Integrated Photonic and Plasmonic Signal Transduction for Micro- and Nanomechanical Sensing

Vladimir A. Aksyuk
Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, MD 20899, USA
vladimir.aksyuk@nist.gov

Measuring unknown quantities by coupling them to mechanical motion dates back at least 5000 years: simple equal-arm balances used for weighing goods in ancient Egypt are in fact mechanical measurement tools, with motion detected optically by the human eye. Modern microfabrication enables sophisticated, high performance 100 micrometer scale physical sensors, while in the quest for ever faster and more precise measurement of vastly smaller forces, masses, as well as other quantities, mechanical tools have now been reduced to well below one micrometer in at least two of the three physical dimensions.

Even at sub-wavelength dimensions, light remains a competitive and, in many cases, superior choice for the mechanical signal detection, for both fundamental and engineering reasons. Optomechanical interactions are strongly enhanced by high quality factor nanophotonic resonators, localizing photons and extending interaction times, making possible quantum-limited nanoscale motion readout at modest optical power and with low power dissipation. Si photonics technology transforms these devices into fiber-connectorized, compact, robust, stable and practical sensors requiring no optical alignment.

Their superior precision and bandwidth have recently been used to advance atomic force microscopy (Figure 1), replacing traditional microscale cantilevers with their laser-readout optics. Similar, integrated cavity-optomechanical detection has been employed to characterize nanoscale stress-controlled SiN tuning fork resonators which exhibit some of the highest measured *fQ* products and show great practical promise for precise, high bandwidth, and high bias stability on-chip motion measurement. Integration of gap-plasmonic resonators into nanomechanical systems achieves not only precise but truly local motion measurement, confined to a 100 nm scale footprint, capable of spatially distinguishing between NEMS mechanical modes. Broadband and lossy nature of plasmonics allows the use of white light for motion readout and enables very compact thermo-optically driven plasmomechanical oscillators.

These examples illustrate the significant, yet largely unexplored, technological potential of highly integrated transducers combining Si photonics, MEMS, NEMS, cavity-optomechanical and plasmonics.

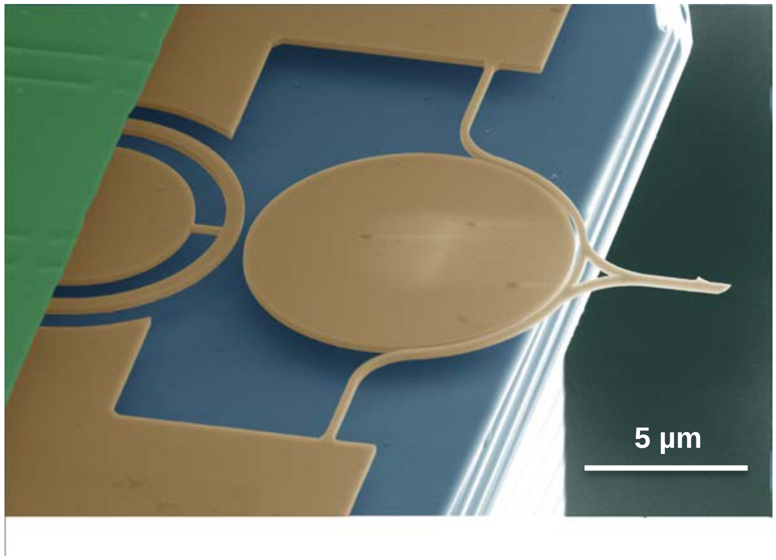

Figure 1: Nanoscale atomic force microscopy probe with integrated photonic cavity-optomechanical readout. Scaling down the mechanical cantilever increases speed and decreases drag and noise in air/fluid. The photonic motion readout with the evanescently-coupled high *Q* microdisk optical cavity simultaneously achieves high bandwidth and high precision. The fast fiber-connectorized chip-scale integrated probe enabled direct measurements of local thermal expansion dynamics and thermal conductivity at the nanoscale.