Multi-pronged tips for advanced scattering near-field microscopy

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In the world of near-field measurements, the scattering scanning near field microscope (sSNOM) is an important tool that merges the accuracy of the atomic force microscopy with the versatility of the regular SNOM. The sSNOM has proven to be particularly important in the study of plasmon-polaritons in graphene and other 2D materials. Typically, this measurement involves scanning over the sample and observing areas of constructive and destructive interference between the tip-launched plasmon and its reflection from the sample edge. In consequence, this type of measurement is restricted to close vicinity of the system edge, or in other case to proximity of a sharp metallic plasmon-launching feature.

Here, we will show plasmon detection in the bulk, made possible by custom two-pronged sSNOM tips and by gate-tuning the plasmonic resonance's location. We can therefore locally characterize the conductivity and density of states in the entirety of a 2D material sample. The tips we use are fabricated in a galium focused ion beam microscope (FIB), starting with commercially available (rocky mountain nanotechnology) PtIr tips. These tips are then cut and reshaped by the FIB with a 10nm accuracy, to form a bi-tipped sSNOM probe, with the minimal distance between the tips roughly 60nm and the tip apex about 40nm in size. While using the SNOM, each of these sub-tips couples light into plasmon-polaritons and vice versa. The interference of plasmons launched from both tips results in changes to the backscattered signal measured in the SNOM. By gate-tuning the graphene, we change the graphene plasmon wavelength and thereby bring the bi-tip in or out of resonance. Notably, this measurement does not involve any edges or sharp features in the system and therefore can be performed in the system bulk – a completely new capability for the SNOM.

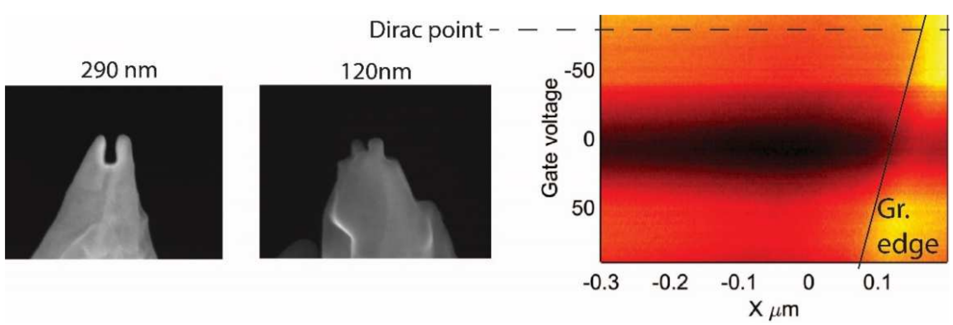

Fig. **a.** FIB fabricated multi-pronged tip with 290nm inter-tip distance **b.** same with 120nm distance **c.** a map of a SNOM scan of a gated graphene device, near the edge. The y-axis shows the backgate voltage and the x axis is roughly the distance from the edge. The dirac point is extracted from conductivity measurement and marked by a dashed line. A comparison with the known\measured plasmonic wavelength, at the same voltage difference as the resonance, shows good agreement with the inter-tip distance.