Magneto plasma oscillations in n-InSb with FEL at terahertz radiations revisited

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***Abstract*—We have investigated the magneto transmission of the electron plasma in heavily doped InSb up to 33T, which shows field induced transparency modulated by quantum oscillations at helium temperature. Transmission was measured in the far infrared using a recently developed setup coupling terahertz radiation from FEL to a 33T magnet via a waveguide. The onset of the field-induced transparency and the period of the frequency-dependent transmission oscillations match with our calculations based on a classical magneto-plasma including multiple reflections and the Faraday effect. The additional features on transmission we try to correlate to the measured DC conductivity.**

I. INTRODUCTION

THE electron plasma in heavily doped InSb at helium temperature shows field induced transparency modulated by quantum oscillations. In the region of classical magnetic fields, this has been extensively studied. In the region of quantizing magnetic fields first Furdyna et al. has experimentally investigated up to 10T [1] and then Aronzon et al. has investigated up to 20T pulse field [2]. Both the groups have observed Shubnikov-de Haas type oscillation in helicon transmission data. In our experiment for the first time we have simultaneously measured transport properties and helicon transmission on InSb beyond the extreme quantum limits (i.e. exceeding the oscillatory region) up to 33T DC fields hence extrapolating the previous results.

II. RESULTS

In the transmission measurement we observe field-induced transparency beginning at 7T with field dependent oscillations which become more distinguishable at high magnetic fields and with a faster periodicity at higher THz frequencies. These experimental data can largely be explained with calculations based on the dielectric response of a semi-classical magneto-plasma [1] including multiple reflections and the Faraday Effect [3]. However, we have observed two new effects at low temperatures, not explained with the semi-classical results; i.e. the appearance of transmission maxima around 9T in the relatively non transparent region and a vanishing of transmission at very high magnetic fields. These two new effects disappear at higher temperatures ~40K. From DC conductivity measurements in the same sample these effects appear to be related to the DC conductivity.

We see minima in longitudinal conductivity caused by singularities in the density of states lead to maxima in the transmission and vice versa (~9.2T and14.2T). In the extreme quantum limit (above 20T) increase in longitudinal conductivity with field causes a decrease of the transmission amplitude.

These results were obtained thanks to the newly developed transmission set-up combining the magnetic fields from the High Field Magnet Laboratory (HFML) and the terahertz free electron laser (FELIX) which allows to perform THz experiments over a broad range of frequencies (7-100 cm-1, 0.2-3THz), radiation powers (up to 200W/cm^2), magnetic fields (up to 33 T) and temperatures (down to 1.4 K). Our results show that the new equipment has a great potential to see new physical phenomena.

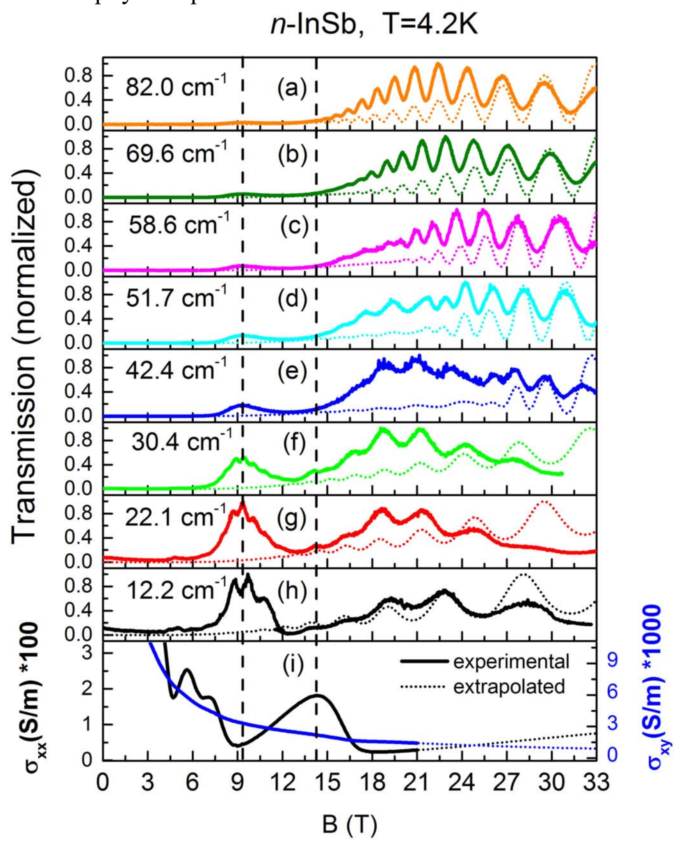

Fig. 1 (a)-(h) Normalized THz transmission vs. magnetic field through a slab of InSb for various FEL frequencies between 12-82 cm^{-1} at 4.2 K. Solid lines are experimental measurement and dotted lines are calculations based on [1] and [3] including the shape of laser profile. (i) Longitudinal (black) and transverse (blue) conductivity vs. magnetic field measured on the same sample up to 21 T at 4.2 K. Solid lines are experimental measurement and dotted lines are extrapolated curves.

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