Topological edge photocurrents in graphene in the quantum Hall effect regime

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1. Introduction

The study of a photoresponse of conducting channels emerging at the edges of materials with non-trivial topology is central to the optoelectronics of topological insulators [1]. Such one-dimensional chiral channels naturally occur in two-dimensional electron systems subjected to a strong perpendicular magnetic field in the regime of the quantum Hall effect. Graphene with the Dirac-like electron spectrum is a unique system for the study of topological effects because the large cyclotron gap (between the zero and the first orbit Landau levels) of about 30 meV is achieved already in the magnetic field of 1 T, which enables the observation of the Hall conductivity quantization at room temperature [2], and is promising for electronic applications [3].

In this talk, we report the observation, theoretical and experimental study of the photogalvanic effect in chiral edge channels in graphene in the quantum Halle effect regime. We show that the excitation of a graphene sample by microwave or terahertz radiation gives rise to an electric current circulating along the sample edges.

2. Microscopic picture

Electron states in graphene are 4-fold degenerate because of the spin and valley degrees of freedom. The valley mixing at a graphene edge shifts the valley degeneracy and forms, in a strong perpendicular magnetic field, the electron-like and hole-like chiral edge channels which are responsible for the Hall conductivity quantization [4]. The excitation of the edge carriers by a high-frequency electric field destroys the thermal equilibrium in the channel. For the photon energy smaller than the bulk cyclotron gap, the absorption is dominated by the indirect optical (Drude-like) transitions involving momentum scattering. Because of the edge-channel dispersion, such transitions are possible and lead to a dissipative contribution to the edge current measureable in experiments. While the current direction is controlled by the magnetic field polarity, its magnitude depends on the radiation polarization since the edge-channel absorbance is polarization sensitivity.

3. Experimental details

Experiments were done on Hall-bar samples made of stacks of exfoliated graphene covered with hexagonal boron nitride at 4.2 K. Transport data reveal that the first plateau of the quantum Hall effect is achieved at 0.5 T. Exciting an unbiased sample by terahertz radiation we detect electric currents which flow in the opposite directions at the opposite edges of the sample. At magnetic field values corresponding to the first quantum Hall plateau, the edge currents become uni-directional, being the same for *n*-type and *p*-type structures, while the current amplitude depends on the radiation polarization, which supports the microscopic picture above.

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