Evolutionary Photonics
CNF Project # 980-01
Principal Investigator: Michal Lipson

Abstract:
We simulate an evolutionary process in the lab for designing a novel high confinement photonic structure, starting with a set of completely random patterns, with no insight on the initial geometrical pattern. We show a spontaneous emergence of periodical patterns as well as previously unseen high confinement sub-wavelength bowtie regions. The evolved structure has a Q of 300 and an ultra small modal volume of $0.112(\lambda/2n)^3$. The emergence of the periodic patterns in the structure indicates that periodicity is a principal condition for effective control of the distribution of light.

Summary:
We demonstrate and fabricate the design of a sub-diffraction limit mode volume optical resonator. The device is in a single layer slab, with a center bow tie cavity and surrounded by distributed Bragg layers. The bow tie creates a small modal volume cavity. The Bragg layers act to confine light in the bowtie cavity and increase Q of the structure.

The device geometry was generated with an evolutionary algorithm from random. There was no initial seeding for the device geometry. The merit function for device design was the field intensity in the structure center. Repeated runs of the algorithm generated the same basic geometry. Structure was limited to 250 nm thick silicon substrate, 4 by 5 µm, and surrounded by either oxide or air lower index material.

The device was analyzed and found to have sub-diffraction limited mode volume of $0.112(\lambda/2n)^3$. Excitation was provided by 1.5 µm wavelength continuous wave. Device simulation was run until a steady state was achieved. The unusual shape of the resonator has not been previously reported in the literature and opens a potential for future optical structure design. The small mode volume could be used to offset low Q values and increase bandwidth of resonators which need high bandwidth and high nonlinear effects.

The algorithm demonstrates a completely different approach for ground up structure design. It could be used to explore photonic devices with unusual properties, which are difficult or impossible to design efficiently “by hand”.

The CNF nanocluster was used for evolutionary simulations for device design. Devices were fabricated with JEOL e-beam lithography on SOI wafers.

References:
Evolutionary Photonics

CNF Project # 980-01
Principal Investigator: Michal Lipson
Users: Alexander Gondarenko, Stefan Preble, Jacob Robinson, Long Chen
Affiliations: Electrical & Computer Engineering; Applied & Engineering Physics; Cornell University
Primary Funding: NSF
Contact: ML292@cornell.edu, AAG42@cornell.edu

- An evolutionary algorithm on a distributed computing platform at CNF nanocluster was used to design a new class of optical resonators.

- The new resonators show a sub diffraction limit optical mode volume $0.112(\lambda/2n)^3$.

- We attempted to design structures by hand, similar to the ones produced by the algorithm, but in simulations, our devices performed poorer.

- We fabricated hand and computer evolved devices to show fabrication feasibility.

- The devices shows a narrow central slot (10s of nanometers), surrounded by distributed Bragg layers.

Figure 1: Device “hand designed” from results of evolutionary algorithm. 1.5 µm excitation field. Designed for sub diffraction optical mode volume.

Figure 2: Device designed by evolutionary algorithm, theoretically out-performs hand designed device. 1.5 µm excitation field. Designed for sub diffraction optical mode volume.