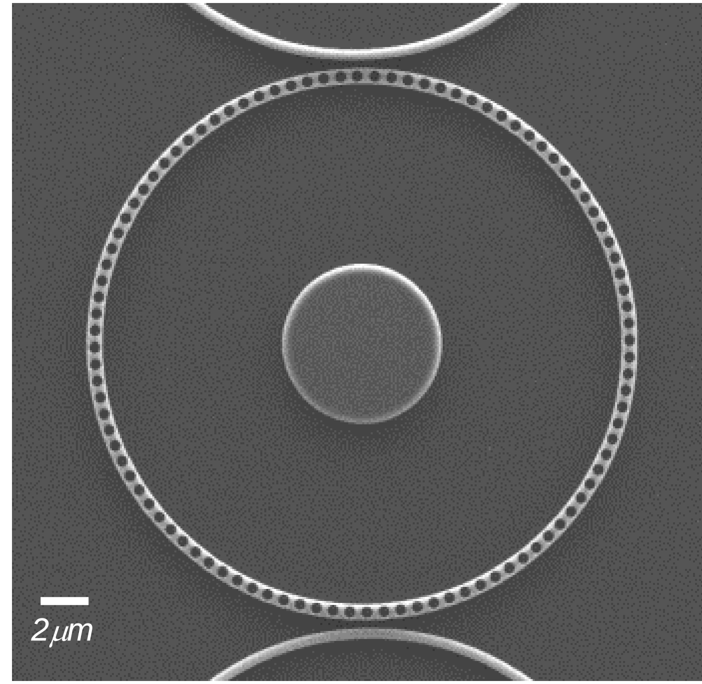
Georgia Tech IEN EBL Facility
NNIN Highlights 2014
External User Projects

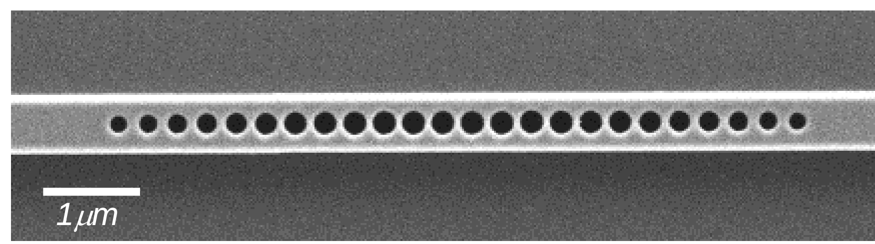
Silicon based Photonic Crystal Devices

Silicon based photonic crystal devices are ultra-small photonic devices that can confine light in a space of less than 1μm^3. By utilizing the state-of-the-art nanofabrication technique, critical dimensions of these devices have been controlled within 10nm.

These devices provide promising solutions to low-energy optical modulation, biological sensing and optical signal processing applications, due to its high optical confinement properties. The photonic crystal micro-ring resonator has potentially 50% less power-consumption than conventional silicon-based devices in optical modulation.

Past demonstrations of DNA sensing on the photonic crystal micro-ring resonator also provide more than 2-fold enhancement of sensitivity than conventional devices.





Top: photonic crystal micro-ring resonator for low-energy optical modulation and bio-sensing applications.

Bottom: photonic crystal nano-beam for optical signal processing applications.

Stanley M. Lo and Philippe M. Fauchet, Vanderbilt University
Work performed at Georgia Tech Institute for Electronics and Nanotechnology

Optical Devices with Parity-Time Symmetry

According to quantum theory, physical observables are represented by Hermitian Hamiltonians with real eigenvalues. However, it has been shown that non-Hermitian Hamiltonians can have a real eigenvalue spectrum if they follow parity-time (PT) symmetry. A Hamiltonian is PT symmetric if it shares the same eigenfunctions with the PT operator and also has even symmetry in the real part of the complex potential and odd symmetry in the imaginary part.

Optical devices which demonstrate PT symmetric behavior have a spatially even refractive index profile and an odd gain/loss distribution. The development of on-chip integrated photonic devices with this behavior requires fabrication of polymer waveguide structures. Waveguide patterns with features such as channel waveguide arrays (Figure 1) and ring resonators (Figure 2), are written into thin films of PMMA via electron beam lithography. Gain, loss, and refractive index changes can be introduced by doping the polymer with organic dyes, quantum dots, etc. to achieve PT symmetry.

