“Enabling the study of nanoscale Graphene physics using nanoconfined, large momentum IR light”

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Mid-infrared light confined to nanoscale volumes is a powerful and versatile probe of Graphene physics. For instance, recent IR-sSNOM experiments show that one can excite, image, and spectrally characterize Dirac plasmons in Graphene with nanoscale sensitivity[1,2,3]. Due to the uncertainty principle: $\Delta x \, \Delta k \geq 0.5$, conventional IR microscopy lacks both the spatial momentum and spatial resolution necessary to launch and simultaneously image such surface waves. In the IR-sSNOM technique, nanoconfinement of IR light between a sharp metallic tip (<10nm radius) and the sample surface can reduce Δx to <10nm and consequently increase Δk by as much as 3 orders of magnitude over the diffraction limited value. The IR frequency of the excitation, however, remains unchanged. Beyond the recently demonstrated plasmonic applications, we believe the potential for using IR light with such a large spatial momentum is not yet fully recognized by the Graphene community. In this work, we demonstrate yet another consequence of the extremely large Δk of naconfined IR light: ultrasensitivity to Graphene thickness. We show this phenomenon experimentally with high resolution (<20nm) IR sSNOM images which clearly show monotonically increasing contrast for 1,2,3, 4 Graphene layers. We confirmed the layer number by colocalized confocal Raman and high resolution AFM measurements. Our proof of principle experiment confirms a 3D sensitivity for nanoconfined IR light to be better than 20 x 20 x 0.35nm for single to multilayer Graphene samples.

1. G.O. Andreev, *et al.* "Extraordinary sensitivity of nanoscale infrared spectroscopy demonstrated on Graphene and thin SiO2", Bulletin of the American Physical Society, (Oral Presentation on 3/22/2011)

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3. Chen, J. *et al.* “Optical nano-imaging of gate-tunable graphene plasmons”, Nature 487, 77-81 (2012)