Abstract:
Confinement of light in optical microcavities has important applications in the development of low threshold lasers, optical sensors, switches, and modulators as well as the study of cavity Quantum Electrodynamics (cQED) [1, 2]. The majority of dielectric optical microcavities fall into one of two categories: geometric shapes such as disks, rings, and spheres where light is confined by total internal reflection or photonic crystal cavities where light is confined due to frequency band gaps in periodic media [3]. Geometric resonators have shown significant enhancement of light intensity due to large quality factors but generally have large effective mode volumes. Large intensity enhancement has been shown in highly localized regions in photonic crystal cavities, however, the resonant modes in these structures occur only within a small spectral range. A different type of resonant cavity has been observed in randomly arranged semiconductor powders and dyes [4]. Unlike previously demonstrated cavities, light confinement in these systems is achieved via a complex interaction of constructive and destructive interference of light experiencing multiple scattering events. These localized modes are responsible for the coherent feedback lasing recently observed in random media. High Q modes in disordered media can be advantageous for applications due to the existence of resonant modes over a broad frequency range as opposed to photonic crystal cavities where resonant modes are clustered at frequencies within the bandgap [5].

The incorporation of such microcavities as optical devices, however, is challenging. Due to the random nature of these structures, coupling to a specific desired mode and controlling the frequency of this resonance is extremely difficult. Using evolutionary algorithms to design the disordered resonator for single mode operation at 1550 nm, and electron beam lithography for fabrication, we create a disorder-based resonator for integrated photonic devices. This bridges the gap between well-ordered optical microcavities and resonances in random media by demonstrating the ability to tune the degree of coupling light into single localized modes in random media at a well defined frequency and position.

Summary:
We fabricate the disordered resonator with an overall size of about 25 square microns on an SOI platform with a 3 µm buried oxide layer and a 300 nm thick Si layer. The pattern is defined using electron beam lithography and etched using ICP plasma etching. We couple light into the structure using a single mode waveguide in the telecommunication wavelength of 1550 nm.

Based on numerical simulations, this resonator, with feature sizes of approximately 150 nm, confines light to a volume of about a half wavelength in Si cubed with a quality factor of nearly 200.

References:
Integrated Disordered Optical Resonators

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Figure 1, top right:
SEM of disordered resonator in SOI.

Figure 2, below left:
Light intensity in disordered resonator illuminated from a waveguide at 1550 nm computed using FDTD.

Figure 3, below right:
Spectrum of intensity trapped in resonator when illuminated by a waveguide. Inset shows reflectance spectrum.