The long-term impact of this research will be insight into a new class of optical waveguides and the potential of easily fabricated devices which are unmatched by any currently known methods. This work will contribute to a larger effort to improve the technology of integrated optics.

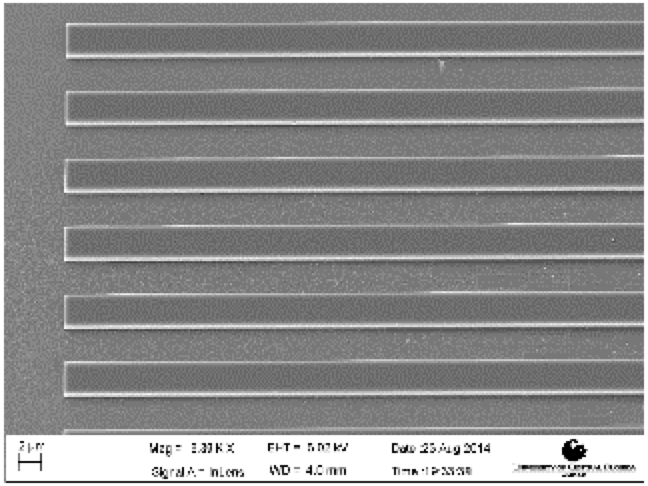


Figure 1. Array of PMMA channel waveguides.

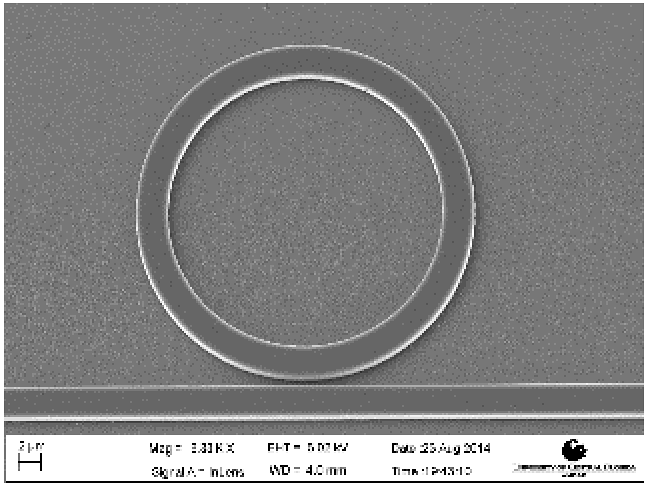


Figure 2. PMMA ring resonator and channel waveguide

L. Pye, A. Abouraddy; CREOL, University of Central Florida
D. Brown; Georgia Institute of Technology
Work performed at Georgia Tech Institute for Electronics and Nanotechnology

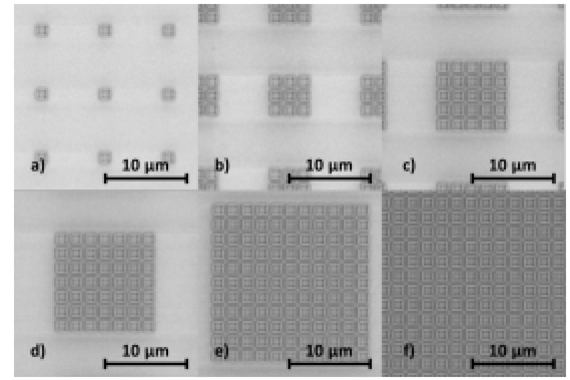
Array Truncation Effects in Infrared Frequency Selective Surfaces

Infrared frequency selective surfaces and related structures (such as metasurfaces) are typically considered infinite in extent in simulations and approximated as such in real life. However, certain applications require small scale interactions, where the effects of finite array size are observed.

