Photon drag current in quantum wells enhanced by cyclotron motion

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We report on the theoretical study and experimental observation of the photon drag effect in quantum wells (QWs) excited by terahertz radiation. The dc electric current is caused by the transfer of photon momenta to free carriers. We show that the application of an external static magnetic field leads to a drastic enhancement of the photon drag response under the cyclotron resonance conditions.

We develop a quasi-classical theory of the cyclotron-resonance-assisted photon drag effect. The photocurrent arises at the oblique incidence of radiation in the QW subjected to the normal magnetic field. Microscopically, two different mechanisms contribute to the drag current: The dynamic Hall effect resulting from the joint action of electric and magnetic fields of the radiation on the charge carriers and the mechanism related to the spatial oscillations of the electric field in QW plane. The external static magnetic field B causes the cyclotron motion of carriers leading to a resonant enhancement of the photon drag. Remarkably, the theory predicts the resonant behavior of the photon drag current at the cyclotron resonance, i.e., at $\omega = eB/(cm^*)$, with ω being the radiation frequency and m^* the effective mass, but also at the double frequency, $\omega = 2eB/(cm^*)$, where the radiation absorption does not have any peculiarity. The latter resonance emerges in QW structures where the electron momentum relaxation time depends on its energy and, therefore, can provide information on the detail of scattering, which is not easily accessible by other experimental methods.

Experiments were carried out on high-mobility InSb/InAlSb QWs grown along the (001) crystallographic axis. Exciting the samples with polarized terahertz radiation and sweeping the magnetic field, we observed a resonant photosignal [1]. The magnetic field at which the resonance is observed linearly scales with the radiation frequency and corresponds to the cyclotron resonance conditions. Almost Lorentz shape of the resonance, its position, as well as the polarization dependence of the photocurrent indicate that the current is caused by photon drag effect. The experimental data are well described by the developed microscopic theory with no fitting parameters. The results suggest that the photon drag measurements can be used as a complementary method to study the electron scattering and effective mass, being of particular importance at high temperatures, where other measurements are inefficient.

[1] S. Stachel, G. V. Budkin, U. Hagner et al., arXiv:1312.0726, Phys. Rev. B (2014).