Inherent coupling of lateral and normal forces in qPlus AFM

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Interpretation of atomic force microscopy (AFM) measurements of nanoscale interactions rely on methods derived from an idealised model of the microscope's sensor. One assumption is that the motion of the tip apex is both normal to the surface and parallel to the motion of the cantilever. Due to the low amplitude and microscopic tips of conventional AFM sensors this approximation is valid. In the case of sensors (such as the qPlus sensor) where the tip length approaches the length of the cantilever, however, this assumption can be shown to be invalid by simple geometry.
By careful consideration of the tip geometry, and the equation of motion of the cantilever we are able to quantify this lateral motion. Furthermore, we derive the effect this has on AFM calibration, imaging, and force measurements. We specifically demonstrate that our conclusions are not at odds with the sub-Ångstrom resolution demonstrated by qPlus sensors, and that force measurements are largely unaffected *unless significant lateral forces are present*.