Comparison of methods for recovery of atomic scale lateral forces from torsional mode NC-AFM

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In principle, bimodal noncontact atomic force microscopy (NC-AFM), with simultaneous excitation of the first flexural, and first torsional mode of the cantilever, allows for the simultaneous measurement of both normal, and lateral, forces simultaneously, via measurement of the frequency shift of both modes [1]. In addition, the high sensitivity of the lateral oscillation to the short range interatomic forces, makes it particularly attractive for imaging of samples with low force corrugation [1], or in the presence of high background forces.

In practice, however, quantitative recovery of the lateral forces is complicated both by the bimodal operation, and the unusual shape of the lateral frequency shift when integrated in the x direction. Several methods have been proposed for the recovery of these forces, with varying degrees physical assumptions, mathematical complexity, and difficulty of implementation [1,2,3].

In this work, we perform a quantitative comparison of the different methods available in the literature, and compare the lateral forces recovered to those derived via lateral differentiation of the full potential obtained by integration of the frequency shift of the first flexural mode.

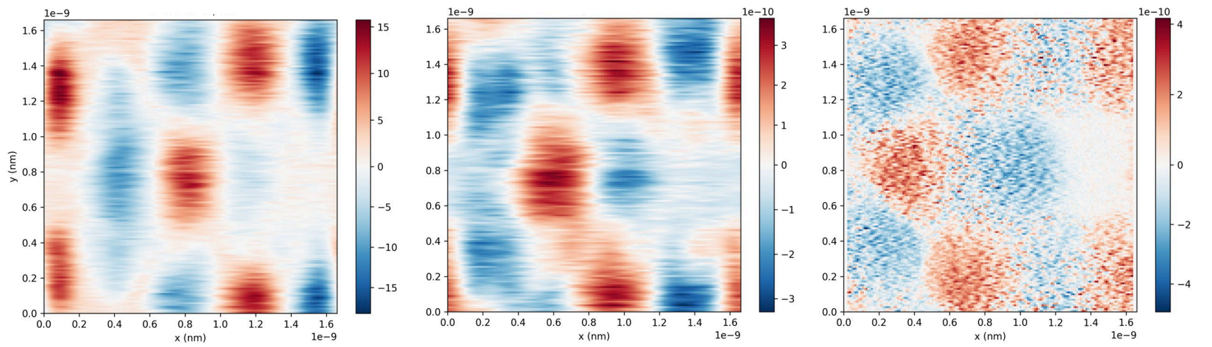

Figure 1. Constant height NC-AFM of atoms around a cornerhole on the Si(111)-7x7 surface. Left - Torsional frequency shift image (in Hz). Middle - F_x derived from Torsional frequency shift via a modified Fourier decomposition method [3] (in Newtons). Right - F_x derived simultaneously via dU/dx of potential from first flexural frequency shift (in Newtons).

Reference

[1] S. Kawai, et al., Phys. Rev. B , 2010

[2] Y. Naitoh et al., Nature Nanotech, 2017

[3] T. Seeholzer et al., New Journal of Physics (2019)