Electron trajectories for magnetic focusing in graphene*

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Scanning Gate Microscopy (SGM) is a powerful tool for gaining insight into the local electronic properties of nanoscale devices. The charged tip of a scanned probe microscope is held just above the sample surface, creating an image charge inside the device that scatters electrons. By measuring the change in conductance while the tip is raster scanned above the sample, an image of electron motion can be obtained [1-3]. Using this technique, we previously imaged magnetic focusing in a two-dimensional electron gas (2DEG) inside a GaAs/AlGaAs heterostructure [2]. We have recently used a cooled SGM to image cyclotron orbits [3] in ballistic hBN-graphene-hBN devices in magnetic focusing regime [4]. Magnetic focusing occurs when orbits passing into the sample from one narrow contact pile together on a second contact that is located an integer number of cyclotron diameters away.

In this talk, we describe our SPM imaging technique by presenting ray-tracing trajectories of ballistic electron flow through the sample that include scattering by the image charge below the tip. The electrostatic image charge creates a density dip Δn_{tip} that locally reduces the Fermi energy $E_F(n + \Delta n_{tip})$, creating a force $\boldsymbol{F} = \nabla E_F$ that pushes electrons away from the tip location. This force scatters orbits away from the receiving contact, as shown by the red traces in Fig. 1a. An experimental SPM image of the cyclotron orbit on the first magnetic focusing peak shown in Fig. 1b displays the measured change ΔR_m in transresistance *vs*. tip position. A corresponding simulated image in Fig. 1c is obtained by displaying the change T in transmission caused by the presence of the tip. In the simulations, we injected 10,000 trajectories into the graphene with a uniform distribution across the width of the contact and a uniform angular distribution at each point. The simulated image (Fig. 2c) is a good match to the experimental results (Fig. 2b). This approach allows us to investigate the influence of the electron density n and magnetic field B on images of electron flow by comparing experiments with simulations.

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References

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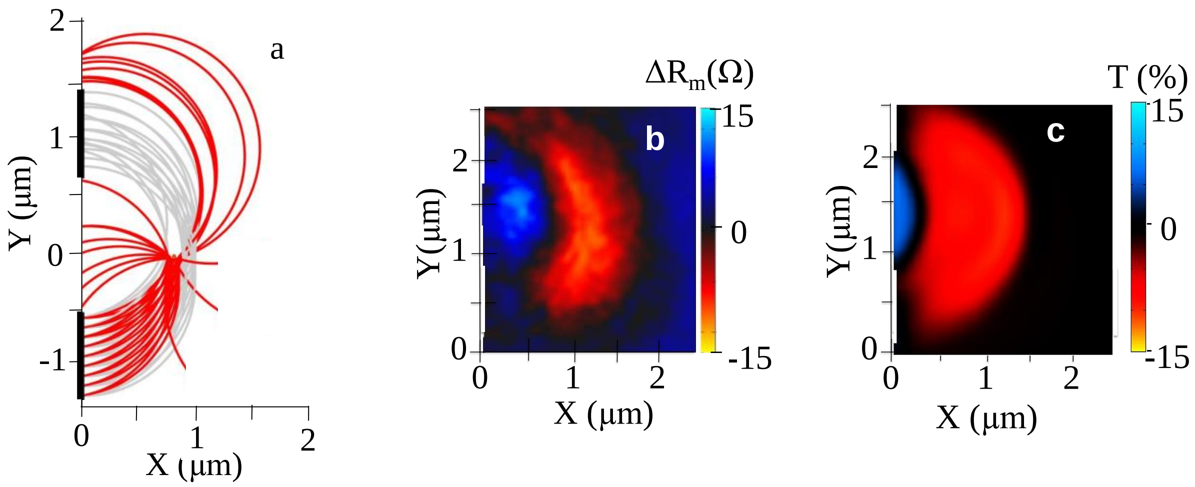

Figure 1: (a) Ray-tracing trajectories for B = 0.130 T and tip position (0.75 μm, 0 μm). Cyclotron-orbit trajectories are deflected by the density change beneath the tip. (b) Experimental and (c) simulated cyclotron orbit images on the first focusing peak for n = 1.29x10^{11} cm^{-2} and B = 0.130 T.