Theory of Photo-induced Forces in Tip-Sample Junctions

Faezeh Tork Ladani* [(1)], Junghoon Jahng * [(2)], Vartkess A. Apkarian[(3)], and Eric O. Potma[(1,3)]

(1) Department of Electrical Engineering and Computer Science, University of California Irvine, Irvine, CA, 92697

(2) Department of Physics and Astronomy, University of California Irvine, Irvine, CA, 92697

(3) Department of Chemistry, University of California Irvine, Irvine, CA, 92697

http://www.chem.uci.edu/~potma/webpage_test.htm

Photo-induced force microscopy (PiFM) is an emerging near-field technique for probing electric field distributions and optical excitations, by means of the optically induced forces experienced by a sharp tip. Experimental findings suggest that PiFM is promising for various nano-scale applications such as imaging and spectroscopy at the single molecule level. Yet, a comprehensive analytical model is absent though essential for a better physical understanding of the relevant optical interactions. In particular, the configuration including the tip, substrate, and nanoparticle (i.e. molecule) is a complex structure with different coupling mechanisms, whose details can strongly influence the photo-induced forces, probed by the tip. Although numerical full wave simulations are useful, ultimately they are unable to provide the physical understanding that is needed to appreciate the different mechanisms at play in the tip-sample junction.

We present an electrodynamic model of the PiFM system based on the dyadic Green's function for calculation of the photo-induced forces on the cantilever in the presence of a nanoparticle on a planar stratified substrate. We consider the sample to be illuminated by an evanescent field transmitted through a multilayer substrate. Multiple scattering in the tip-sample junction and the substrate is explicitly modeled through the dyadic Green's function for stratified medium, while higher order multipoles of the tip are considered as well. This model not only provides an analytical foundation for studying PiFM but also enables us to investigate the correlation of the specific spectral features, includingthe description of photo-induced forces in the presence of nano-structures with Fano resonances.