Klein-tunneling transistor with ballistic graphene

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Abstract

Today the availability of high mobility graphene up to room temperature makes ballistic transport in nanodevices achievable. In particular, p-n-p transistors in the ballistic regime give access to the Klein Tunneling (KT) physics and allow the realization of devices exploiting the optics-like behavior of Dirac Fermions (DF) as in the Vesalego lens or the Fabry Pérot cavity [1, 2, 3]. New electronic architectures based on Klein tunneling open the way to applications, especially in microwave electronics where both high mobility and a switching capability are needed to achieve large voltage and power gain at high frequency.

Our device exploits the total internal reflection in a KT prism (see figure 1) [4] which leads to the tunable suppression of the transistor transmission. The prism is made of an n-doped ballistic triangular domain embedded in a p-doped diffusive area, both domains being controlled electrostatically. Alike in light reflectors, an array of KT-prisms can be used to form the active channel of a KT transistor (see figure 2); this geometry minimizes the gate length to keep ballistic transport conditions. The behavior of the KT transistor is calculated by scattering theory as well as atomistic simulations using the non equilibrium Green function (NEGF). Both approaches predict for the Klein tunneling transistor a strong suppression of conductance at large gate doping that can eventually drop below the minimum conductance at charge neutrality. This KT transistor can be used as a tunable barrier for electrostatic quantum confinement to achieve, e.g. single Dirac fermion pumps working at low temperatures. It is also suited for microwave electronics as it cumulates significant resistance in the OFF state with a large conductance in the ON state.

In this talk I will describe the implementation of such a KT transistor, and the possibility to realize it by depositing graphene onto local bottom gates and a few layers of hexagonal boron nitride (hBN). The use of hBN as a dielectric gives access to ballistic transport in the device while keeping a good gate coupling suitable for the realisation of abrupt p-n junctions. Those elements are essential to enter the regime of DF optics where refraction and transmission at p-n junctions are determined by Fresnel-like relations.

References

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Figures

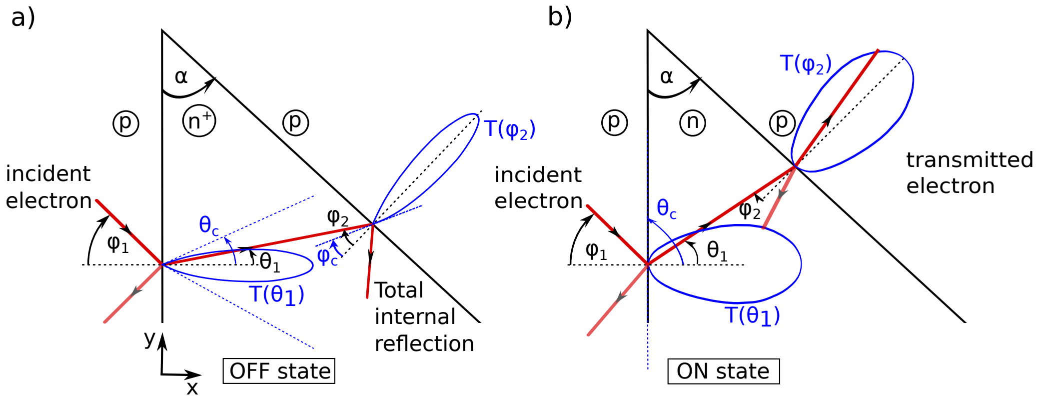

Figure 1: Principle of total reflection in a Klein tunneling prism. The refraction angle of Dirac fermion (DF) beams (red rays) and their angular dependent transmission amplitude (blue lobes) are controlled by the optical-like index ratio $\bar{n} = -\sqrt{n/p}$ of the p and n regions. a) OFF state $n \gg p$. Anisotropic forward scattering occurs at p-n junction : the refracted rays are mostly transmitted along the junction normal within a lobe limited by $|\theta_1| < \theta_c$. The n-p junction selects the incident carriers that are close to the normal to the junction (i.e. $|\phi_2| < \phi_c$); other being reflected. b) ON state $n \simeq p$. In this case $\theta_c = \phi_c = 90\,\mathrm{deg}$ which means all indent rays are transmitted with large transmission coefficient at both interfaces.

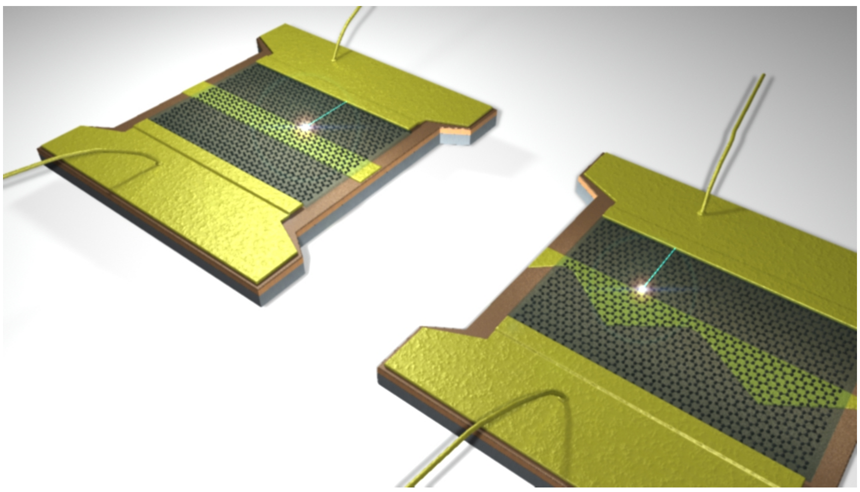

Figure 2: Artist view of graphene transistors, with a standard rectangular bottom gate (left), and with a prismatic bottom gate (right).