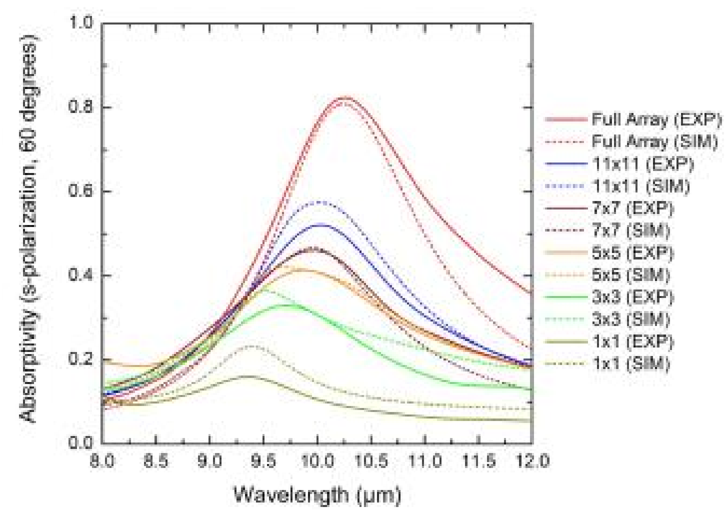
Here, a square loop infrared FSS resonant near 10 μm was designed to investigate the effects of truncation. These effects were demonstrated by fabrication of patterned areas of 1 × 1, 3 × 3, 5 × 5, 7 × 7, 11 × 11 sub-arrays as well as a fully populated quasi-infinite array. Proximity effects in the electron-beam lithography were mitigated by dosing and line width biasing to ensure that each square loop had the same geometry.

Array truncation effects were observed experimentally in the far-field through spectral absorptivity measurements, where blue-shifting of the resonant wavelength upon truncation happens due to the decreased inter-element coupling experienced by the outer elements in the truncated arrays. These effects were observed in the near-field as well (not shown), where disruptions in the uniformity of the local electric field distributions occurred as a result of truncation.

Jeff D' Archangel[1], Eric Tucker[2], and Glenn Boreman[2]
[1]CREOL, University of Central Florida
[2]University of North Carolina at Charlotte
Work performed at Georgia Tech Institute for Electronics and Nanotechnology



SEM micrograph of truncated arrays as well as a quasi-infinite array.



Spectral absorptivity of the truncated arrays as well as the full (quasi-infinite) array.

"Array truncation effects in infrared frequency selective surfaces," Optics Express 22 (13), 2014.

E-Field Mapping for Infrared Antenna

This project focuses on mapping the local electric field (E-field) of various antenna structures using scattering type Scanning Near-field Optical Microscope (*s*-SNOM).

The design of these antenna and their near-fields response are simulated in HFSS, a finite element method software commercial software package. Then, the devices are patterned via e-beam lithography at the Nanotechnology Research Center at Georgia Institute of Technology. Metallization and lift off on the samples are done at UNC-Charlotte, then verified by scanning electron microscopy (SEM) (Figure 1).

The *s*-SNOM measurements are done using a custom built system utilizing an atomic force microscope (AFM) operating in tapping mode (Figure 2). Structures are excited with infrared laser radiation (10.6 μm wavelength), then the AFM tip scatters the excited near field signal back into the system so it can be measured. The *s*-SNOM measurements are used to extract data pertaining to the E-field (amplitude and phase information) of various antenna structures (Figure 3).

