

Fabrication of Waveguides for Biophotonics and Resonators for Quantum Photonics

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Primary CNF Tools Used: JEOL 9500, E-beam Spin Coaters, Olympus MX-50 Microscopes, Oxford 82, Oxford 100, PT770 RIE, Oxford Cobra ICP, Plasma Therm Tikachi HDP-CVD, Oxford PECVD, Primaxx Vapor HF Etcher, Yes EcoClean Asher, Yes Asher, Filmetrics systems, Zeiss Ultra SEM, Zeiss SEM Supra, Veeco AFM, Disco Dicer Saw

Abstract:

Our group investigates nanophotonic devices for biosensing, quantum sensing, and single photon sources. The geometries we're currently focused on are waveguides for coupling to neurons, Mach-Zehnder Interferometers (MZI) for biosensing, dual photonic crystal (PhC) nanobeams for room-temperature single phonon quantum sensing, and Circular Bragg Cavities (CBGs) for Purcell enhancement of single photon emitters. Recent research achievements include measurement of resonances in the dual nanobeam cavities, and validation of a custom axisymmetric Finite-Difference Frequency-Domain solver used to inverse design the CBGs. Preliminary simulations and measurements are currently underway for the biophotonic devices.

Summary of Research:

Newest users were successfully trained on the Oxford PECVD, Photolithography, and Oxford 82 to facilitate the fabrication of future biophotonic devices. Simulations of waveguide geometries for biosensors based on MZIs are on-going, with fabrication to follow. Coupling measurements between in-house fabricated fiber probes and waveguides (a neuron surrogate) are currently underway.

Successful fabrication of suspended single and dual PhC nanobeams is routine due to thorough process development. Notably, anisotropic etches are achieved using a Hydrobromic Acid (HBr) inductively coupled plasma (ICP) etch, instead of the sulfur hexafluoride and oxygen (SF_6/O_2) chemistry frequently seen in literature for silicon etches. The PhC nanobeams are

released with vapor hydrogen fluoride (HF) etching to create the suspended structures without any stiction. Extensive lab work have resulted in the first successful resonance measurements with good agreement between simulations.

Fabrication of CBGs are also promising; a slight ellipticity was recently measured due to the pattern rastering behavior of the JEOL 9500. This was only found due to successful fabrication of high optical quality factor (Q) of the CBGs. The measurements were in good agreement with the custom FDTD solver, validating the implementation – a paper detailing the process is in progress.

Conclusions and Future Steps:

An initial waveguide geometry for the MZI will necessitate a fabrication at Cornell Nanoscale Facility (CNF) with some process development expected. A suitable geometry for neuron and axon growth on chip will also be investigated and potentially fabricated at CNF. The functioning PhC nanobeams will be placed under vacuum in attempts to measure an optomechanical signal. The CBGs will be characterized before distribution to collaborators for single photon emitter integration.

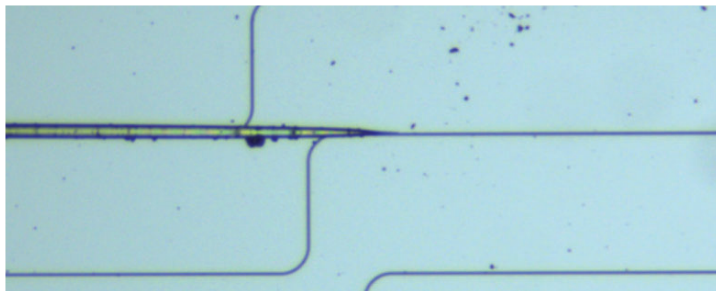


Figure 1: A fiber probe brought close to a waveguide for coupling measurements.

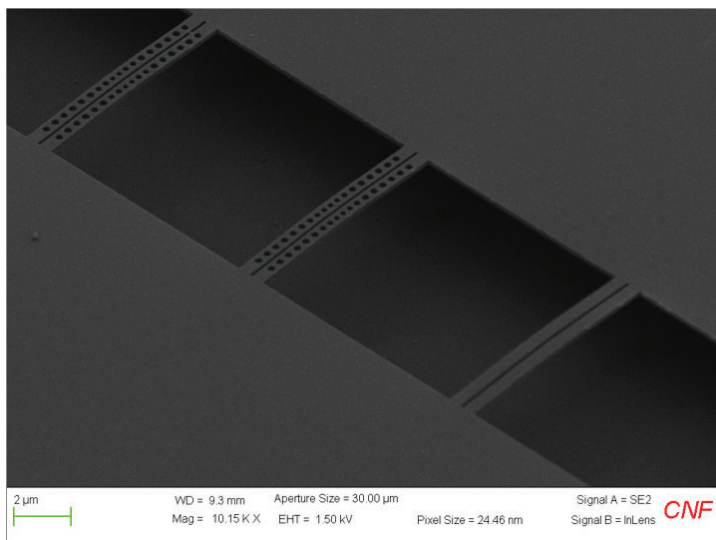


Figure 2: Fabricated free standing dual photonic crystal optomechanic nanobeam cavities.

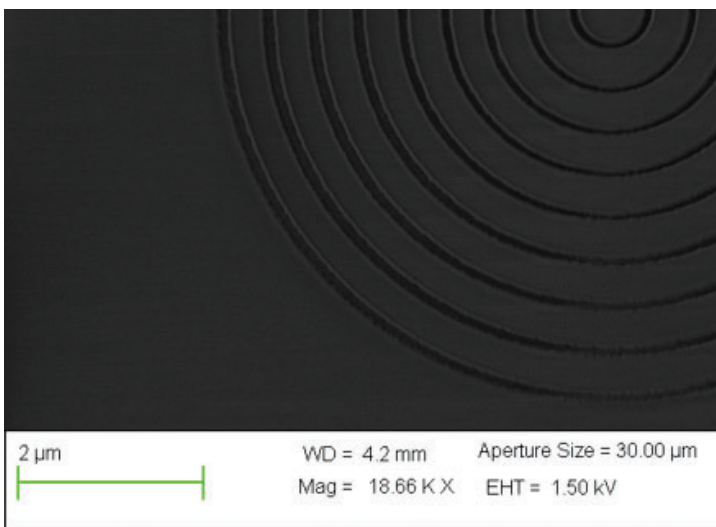


Figure 3: A fabricated CBG with some vertical roughness visible from the top-down raster.

References:

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- [3] Weituschat, L.M., Castro, I., Colomar, I. et al. "Exploring regenerative coupling in phononic crystals for room temperature quantum optomechanics," Scientific Reports 14, 12330 (2024). <https://doi.org/10.1038/s41598-024-63199-1>
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