Novel relativistic plasma excitations in a gated two-dimensional electron system

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A new mode is discovered in microwave response of a two-dimensional electron system (2DES) covered by a conducting top gate in the relativistic regime for which the 2D conductivity $\sigma_{2D}>c/2\pi$. This mode shows a very unusual frequency and amplitude dependence on the magnetic field, conductivity, gate geometry, and separation from the 2DES, and survives for temperatures up to 300 K, allowing for new room-temperature microwave and terahertz applications.

I. INTRODUCTION

LIGHT-matter coupling between 2DES and a photon microcavity has led to new studies being conducted in many research fields. Most previous studies have focused on the electrodynamic effects under the condition in which the dispersion curves for 2D plasmons and light exhibit an anticrossing. However, there is a second regime in which electrodynamic effects govern 2DES plasma dynamics. The conductivity σ_{2D} defines the character and rate of the Maxwellian relaxation of charge fluctuations. The two-dimensional conductivity, σ_{2D}, of a film has units of velocity. According to electrostatics, charges in a two-dimensional system relax by spreading with an effective velocity $2\pi\sigma_{2D}$. For systems with $2\pi\sigma_{2D} > c$, the electrostatic approach ceases to remain valid and electrodynamic effects must be taken into account. Heretofore, the dynamic response of a 2DES with such a large conductivity has remained unexplored, despite a number of interesting physical predictions, including the strong enhancement of radiative decay of collective excitations [1] and the emergence of a new family of weakly damped relativistic plasma excitations [2].

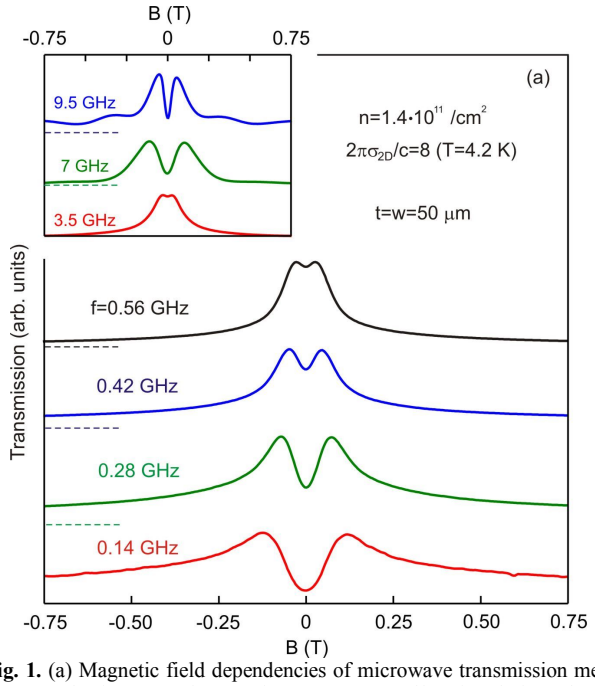

Fig. 1. (a) Magnetic field dependencies of microwave transmission measured for several microwave frequencies. Curves are offset for clarity. The dashed lines indicate zero signal level.

II. RESULTS

The microwave response of a two-dimensional electron system (2DES) covered by a conducting top gate is investigated in the relativistic regime for which the 2D conductivity $\sigma_{2D} > c/2\pi$. Weakly damped plasma waves are excited in the gated region of the 2DES. The frequency and amplitude of the resulting plasma excitations show a very unusual dependence on the magnetic field, conductivity, gate geometry and separation from the 2DES. We show that such relativistic plasmons survive for temperatures up to 300 K, allowing for new room-temperature microwave and terahertz applications [3].

REFERENCES

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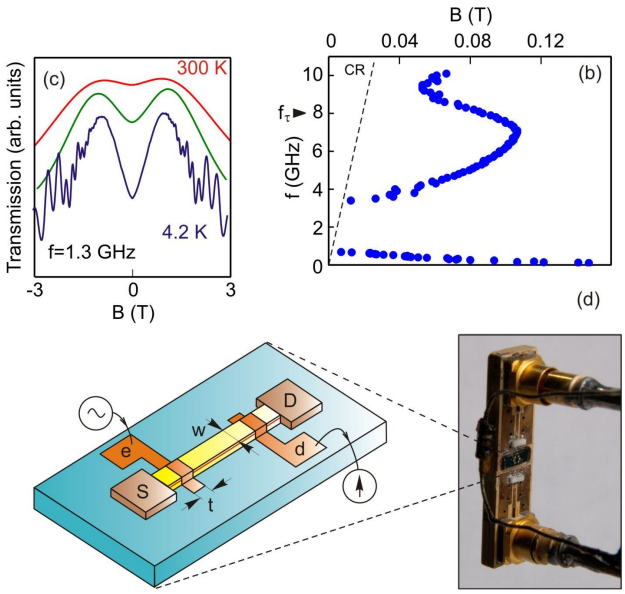

Fig. 2. (b) Two branches of magnetic field position of the absorption resonances versus excitation frequency. The dashed line represents the the cyclotron resonance. (c) Magnetic field dependencies of the microwave transmission of a sample with electron density 44×10^{11} cm^{-2} measured for three temperatures: T=4.2 K, 160 K, 300 K. (d) Schematic view of a sample geometry.