MEMS and NEMS
Room 205 ABCD W - Session MN1-FrM
Integration and Multiphysics

Moderators: Philip Feng, University of Florida, **Jaesung Lee**, University of Central Florida

8:15am **MN1-FrM-1 MEMS-Enabled Photonic Integrated Circuits*, Marcel Pruessner***, *Todd Stievater, Nathan Tyndall, Steven Lipkowitz, Jacob Bouchard, Kyle Walsh,* US Naval Research Laboratory **INVITED**

Photonic integrated circuits (PICs) are maturing and are rapidly finding application beyond telecommunications, including for sensing and quantum photonics. Many of these applications require PICs that operate at non-telecom wavelengths (e.g. in the visible wavelength spectrum) as well as PICs with new functionality enabled by micro-electro-mechanical systems (MEMS). In collaboration with AIM Photonics, we have developed a foundry PIC platform optimized for visible wavelengths focusing on reducing propagation loss and designing efficient PIC components[1]. At the same time, we have also investigated novel functionality in PICs enabled by MEMS. This presentation will focus on “MEMS-enabled photonic integrated circuits,” their fabrication and incorporation in PIC foundries, and novel functionality enabled by combining PICs with MEMS. A variety of MEMS-enabled PIC devices will be discussed including MEMS-tunable phase shifters[2] and optical cavities[3], optical forces in cavity optomechanical systems[4], mode conversion using MEMS perturbation[5] and phase matching[6], and broadband waveguide thermal emitters[7] enabled by MEMS bulk micromachining techniques[8].

[1] https://doi.org/10.1117/12.3012847 and https://doi.org/10.1364/OE.504195

[2] https://doi.org/10.1364/OE.24.013917 and https://doi.org/10.1364/OSAC.419410

[3] https://doi.org/10.1063/1.2883874 and https://doi.org/10.1364/OL.44.003346

[4] https://doi.org/10.1364/OE.19.021904 and https://doi.org/10.1103/PhysRevLett.108.223904

and https://doi.org/10.1021/acsphotonics.8b00452

[5] https://doi.org/10.1364/OE.488624

[6] https://doi.org/10.1364/OL.474806

[7] https://doi.org/10.1038/s41467-024-48772-6

[8] https://doi.org/10.1063/5.0252536

8:45am **MN1-FrM-3 Slot Mode Optomechanical System for Mass Sensing*, Cheeru Thrideep,*** University of Alberta, Canada*; Miroslav Belov,* NRC, Canada*; Wayne Hiebert,* University of Alberta and The National Institute for Nanotechnology, Canada

Optomechanical systems have demonstrated their significance in sensing applications. We study a slot mode optomechanical system where in a THz optical mode from a Photonic Crystal (PhC) cavity is coupled to a MHz mechanical mode of the cantilever to construct an effective mass sensitive device specifically operating at low-frequency region.

In slot-mode optomechanical devices, the coupling of photonic and phononic beams is utilized to enhance the optomechanical coupling strength beyond what is achievable in single nanobeam crystals. We consider the integration of Silicon PhC with cantilevers on either side which essentially behave as a slot mode optomechanical system. A modified inline coupling technique in reflection mode is used to couple light into the cavity by manipulating losses at the mirrors. To achieve this, the coupling end of the waveguide is provided with only 1 to 5 holes to access different coupling regimes. We utilized COMSOL to model our slot-mode optomechanical system, considering both photonic and phononic bandgap. The PhC- cantilever system was fabricated, and the chip underwent testing through a pump and probe system to evaluate the device’s mass sensitivity. We were able to realize a mass sensitivity of 51zg despite the encountered temperature fluctuation noise. This aligns with the notion that our shorter cantilever demonstrated an improved G of 0.12 GHz/nm, as compared to the value achieved by our research group for a longer cantilever coupled to a racetrack resonator.

9:00am **MN1-FrM-4 Integration of Metal Microsystems for Gas Sensing*, David Hayes***, *Henry Davis, Jeremy Cook, Jordan Grow, James Harkness, Isa Kohls, Richard Vanfleet, Brian Jensen, Nathan Crane, Robert Davis,* Brigham Young University

Microfluidic devices are a versatile and powerful class of analytical and production tools with applications spanning medical diagnostics, drug development, food safety, and chemical production among others. A subset of microfluidic devices are microscale gas chromatography columns, which offer high speed chemical separations and system miniaturization. Hermetic sealing of micro chromatography channels and interfaces are challenges that have inspired a wide range of solutions. We will describe our developments in interfacing to both 3D printed metal microcolumns and machined metal microfluidic structures using pressure-controlled microbrazing.

9:15am **MN1-FrM-5 Nanomechanical Resonances of Graphene Membranes Integrated on $LiNbO_3$-on-Insulator Chips*, Nawara Tanzee Minim***, *S M Enamul Hoque Yousuf, Yunong Wang, Philip Feng,* University of Florida

We present the integration and dynamic characterization of graphene membrane suspended over engineered dual-depth trench structures on a lithium niobate ($LiNbO_3$) -on-insulator (LNOI) substrate for probing out-of-plane flexural resonances. The substrate comprises a 600 nm $LiNbO_3$ film atop 4.7 μm thermally grown SiO_2 and a bulk silicon handle wafer, enabling piezoelectric compatibility and optical transparency. The device features rectangular trenches (12 μm × 70 μm, 300 nm deep) patterned via lithography and etching, with centrally embedded circular cavities (12 μm diameter, 1.5 μm deep) fabricates with focused ion beam (FIB) milling after carbon coating to introduce localized geometric perturbation. The structure is actuated using a broadband piezoelectric shaker coupled to the chip, inducing flexural motion across the suspended regions, and resonance modes are detected using laser interferometry. This architecture enables the comparative analysis of flexural eigenmodes in shallow vs. deep trench regions, highlighting the effect of local stiffness gradients, boundary conditions, and air damping. The use of $LiNbO_3$ as the underlying substrate introduces unique opportunities for acousto-optic and electro-mechanical coupling due to its strong piezoelectric and nonlinear optical properties. By leveraging the anisotropic elastic constants of $LiNbO_3$ and the high mechanical compliance of graphene, this platform facilitates the study of mode hybridization (coupling between localized modes of the deep circular trench and delocalized modes of the surrounding shallow trench, mediated by the continuous graphene membrane) and strain-tunable resonances through in-plan actuation of piezoelectric response in nanoscale membranes. Furthermore, the dual-depth trench geometry introduces spatially varying boundary stiffness, enabling mode localization and geometric control over frequency splitting. These architectures are compatible with SAW devices and $LiNbO_3$ photonic circuits, offering a pathway to integrated NEMS-photonic systems for sensing, transduction, and filtering applications.

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