Terahertz photocurrents in heterostructures with one-dimensional lateral periodic potential

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***Abstract* — We report on the observation of terahertz radiation induced photogalvanic currents in semiconductor quantum well structures with one-dimensional lateral periodic potential. The current response is well described by the phenomenological theory of the superposition of the linear and circular photogalvanic effects. Experimental data demonstrate that the inversion asymmetry of semiconductor heterostructures can be controllably varied by means of electron beam lithography. The inversion asymmetry in quantum well structures is of importance for rapidly growing field of spintronics providing an effective tool for the spin manipulation by an electric field.**

I. Introduction And Background

Two-dimensional electron systems (2DES) subjected to a one-dimensional weak periodic potential $eV \ll E_F$, where the period of the grating is much smaller than the electron mean free path but larger than the Fermi wavelength, display interesting anisotropic magnetotransport properties [1]. The resistance depends on the ratio of cyclotron orbit and period and shows pronounced commensurability oscillations as a function of a perpendicular magnetic field. On the other hand, the periodic potential alters the symmetry of the underlying crystallographic lattice if the primitive lattice vector of the periodic potential is aligned along specific directions. Hence it is expected that, due to the symmetry alteration, such a periodic potential modifies the photogalvanic current flow under terahertz excitation [2,3].

II. Samples and Experimental Set-up

Here we study photocurrents in (001)-grown GaAs/AlGaAs heterojunctions with superimposed grating having a period of 2.5 µm (see Fig. 1). The grating is obtained by electron beam lithography and subsequent reactive ion etching using $SiCl_4$. Care was taken not to etch through the 2DES. To get a large patterned area of about 1.4 mm^2, 64x150 µm squares were stitched together. The one-dimensional gratings are oriented along either [010] or [110] crystallographic directions. For optical excitation we use pulsed molecular terahertz (THz) lasers [3]. Circularly and linearly polarized radiation is applied at normal incidence in the wavelength range from 77 µm to 496 µm. To measure polarization dependencies we used $\lambda/4$ plates for conversion of linear to circular polarization, with variation of helicity as $P_{circ} = \sin 2\varphi$, where φ is the angle between the initial plane of laser beam polarization $\boldsymbol{E}_l$ and the c-axis of the $\lambda/4$ plate.

III. Results

With illumination at normal incidence of the samples with the grating aligned along the [010] crystallographic direction we observed a photocurrent signal measured across a contact pair. The width of the photocurrent pulses is about 100 ns which corresponds to the THz laser pulse duration. The signal strongly depends on the light polarization. The effect is observed for all applied wavelengths. In samples without a grating as well as with the grating along the [110]-direction no signal at normal incidence has been detected. From these experimental data we conclude that the lateral periodicity along one of the cubic axes removes any symmetry restrictions from the system. We have developed a phenomenological theory of the photogalvanic effect in the lateral structures and described an appearance of the photocurrent under the symmetry reduction from the C_{2v} point group for the unstructured samples to the C_1 point group lacking any symmetry operations except for the identity one. The theory describes well the photocurrent behavior upon the periodic potential orientation and variation of the polarization state, see solid curve in Fig. 1.

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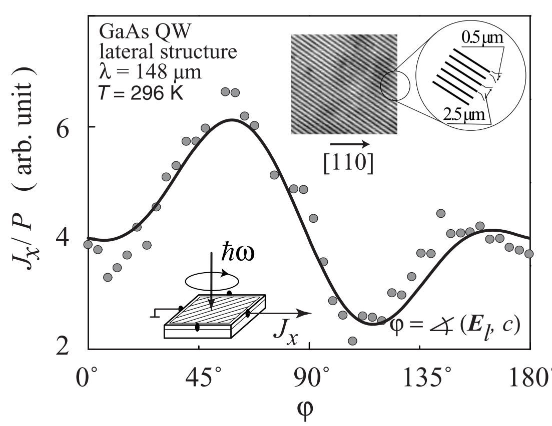

Fig. 1: Photocurrent dependencies of heterostructures with one-dimensional lateral periodic potentials

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