Zooming into atomic interactions with lateral force microscopy

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One of the challenges of atomic force microscopy, in contrast to scanning tunnelling microscopy, is that the signal includes both long-range and short-range components. Measurements with high spatial resolution require sensitivity to the short-range interactions. Over flat surfaces, we can make the simple but profound observation that long-range interactions act in the direction of the surface normal whereas short-range interactions have a strong lateral component. To be sensitive to these short-range forces, we use frequency-modulation lateral force microscopy (LFM) [1,2]. Making direct measurements in the lateral direction allow these short-range components to be isolated (reviewed in Ref. [3]).

In this contribution, I will introduce LFM – both the practical implementation and what we expect to observe. What signal do we expect to see when we image a single adsorbate? This is dependent upon the distance of the tip to the surface, and changes drastically if there are only attractive components versus when there are also repulsive interactions. [4]

Perhaps one of the most intuitive applications of lateral forces is the study of friction. We used the unique reconstruction of the Si(100) surface and observed friction anisotropy at the single atom level. Complimentary DFT-based simulations showed excellent agreement and demonstrated that we can understand this interaction atom-by-atom. [5]

Finally, we have applied LFM to understand the response of a single molecular adsorbate to external forces. Studies have shown a dramatic increase in spatial resolution when a single CO molecules is at the apex of an AFM tip. [6] But when lateral forces are exerted, it acts as a torsional spring. By studying this system with LFM, using a CO molecule on the surface, we were able to determine the torsional spring constant of the CO molecule at the tip. [7]

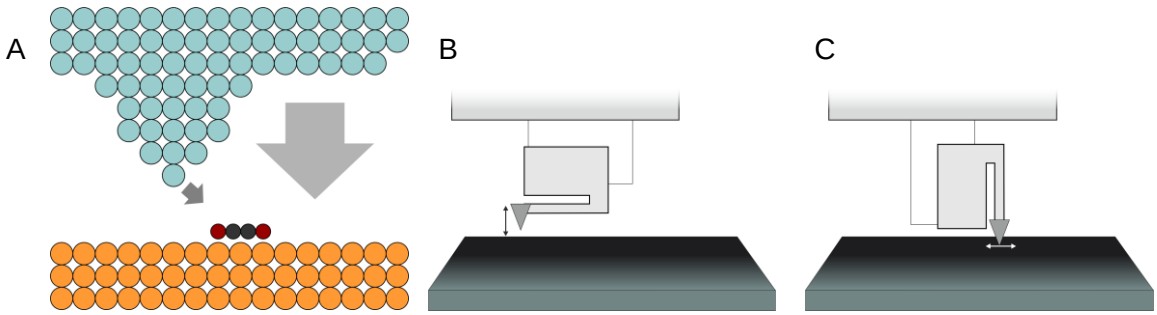

Figure: A) While long-range forces act predominantly in the direction of the surface normal, short-range components have strong lateral components. B) In FM-AFM the tip oscillates in the direction of the surface normal. We use C) FM-LFM where the tip oscillates laterally.

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