Terahertz radiation induced photocurrents in graphene with a lateral periodic potential

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Abstract

We report on the observation of terahertz radiation induced photocurrents in graphene with a lateral periodic potential. These effects generate a dc electric current from an ac electric field. To enable the photocurrent generation a metal gratings have been deposited on top of graphene. The lateral potential is realized by electron beam lithography and subsequent deposition of a metal gate on top of the graphene layer. An insulating layer of aluminum oxide is used to separate gate and graphene. One set of samples (A) consists of periodically deposited stripes with different widths and spaces on epitaxial graphene grown on SiC (see Fig.1). Furthermore, we prepared exfoliated graphene flakes with an interdigitated double gate structure (B), where both gates can be controlled individually. Both types do not possess inversion symmetry.

We demonstrate that terahertz (THz) laser radiation (f = 2.54 THz, λ = 118 µm) shining on the modulated devices results in a directed electric current which is sensitive to the radiation polarization state. In particular a current which reverses its sign upon switching the photon helicity (*i.e.*, it changes sign upon changing from left to right handed circular polarization) is detected (see Fig.2). To avoid illumination of the sample edges in samples (A), leading to edge photogalvanic currents [1], we use a large area of 4.5 × 4.5 mm^2 with a size larger than the laser spot. At normal incidence, the photocurrent is only observed when the superlattice is illuminated, while no signal is observed on the unpatterned reference sample. This proves the symmetry breaking induced by the asymmetric lateral potential. Under oblique illumination the dynamic Hall effect leads to an additional current contribution [2]. The photocurrent cause by the lateral potential is shown to consist of two contributions; (i) polarization independent, and (ii) dependending on both the linear and circular polarization. The results are analysed in terms of the theory of ratchet effects in the structures with lateral potential [3,4] and of plasmonic Dyakonov-Shur mechanism in periodic structures [5]. The theory of the former one predicts that the photocurrent is controlled by elastic scattering processes and can be used to characterize the scattering mechanisms in graphene. In particular studying frequency dependence of the individual contributions to the photocurrent one can deduct the dominant elastic scattering mechanism in graphene. The frequency dependence was studied using the free-electron-laser FELBE at the HZDR. Our experimental findings can be well described by theory [4].

In addition to the large area structures (A), consisting of a single gate, we fabricated and studied photocurrent in interdigitated comb-like double-gate structures deposited on exfoliated graphene flakes. Each gate can be controlled separately; therefore, the intrinsic degree of the lateral potential asymmetry of the double-gate structures can be controllably varied. Investigation of the photocurrents in such type of structures provided an access to internal asymmetry of the graphene flakes. Moreover, we discuss the possibility to use such structures as a fast detector of terahertz radiation as it has been suggested in [5].

References

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Figures

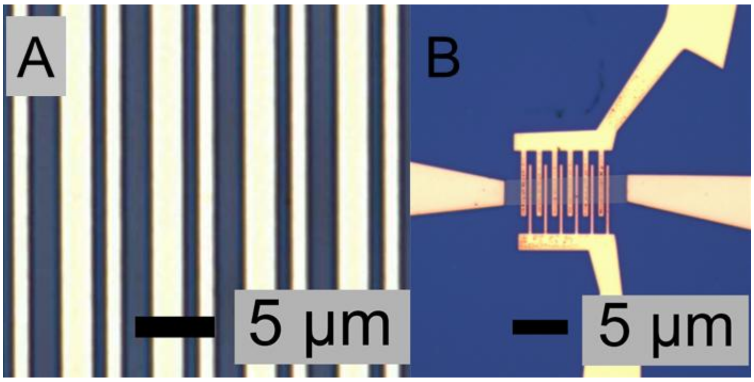

Fig. 1: Optical images of both types of samples: (A) aysmmetric potential on large area epitaxial graphene, (B) dual-gate structure on exfoliated graphene (shape of the flake is sketched)

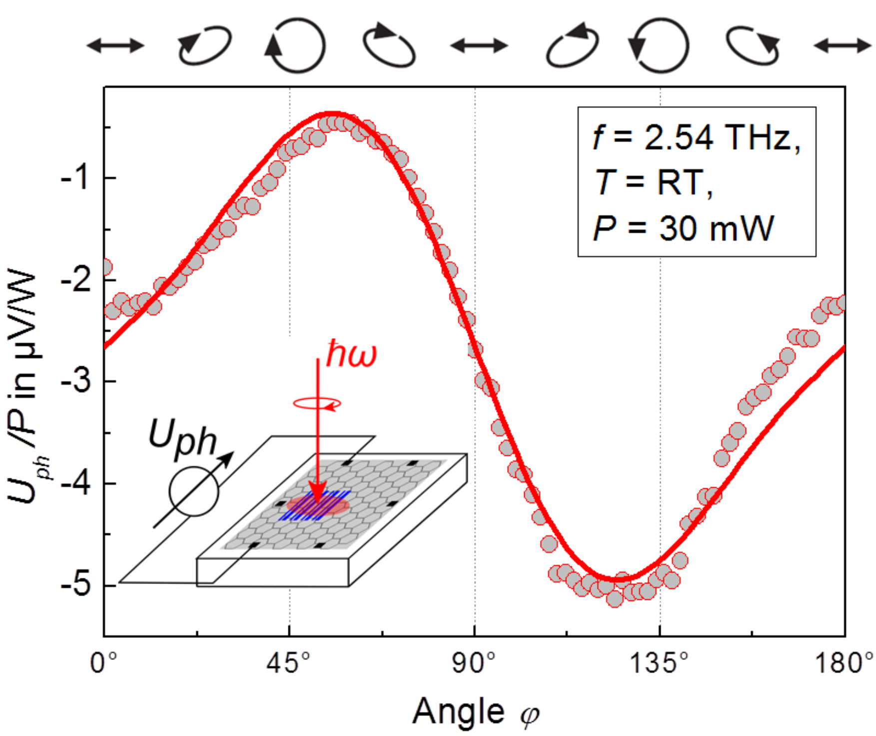

Fig. 2: Measurement of the ratchet current in samples of type (A). Due to the geometry of the sample and the setup, edge photogalvanic currents and the circular ac Hall effect can be neglected.