Imaging Dirac fermion optics with a scanning gate microscope

Nicolas Moreau[1]
Boris Brun[1], Viet-Hung Nguyen[1], Sowmya Somanchi[2], Kenji Watanabe[3], Takashi Taniguchi[3], Christoph Stampfer[2], Jean-Christophe Charlier[1], Benoît Hackens[1]

[1] *IMCN, Université catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium*
[2] *JARA-FIT and 2nd Institute of Physics – RWTH Aachen, Germany*
[3] *National Institute for Materials Science, Namiki, Tsukuba, Japan*

Nicolas.Moreau@uclouvain.be

Since charge carriers in graphene behave as massless Dirac fermions, Klein tunnelling is at play, allowing perfect transmission for charge carriers impinging on a p-n junction at normal or near-normal incidence. In addition, a diverging flow of Dirac fermions is refocused at a p-n interface, an effect known as Veselago lensing [1].
In this work, we form a movable and tunable circular p-n junction in high-quality hBN-encapsulated graphene thanks to an electrically-biased sharp metallic tip. As we scan the tip above the graphene device at low temperature, we map the tip-induced changes of electrical conductance, a technique known as scanning gate microscopy (SGM). The SGM conductance maps measured in the vicinity of a graphene constriction (see Fig. 1) exhibit a spatial contrast directly related to the current flow through and around the tip-induced circular p-n junction [2]. This is indeed confirmed by tight-binding simulations of current flow in the same geometry (Fig. 2). The present study also reveals low current density points away from the the circular p-n junction, highly sensitive to the junction smoothness. We discuss the conditions of correspondence between the SGM conductance map and the current flow in different situations, depending on the constriction and p-n junction geometries.

References

[1] V.V. Cheianov, V. Fal'ko and B.L. Altshuler, Science 315, 1252 (2007).
[2] B. Brun, N. Moreau, V.H. Nguyen, S. Somanchi, K. Watanabe, T. Taniguchi, C. Stampfer, J.C. Charlier and B. Hackens, arXiv:1811.02929 (2018).

Figures

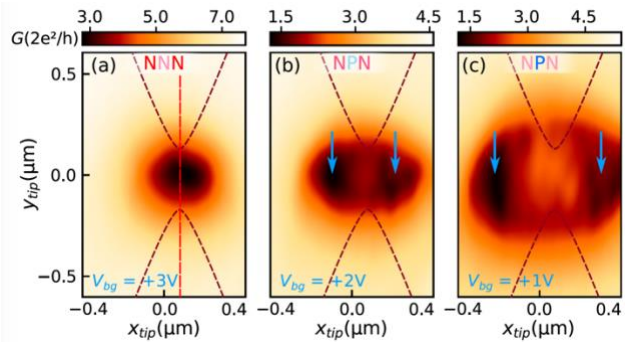

Figure 1: sequence of SGM images measured on a constriction (whose position is indicated by the dashed lines), patterned by etching an hBN/graphene/hBN heterostructure, for a constant tip voltage (V_{tip} = -7 V) and varying back-gate voltages (V_{bg}, as indicated on the figures). In (b-c), a circular npn junction is formed when the tip is located over the center of the constriction.

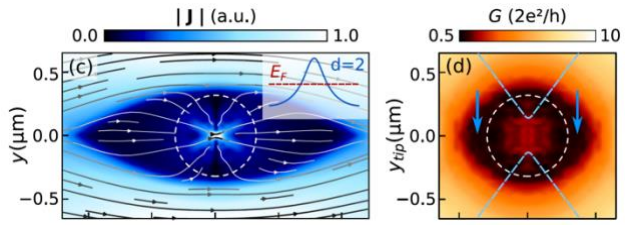

Figure 2: left : tight-binding simulation of the current density J around a fixed circular tip potential perturbation, indicated by the white dashed circle (the profile of the perturbation is indicated in the inset). **Right**: tight-binding simulation of the SGM map, obtained by moving the same tip perturbation around a 250 nm-wide constriction (blue dashed lines).