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Tunable terahertz cyclotron emission from two-dimensional Dirac fermions

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Abstract — We report on the emission of Terahertz radiation from Landau quantized Dirac electrons in HgTe/CdHgTe based quantum wells. We show that this cyclotron emission is continuously tunable with magnetic field from 500 GHz up to 2.5 THz. Moreover, given the relativistic nature of charge carriers, the cyclotron mass and therefore the emitted frequency are also tunable with the electron density. These results pave the way for the long-awaited Landau laser which could additionally be tunable by a gate voltage with a fixed magnetic field.

I. INTRODUCTION

This work is embedded in a long search of achieving a Landau laser tunable over the terahertz frequency range [1]. Indeed, excited electron under high external magnetic can recombine radiatively and emit light of energy of tens of meV. Graphene was a promising candidate to achieve this goal, as its Landau levels (LLs) fan chart features a square-root-like behavior in magnetic field, due to its inherently linear energy dispersion. This would imply a drastic diminution of Auger scattering processes as the different LLs are not equidistant. Unfortunately, it has been shown [2] that such non radiative effects are still present in graphene as it is still possible to find different transitions between LLs that fulfill the energy conservation. In this work we were interested in different QWs based on HgTe/CdHgTe and hosting a Dirac fermion phase [3]. Indeed, in addition to its topological properties, its energy dispersion at zero magnetic field features both linear and quadratic terms so that the Auger scattering processes could be even more suppressed. We performed electrically driven cyclotron emission experiments, considering 2D massive and massless Dirac fermions in HgTe/CdHgTe QWs, of different carrier concentrations. This allowed us to measure a sizable cyclotron emission, tunable over the 0.5 to 3 THz range. Very recent additional experiments carried out on gated QWs are also presented. These latest results open a promising way to achieve a tunable laser covering the terahertz gap [4].

II. RESULTS

The Landau emission spectroscopy measurements were performed at 4 K using an n-InSb detector subjected to a high magnetic field, allowing a fine spectroscopy of the cyclotron emission from Dirac electrons. Figure 1 shows a typical set of emission spectra, obtained at different magnetic fields applied

on the sample. One can see that the emission peak is evolving with the magnetic field. This evolution is driven by the cyclotron mass of the sample, determined by its electron carrier density, through the quasi-classical formula $E = (\hbar e/m_c)B$ [5]. We measured samples with different electron densities and extracted the cyclotron mass [6]. The behavior of the latter with the electron density is in perfect agreement with a low energy model that we developed.

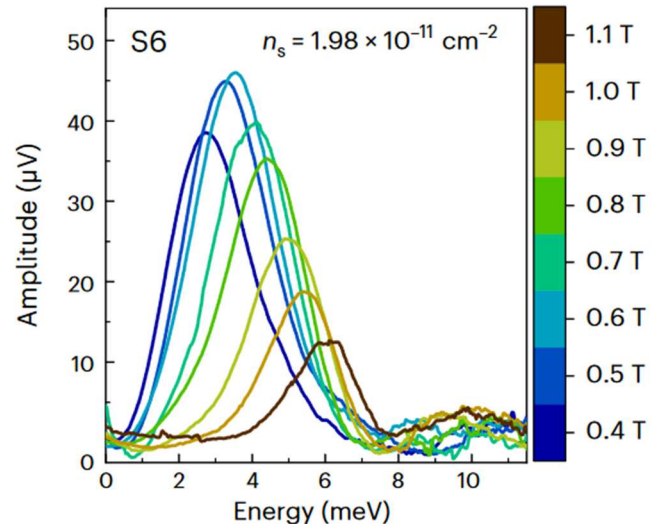


Figure 1: Typical set of emission spectra, obtained at different magnetic fields applied on the sample. The electron density of the sample was determined by mean of magneto-transport measurements.

III. SUMMARY

To summarize, we observed a sizable cyclotron emission from Landau quantized massive and massless Dirac electrons in HgTe QWs. This emission is tunable both by the magnetic field and the electron concentration in the range 0.5 to 2.5 THz. The results are in good agreement with a low energy model taking into account the relativistic nature of the electrons under magnetic field. Our results pave the way towards magnetic field and gate voltage tunable THz Landau lasers.

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