High-index plasmon excitation in high electron mobility GaAs/AlGaAs heterostructures

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Excitation of plasmons with photons incident perpendicularly on a two-dimensional electron gas (2DEG) can be achieved only in an experimantal configuration which allows to fulfil the momentum and energy conservation laws. One of such a configuration can be realized with a metallic grid prepared on the sample surface [1]. Diffraction of the incident light on the grid allows to excite plasmons with a wavelength equal to the period of the grid and its subharmonics. In the case of a semiconductor electron plasma, typical frequency of the radiation falls within a THz band and the grid period is of the order of a micrometer.

A 2DEG of a high electron mobility allows to investigate details of the plasmon dispersion relation because of the possibility to observe low frequency plasmon modes and with high indexes. To this aim, a lithographically processed Hall bar with a Au grid-gate was prepared on a GaAs/AlGaAs heterostructure with a high electron mobility 2DEG. The lenght and width of the bar was equal to $L = 1.3$ mm and $w = 60$ μm, respectively. The period of the grid was equal to $l_0 = 4$ μm and the aspect ratio was 50%. The estimated Hall electron concentration and mobility was equal to, respectively, 2.7×10^{11} cm^{-2} and 6×10^5 cm$^2/Vs$. The samples were cooled down to 4 K and exposed to THz radiation in the range 0.10 - 0.66 THz generated by quasi-optical sources. The measured signal was a photovoltage created between the ohmic contacts of the Hall bar separated by 1.3 mm. The signal was measured with a lock-in technique as a function of the magnetic field and the electrical polarization of the grid-gate at a constant frequency of THz radiation. As a reference, experiments as a function of the magnetic field were carried out on another Hall bar which was not supplied with a grid-gate.

The photovoltage spectra measured as a function of the magnetic field showed up to 23 and 11 maxima in the case of not gated and gated sample, respectively. Dispersion relations derived from the experimental data were interpreted within a model of magnetoplasmon excitation in the Voigt configuration $\omega_{mp,j}^2 = \omega_c^2 + \omega_p(jk_0)^2$ where $\omega_{mp}(B)$ is the magnetoplasmon frequency, ω_c is a cyclotron frequency and $\omega_p(jk_0)$ is the frequency of a plasmon with the k-vector equal to $jk_0 = 2\pi j/l_0$ at zero magnetic field; j is the index of the plasmon mode. We have obtained $\omega_p(k_0) = 150$ GHz and $k_0 = \pi/w$ in the case of not gated samples. We could also obtain the plasmon dispersion in case for gated and not gated sample which both fit to theoretical predictions [2]. We have permormed measurements on a Hall bar gated with a uniform gate and obtained the same result as on a grid-gated sample. The obtained results allowed to verify that in the case of a high-quality GaAs/AlGaAs heterostructure, high index plasmon modes in the Voigt geometry can be described within a non-local approximation neglecting retardation effects.

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