E. Tucker and J. D'archangel, UNC-Charlotte
Work performed at Georgia Tech Institute for Electronics and Nanotechnology

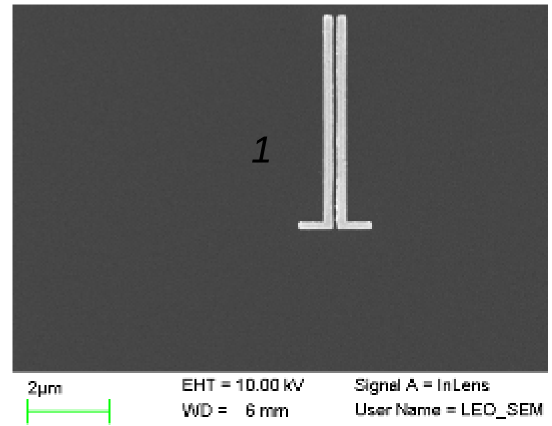


Figure 1: SEM image of folded CPS structure

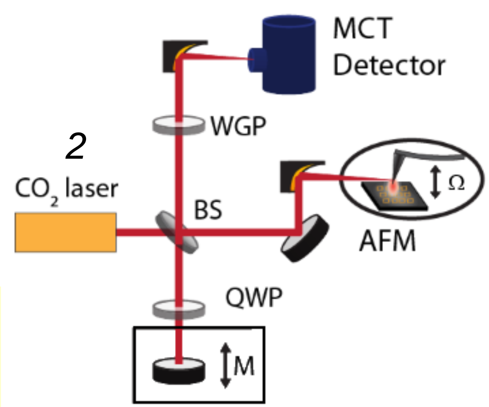


Figure 2: Schematic of the SNOM setup

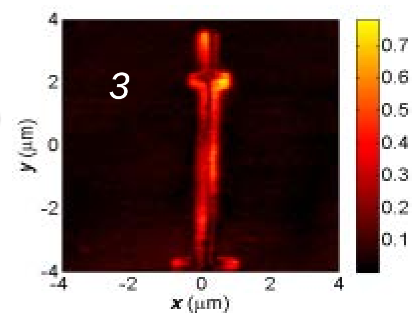


Figure 3: Instantaneous field measurement of Folded CPS structure with s-SNOM;

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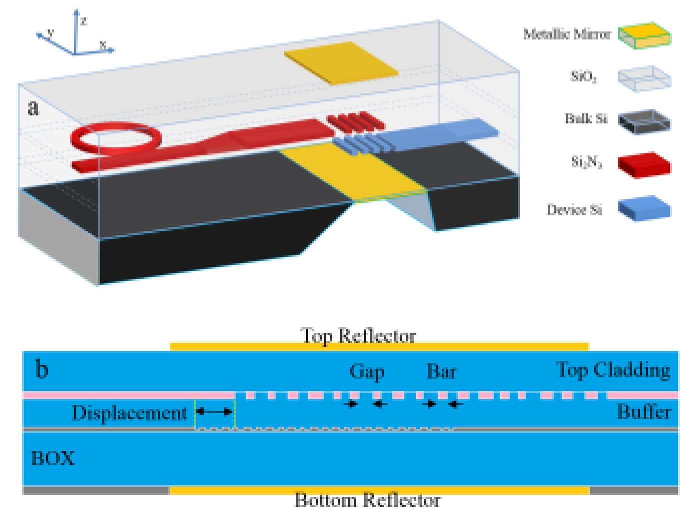
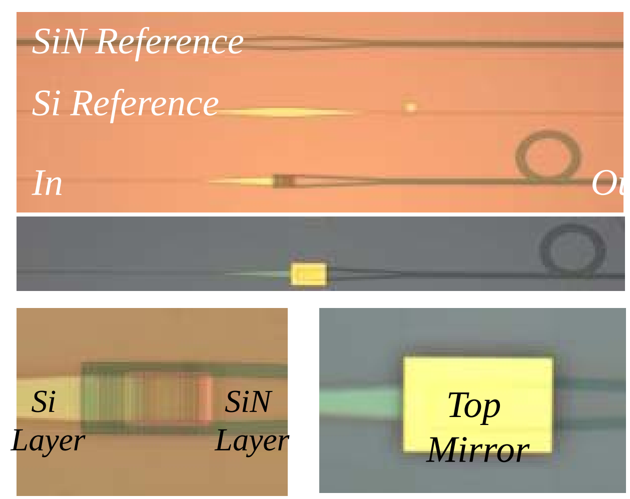
Internal User Projects

Si/SiN Interlayer Grating Coupler

We have designed interlayer grating couplers with single/double metallic reflectors for Si/SiO2/SiN multilayer material platform. Out-of-plane diffractive grating couplers separated by 1.6 μm thick buffer SiO2 layer are vertically stacked against each other in Si and SiN layers. Geometrical optimization using genetic algorithm coupled with electromagnetic simulations using two-dimensional (2D) finite element method (FEM) results in coupler designs with high peak coupling efficiency of up to 89% for double- mirror and 64% for single-mirror structures at telecom wavelength. Also, 3-dB bandwidths of 40 nm and 50 nm are theoretically predicted for the two designs, respectively. Measured values for insertion loss and bandwidth in the fabricated single-mirror coupler confirms these results. This opens up the possibility of low-loss 3D dense integration of optical functionalities in hybrid material platforms.



