ROLE OF OFFSET VOLTAGE AND FEEDBACK LOOP IN KELVIN PROBE FORCE MICROSCOPY, Ivy Yoke Leng Wan, Jack Kohoutek, Hooman Mohseni*, Northwestern University, Electrical Engineering and Computer Science, Evanston, IL, 60201, i-wan@northwestern.edu

Kelvin Probe Force Microscope (KPFM) is an adaptation of the noncontact mode of Atomic Force Microscopy (AFM) [1]. The KPFM is a powerful imaging tool used in many fields to provide information on the nanometer scale. In our lab, the KPFM is used to explore the Casimir effect and also to perform potential mapping of electron confinement in quantum cascade lasers. In a world where nanotechnology devices are heading towards the subnano scale, the Casimir force is one of the most important forces because it grows with the inverse fourth power of distance [2]. In the following we briefly describe our newly developed method to accurately model KPFM, and to optimize the main parameters involved.

We performed tapping mode using KPFM on a metal plate (Figure 1). The tip is connected electrically to a function generator. The function generator sets the offset voltage to the tip and the square wave peak-to-peak voltage (AC voltage). The two signals that provide useful information are changes in phase and amplitude of the deflection signal with varying potential. The deflection signal indicates the movement of the tip. We are interested in the phase signal because it is more sensitive to small forces compared to the amplitude signal. The phase data is sent to both the lock-in amplifier and the oscilloscope. We saw a jump in the phase signal on the lock-in amplifier at a certain offset voltage. The change in amplitude and phase signal as offset voltage changes were explored.

The tip is driven at 300Hz above the resonant frequency. By doing this, the tip is always in noncontact with the sample [3]. The force as a function of tip-sample distance corresponds to the Lennard-Jones interaction [4]. When the offset voltage is turned on, the tip gets pulled towards the sample, and undergoes a phase change (Figure 2). We are interested in this change in phase.

The vibrating tip is modeled as a simple harmonic oscillation of a mass on a spring. The potential difference between the tip and the surface produces an electrostatic force on the tip. The tip scans the surface of a sample at a distance controlled by a feedback loop. When the tip is being pulled closer to the surface of a sample by the electrostatic force, the amplitude of the vibrating tip decreases. The feedback loop then pulls the tip away from the surface until the amplitude of the vibrating tip increases to its original magnitude. This feedback loop is crucial in order to keep the tip at a noncontact mode.

There are two distinct regions that are explored. In the first region, a low offset voltage is applied to the tip. In this region, the electrostatic force pulls the tip to the surface when the offset voltage is applied. Therefore, the amplitude of the oscillating tip decreases. The feedback loop then brings the tip up until the tip is vibrating in the original amplitude. In the second region, a higher offset voltage is applied to the tip. The tip is now pulled closer to the surface and the amplitude decreases more. The feedback loop now needs to move the tip further to bring the amplitude back to its original magnitude. When moving the tip up, the tip moves from the noncontact region, where the attractive force dominates, to the free oscillation region, where the electrostatic force dominates. This causes a jump in the phase signal. After the jump, the phase signal slowly decreases as offset voltage increases. This is because the tip is being pulled further away, and the force decreases as distance increases. Our model provides insight to the dynamics of KPFM. In particular, it describes the effect of AFM feedback on KPFM measurements and opens new opportunities to utilize this effect.

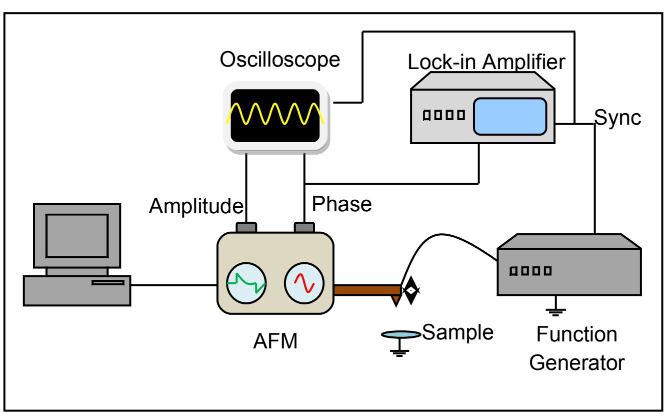

Figure 1. Experimental setup to measure the amplitude and change in phase while varying the offset voltage.

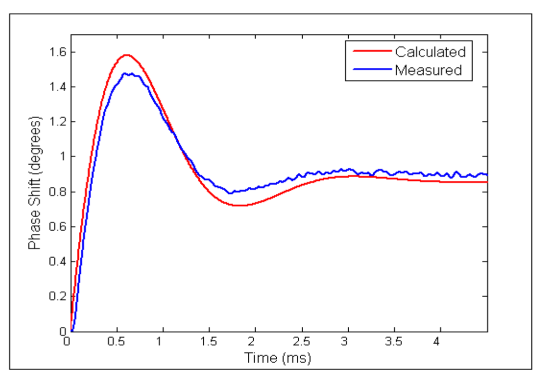

Figure 2. The measured and calculated phase shift.

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