A New Oscillator for SI-Traceable Measurements in Atomic Force Microscopy

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Abstract
Atomic force microscopy (AFM) is used to image, measure, and manipulate surface atoms. In general, an atomic force microscope (see Fig. 1) consists of a microscale cantilever with a sharp tip at its end that is used to probe the sample surface. Forces between the tip and the sample lead to a cantilever deflection according to Hooke's law. Usually, manufacturers provide nominal cantilever stiffnesses (k) to AFM users, who then measure an approximate tip deflection (x) to *estimate* the tip-sample force ($F = kx$). Accordingly, AFM has been used to estimate small forces including van der Waals, chemical bonding, and Casimir forces[1].

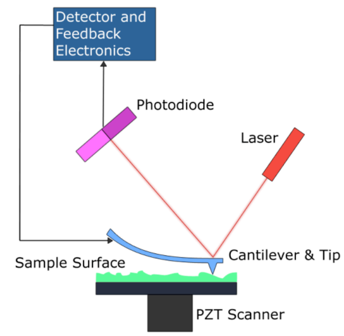

Figure 1. Block Diagram of an AFM.

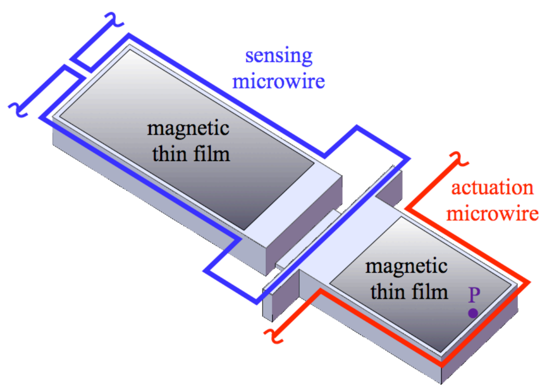

Figure 2. Micro-oscillator composed of a sensing side (left), an actuation side (right), and microwires.

However, commercial AFM suffers from a lack of accurate force measurements because there is presently no universal method to disseminate nanonewton-level forces that are *traceable* to the International System of Units (SI). In an attempt to solve this problem, a new micro-oscillator is being developed as a secondary standard for dissemination of SI-traceable nanonewton-level to AFM users. A novel analog control system will keep the actuation side of the device oscillating with a sinusoidal motion that is fairly insensitive to the quality factor. Thereafter, point P in Fig. 2 will be calibrated as a velocity standard *ex situ*. Then, the device can be used *in situ* with applied electrostatic forces[2] to measure SI-traceable nanonewton-level by standards of the National Institute of Standards and Technology (NIST).

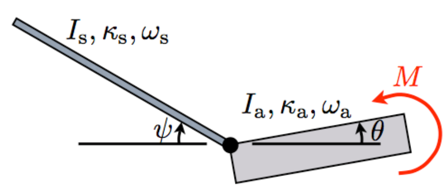

Figure 3. Approximate oscillator model.

The theoretical foundations, microfabrication steps, and preliminary experimental data for the device will be discussed in this presentation. First, we outline the two-degree-of-freedom approximation for the system, which is seen in Fig. 3. Second, the nonlinear control system that transforms the system into a Rayleigh-like oscillator[3] is explained. In fact, we show how the device could be calibrated in air and then used in ultra-high vacuum with a velocity shift within 0.4 percent. Finally, we examine the preliminary experimental data and also explain the possible future use of the new micro-oscillator as a stiffness sensor.

[1]e.g., G. L. Klimchitskaya *et al.*, Phys. Rev. A, **60**(5), pp. 3487–3494 (1999).
[2]e.g., P. J. Cumpson and J. Hedley, Nanotechnology, **14**, pp. 1279–1288 (2003).
[3]p. 147 of A. H. Nayfeh's *Introduction to Perturbation Techniques* (Wiley, 1981) describes the Rayleigh equation.