3D Schematic and Geometrical Optimization Via Genetics Algorithm

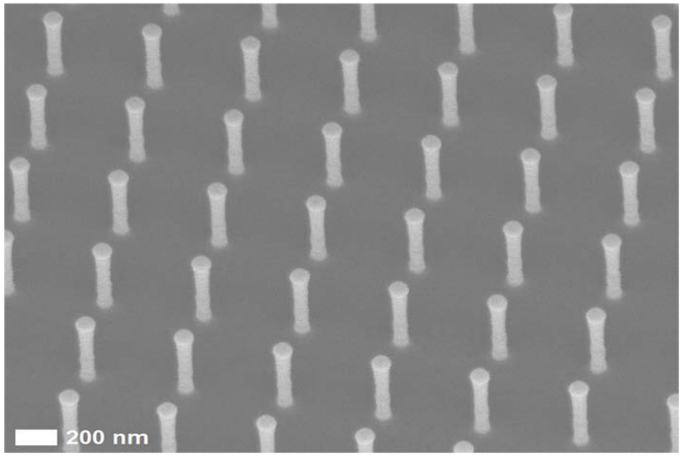


Majid Sodagar, Ali Asghar Eftekhar, and Ali Adibi, Georgia Tech ECE
Work performed at Georgia Tech Institute for Electronics and Nanotechnology

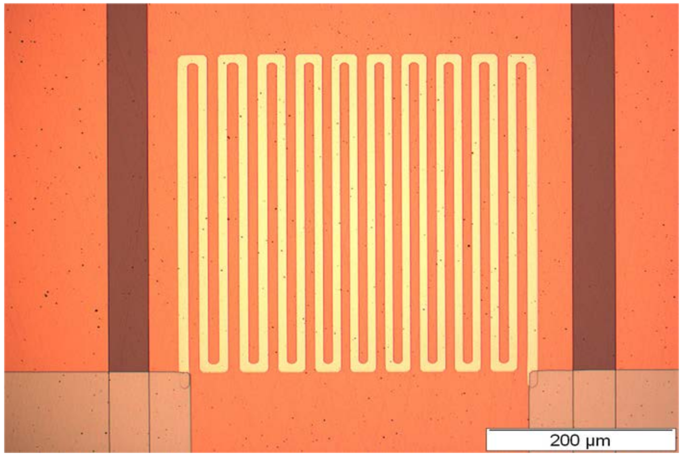
Silicon Nanowire Arrays for On-Chip Thermoelectric Generator

Si nanowire (Si-NW) array based thermoelectric devices are promising for on-chip energy harvesting or Peltier cooling due to high thermoelectric figure of merit. Ten 100 µm x 100 µm arrays of SiNWs with a pitch length of 0.5 µm were patterned using electron beam lithography and HSQ, a negative tone resist. Here, pitch length is center-to-center distance between adjacent wires in a single array. The approximate diameter of nanowires is 100 nm. The Bosch process, was used to successfully etch approximately 0.92 µm of Si to fabricate SiNW arrays.

Resistive heaters were fabricated on a Si wafer to simulate both the background heat flux and hotspots produced during operation of a chip. Resistance thermal detectors (RTDs) are fabricated on top of heater to measure temperature at different locations on the chip. Nine devices were fabricated on a 3 inch Si wafer with seven RTDs and one background heater on each device; two of the RTDs also serve as hotspots. This set-up will help in the measurement of thermoelectric properties of SiNWs.



