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# Terahertz pulsed-field magneto-spectrometer at room-temperature

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***Abstract*—We have developed a compact pulsed-field THz magneto-spectrometer based on a THz molecular laser and heterodyne detection both at room-temperature. The recently developed continuous-wave THz laser uses mid-IR-pumped ammonia as active medium. The receiver is based on a subharmonic mixer pumped by a multiplication chain. A pulsed magnetic field up to 9T is supplied by discharging a capacitor in a small coil at room-temperature. We demonstrate here the use of this spectrometer by measuring the effective mass of electrons in an InAs/AlGaSb heterostructure at room-temperature.**

## I. Introduction

MOST of THz magneto-spectrometers operate with water or cryogenically cooled coils, often in large scale facilities (https://emfl.eu). Without cooling only electro-magnets are available but they provide low magnetic fields only up to 1 T. At 1 THz it signifies that only effective masses up to 0.028$m_0$ are accessible. Here we implemented a table-top THz magneto-spectrometer that combines at room-temperature (RT) a pulsed magnet up to 9 T during 10 ms, a stable THz laser source and a sensitive large bandwidth real-time THz detector.

## II. Experiment

The compact pulsed-field magneto-spectrometer is based on a THz molecular gas laser and heterodyne detection (see Fig. 1). The laser is an optically-pumped terahertz laser (OPTL) based on mid-infrared optical pumping of a polar molecular gas with a quantum cascade laser (QCL). This new concept, developed by us, allows pumping molecules and transitions that are not reachable with $CO_2$ pump lasers [1]. Here the laser operates on the (3,3) pure inversion line of $NH_3$ at 1.073 THz. The output power is of the order of a few 100s of µW. As shown in Fig. 1, the experiment is performed in transmission through the sample placed in the coil by guiding the THz beam inside a stainless steel circular waveguide. The receiver is based on a GaAs Schottky diode subharmonic mixer (Virginia Diodes WR1.0SAX) and the local oscillator (LO) is generated by a microwave synthesizer and a multiplication chain. The intermediate frequency (IF) is amplified, filtered, rectified and again amplified. The instantaneous detection bandwidth is larger than 1 MHz (time resolution better than 1 µs). The sample sits at RT in a copper magnet coil which supplies a field up to 9 T in a bore of 13 mm during typically 10 ms. The sample is a modulation-doped heterostructure grown by MBE on a GaAs semi-insulating substrate. It consists of a 1 µm-thick GaSb buffer layer promoting strain relaxation via the introduction of an array of Lomer dislocations confined at the GaSb/GaAs interface, a bottom $Al_{0.8}Ga_{0.2}Sb$ barrier, a 15 nm thick InAs channel, a top $Al_{0.8}Ga_{0.2}Sb$ barrier with a Si δ-doping plane and a Si-doped InAs cap layer. Hall effect measurements lead to mobility values of 33 800, 325 000 and 600 000 cm$^2$/V.s with corresponding electron sheet density of 1.8, 1.5 and 1.5×10$^{12}$ cm$^{-2}$ at 300 K, 77 K and 2 K respectively.

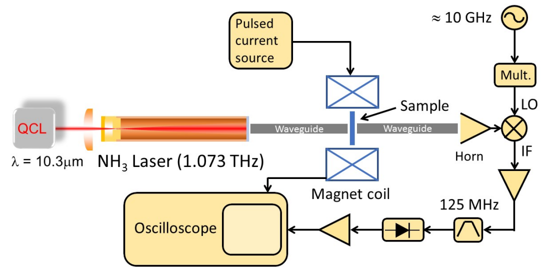


**Fig. 1.** Pulsed-field magneto-spectrometer setup.

## III. Results

Fig. 2 shows the magnetic field pulse and the measured THz transmitted signal through the sample versus time. Two dips due to the electron cyclotron absorption are measured as the field sweeps up and down at a value close to 1.7 T. We can deduce an electron mass value of (0.045±0.002)$m_0$ close to the published values [2]. Magnetic fields up to 12 T and a variable temperature of the sample are also achievable by cooling the coil with liquid nitrogen. In the future we intend to exploit the advantages of the heterodyne down-conversion: full amplitude/phase signal measurement and a phase-locked loop to further increase the signal/ratio.

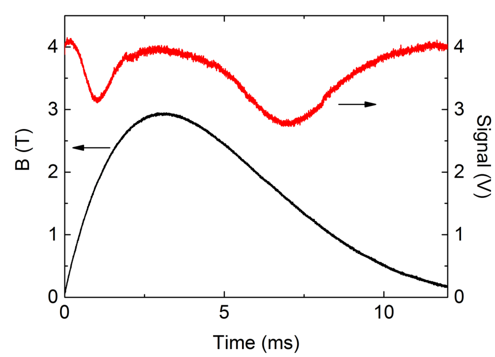


**Fig. 2.** Magnetic field and THz signal versus time (room temperature sample).

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