Cavity optical transducer for scanning probe microscopy

T. Michels[1,2], J. Zou[1], H. Miao[1], V. Aksyuk[1], I.W. Rangelow[2]
[1]*Center for Nanoscale Science and Technology, National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899*
Thomas.michels@nist.gov

[2]*Institute of Micro- and Nanoelectronics, University of Technolgy Ilemanu, 98684 Ilmenau, Germany*

Research and development of transducers based on cavity optomechanics is a topic of high interest particularly because these transducers enable measurement of mechanical motion down to the fundamental limit of precision imposed by quantum mechanics. We have developed an on-chip cavity optomechanical transducer platform that combines high bandwidth and sensitivity near the standard quantum limit with compactness, robustness, small size, and potential for low cost batch fabrication inherent in MEMS [1].

We present design and implementation of a fully integrated and fiber pigtailed sensor for atomic force microscopy. The device combines high sensitivity, high bandwidth optomechanical readout and built-in thermal actuation. It is implemented by a microfabrication process combining one e-beam patterning and 10 optical lithography steps to define silicon nitride torsional cantilever, single crystal silicon-on-insulator (SOI) microdisk optical cavity with high optical Q, SOI optical waveguides, as well as a patterned gold layer for electrically driven thermal actuation. Back and front side anisotropic potassium hydroxide (KOH) silicon etch is used to overhang the cantilever over the edge of the silicon chip and to define v-groves for single mode optical fiber attachment. Two sacrificial silicon dioxide layers are removed by an isotropic hydrofluoric acid (HF) etch to free the mechanically movable structures.

The SiN torsional oscillator can be excited by an electrical signal supplied to an integrated thermal actuator. The oscillator is evanescently coupled to a high-Q whispering gallery mode of the optical cavity and the motion is detected by measuring the resonance frequency shift of the mode. One side of the oscillator probe overhangs the edge of the chip, where it can be easily coupled to a variety of off-chip samples and physical systems of interest. A 10 um long probe is currently designed to have a stiffness of 1 N/m to 3 N/m and a resonance frequency of 100 kHz to 2.5 MHz, while the design can be easily and broadly tailored for specific sensing applications.

[1] H. Miao et. al., *New Journal of Physics* **14**, (2012)

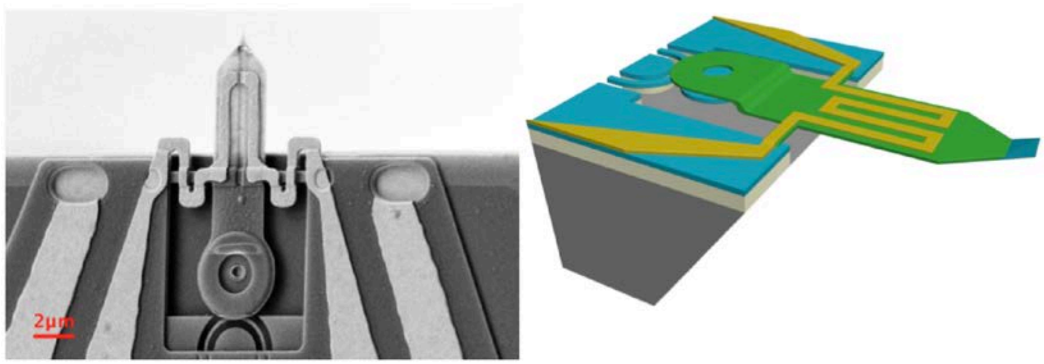

Figure 1: SEM image of the release cantilever (left). Schematic of cavity optical transducer for scanning probe microscopy (right).

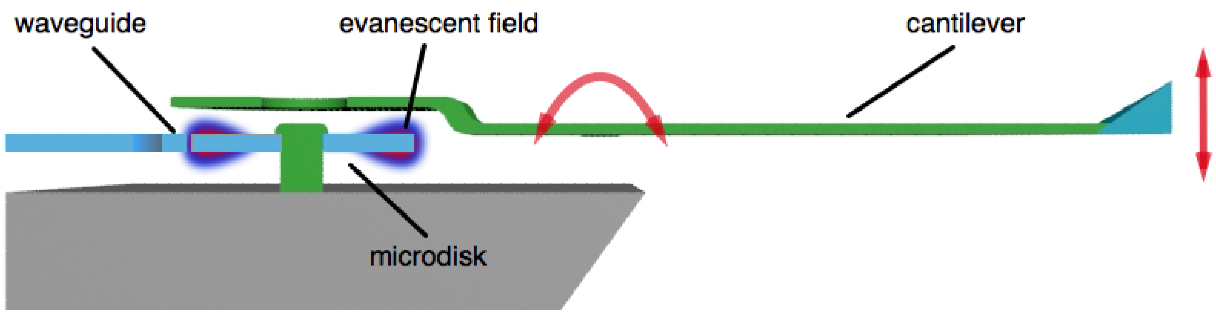

Figure 2: Cross sectional view of optical cavity transducer. Red arrows indicate direction of motion.

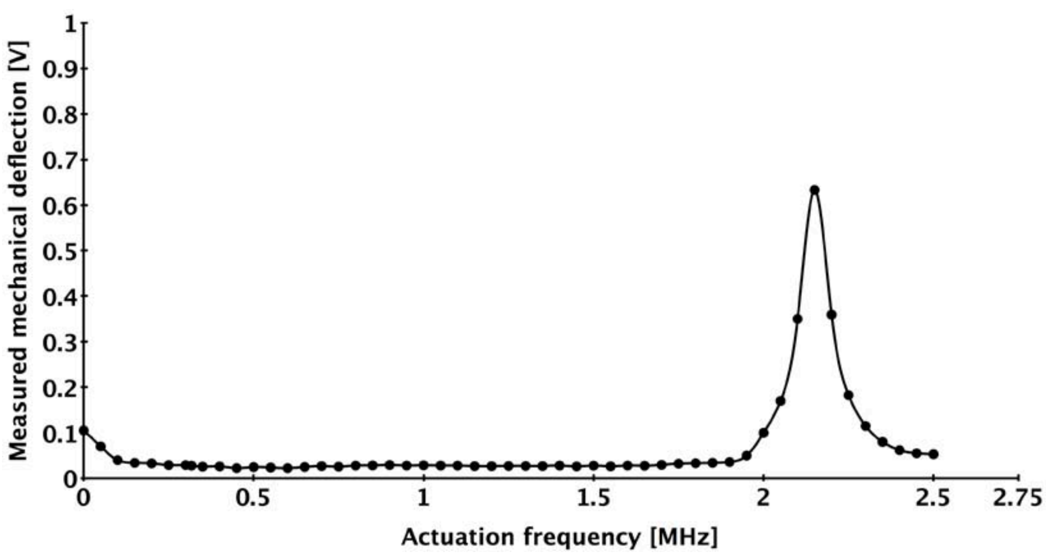

Figure 3: Output of optical cavity transducer when driven by integrated actuator, Maximum signal corresponds to a deflection of 3 nm.