SEM image of SiNW array



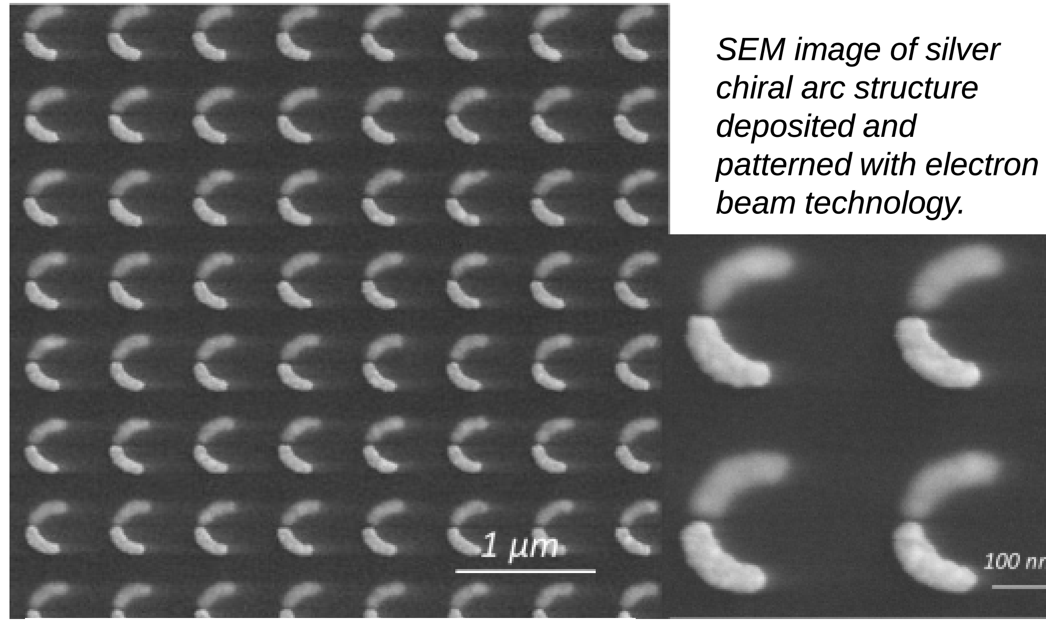
Optical microscope image of fabricated RTD

David Brown and Satish Kumar, Georgia Institute of Technology
Work performed at Georgia Tech Institute for Electronics and Nanotechnology

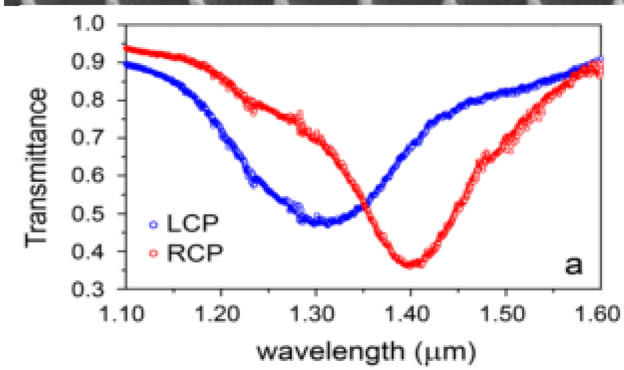
IEN Seed Grant

Giant Chiral Optical Response from a Twisted Arc Metamaterial

We demonstrate enormously strong chiral effects from a photonic metamaterial consisting of an array of dual-layer twisted-arcs with a total thickness of ~λ/6. Experimental results reveal a circular dichroism of ~0.35 in the absolute value and a maximum polarization rotation of ~305º/λ in a near-infrared wavelength region. A transmission of greater than 50% is achieved at the frequency where the polarization rotation peaks. Retrieved parameters from measured quantities further indicate an actual optical activity of 76º per λ and a difference of 0.42 in the indices of refraction for the two circularly polarized waves of opposite handedness. [Abstract. Nano Letters]



SEM image of silver chiral arc structure deposited and patterned with electron beam technology.



Plot of left circular polarized and right circular polarized light normally incident on the metamaterial structure. The structure demonstrates large circular dichroism.

Yonghao Cui, Lei Kang, Shoufeng Lan, Sean Rodrigues, Wenshan Cai, Georgia Tech
Work performed at Georgia Tech's Institute for Electronics and Nanotechnology

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Cui, Y. et. al. "Giant chiral optical response from a twisted arc metamaterial." Nano Letters. ***14.*** *1021*