THz emission from Dirac-like fermions in bulk HgCdTe alloys

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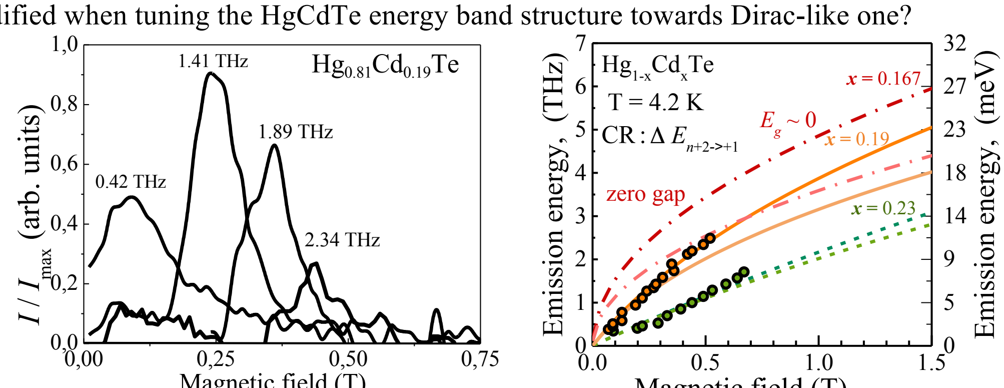
Effect of carriers heating and terahertz (THz)/Far infrared (FIR) magnetically tunable emission were subject of intense studies for decades [1, 2]. Impressive results have been obtained using GaAs and InSb semiconductors leading to the design of cyclotron resonance (CR) emitters based THz/FIR spectrometers [3]. Recent emergence of extremely high crystalline quality MBE grown HgCdTe alloys with extremely narrow band gap and even Dirac-like linear energy spectra rises questions about band structure related modification of electron heating and hope for THz cyclotron emission of high efficiency and tunability [4]. Indeed, decrease of the band gap and the cyclotron mass may lead to magnetic field tunability, greater by an order of magnitude than the one in GaAs or InSb semiconductors and non-equidistant Landau Levels (LLs) may help in decreasing of the parasitic self-absorption phenomena.

In this work we present experimental results on magnetically tunable THz emission from several HgCdTe bulk layers with extremely narrow energy band gaps (below 50meV). The samples were ~3μm thick films, MBE grown on (013) semi-insulating GaAs substrate covered by thick CdTe buffer. Our 4.2K cooled, background radiation shielded CR-THz spectrometer contained two independent 8 T and 14 T superconducting coils placed in the same cryostat. The sample, excited with electric field pulses was inserted into the first coil, while a magnetically tunable cyclotron resonance InSb-CR photoconductive detector was placed in the second one. We use this detector for spectral analysis of the emitted THz radiation. In Fig.1 we show a typical emission spectra for $Hg_{0.81}Cd_{0.19}Te$ sample. One can clearly see CR emission lines moving to higher energies with increasing magnetic field. In Fig.1b a comparison between experimental and calculated transition energies is shown. Points are experimental results and two lines (for each alloy composition) correspond to calculated two lowest conduction band CR transitions –not resolved in the experiments. Transition energies were calculated using 8 band Kane Hamiltonian [5]. Nonlinear character of transition energies versus magnetic field increases with lowering Cd alloy composition showing transition from linear to square root behavior characteristic for Dirac-like band structure. A good agreement between theoretical curves and experimental results demonstrates that emission from our sample can indeed be attributed to the CR excitations in the conduction band. We have also performed preliminary experiments with lower energy bandgaps (going to zero) expecting higher tunability and efficiency of THz emission. Surprisingly we have observed decrease or complete absence of THz emission. Our results leads to discussion: if and how electric heating of electrons is modified when tuning the HgCdTe energy band structure towards Dirac-like one?



a b

Fig. 1. a) Photoconductive signals of an n-InSb detector placed at different fixed magnetic fields as a function of magnetic field of cyclotron terahertz $Hg_{0.81}Cd_{0.19}Te$ emitter. The black solid lines are three selected results for the detector fields 0.2 T, 0.7 T, 1 T and 1.3 T (corresponding to InSb-CR resonant detection at 0.42 THz, 1.41 THz, 1.89 THz, and 2.34 THz respectively). **b)** Comparison of calculated (lines) and measured (points) transitions energies for different Cd composition x as a function of magnetic field.

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