Terahertz Excitations of a Two-Dimensional Electron Gas Interacting with Metallic Resonant Structures

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A crucial point in controlling plasmonic excitations of a two-dimensional electron plasma (2DEP) is finding a rule that quantizies plasmon wave vectors. Our earlier studies [1] have shown that a plasmon wavevector can be quantized according to a period of a grid-gate and a mesa dimension and it is sensitive also to boundary conditions that are determined by position of metallic (gates) or quasi-metallic (ohmic contacts) parts of the structure.

In the present paper, we studied more closely the problem of the wave vector quantization by fabrication of a series of mesa with different dimensions, different topology of off-mesa metalizations and, additionally, with resonant structures positioned directly on mesas. As resonant structures we chose either a grid or a split-ring resonator.

The samples were fabricated with an electron lithography on a GaAs/AlGaAs heterostructure with a 2DEP of a million mobility at 4 K. The mesas were rectangles with their length changing between 30 μm and 90 μm and the width equal to 30 μm. Depending on a mesa, ohmic contacts were alloyed to allow a current flow parallel to its longer only or both sides. On some of mesas we evaporated a gold grid (of the period of 1 μm and the geometric aspect ratio of 1:1) or a split-ring resonator [2] with its resonant frequency around 2.5 THz. The samples were cooled in the dark to 2 K and then illuminated with a white light during a few minutes. We measured a photovoltage between the ohmic contacts positioned at the opposite sides of the mesa under the influence of a 2.54 THz radiation generated by a molecular laser and as a function of magnetic field.

An overall picture of the results is the following. In all cases one can find strong features of plasmonic excitations which frequency corresponds to dimensions of the mesa. However, the response of the samples investigated is far more rich than that. First, we observed optically-induced Shubnikov de Haas oscillations of the photoresponse which allowed to estimate the concentration of the 2DEP. Second, on mesas with a split-ring resonator, we found that the spectrum of magnetoplasmons excited depends on the choice of the ohmic contacts between which the photovoltage was measured. Third, in the case of grid-gated samples, there appeared broad and high-amplitude structures at magnetic fields much smaller than that of the cyclotron resonance.

A general conclusion of the study is that at the moment we cannot controll *all* excitations of a 2DEP in a given mesa. Positive conclusions are that we can predict appearance of *some* of resonances and can construct a detector with a strong THz response in a broad range of magnetic field.

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[1] M. Białek *et al.* Appl. Phys. Lett. **104**, 263514 (2014).

[2] T. Tarkowski and J. Łusakowski, Acta Physica Polonica **132**, 332 (2017).