-probe technique. We showed experimentally that free carriers generated by two-photon absorption in SOI waveguides can introduce large losses which limit the useable pump power for Raman amplification at telecommunication wavelengths. Simply increasing the continuous-wave pump power does not achieve higher gain because the induced losses can be greater than the gain from stimulated Raman scattering.

The understanding of the fundamental limitation from these nonlinear losses led to the design and realization of an optical amplifier which achieved net Raman gain in SOI waveguides. By using a picosecond pulse pumping scheme to reduce the free carrier density, a net (fiber to fiber) optical gain of 6.8 dB was achieved using stimulated Raman scattering in a 1.7 cm long silicon waveguide. This is the first demonstration of net optical gain in single crystalline silicon without any additional material processing. The results suggest the possibility of fabricating lossless silicon based PLCs.

We also designed and fabricated other functional elements for SOI waveguides based planar lightwave circuits (PLCs). The basic characteristics, such as scattering loss and bending loss, were measured. The multimode interference (MMI) couplers of various structures were fabricated and tested. A novel design of waveguide polarization splitter in Mach-Zehnder interferometer structure was realized. The polarization splitter had high TE to TM extinction ratio, low excess loss, wide operation bandwidth and very simple fabrication method.