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Development of a Compact Pulsed Magnet for High-Field Magneto-optical Studies of Carrier and Exciton Dynamics in Nanostructures

We have developed a table-top pulsed magnet system for time-resolved magneto-optical spectroscopy studies, including time-domain terahertz spectroscopy measurements of cyclotron resonance. Magnetic fields as high as 30 T have been generated by using a compact capacitor bank together with a miniature pulsed coil cooled in a cryostat. The system allows direct optical access through an optical window with a large numerical aperture, ideal for ultrafast and nonlinear optical studies in a high magnetic field.

The purpose of this research is to develop a table-top pulsed magnet system that can be combined with conventional ultrafast optical spectroscopy methods for the study of dynamics of high-density carriers and excitons in low-dimensional systems in quantizing magnetic fields. Such a system will open up new possibilities for investigating quantum coherence and correlations in condensed matter systems in the magnetic quantum limit with unprecedented time resolution.

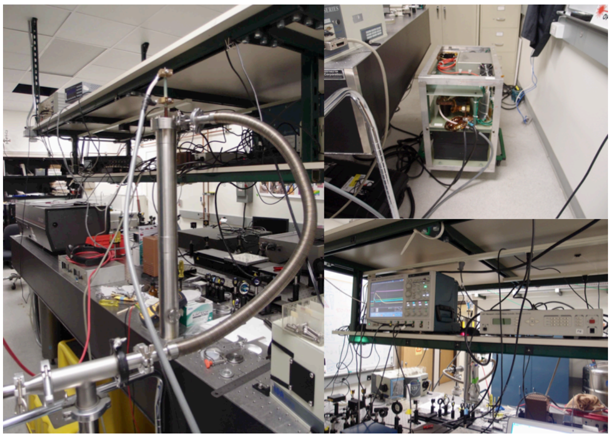

Fig. 1 Table top pulsed magnet system installed on the optical bench of the THz-spectroscopy. Cryostat(left), capacitor bank(right upper) and optics(right lower).

Figure 1 shows a photograph of the system developed at Rice University, Houston, Texas, USA. The system consists of a portable capacitor bank, a cryostat, and a miniature magnet. The cryostat has a horizontal free access bore of about 10.4 mm diameter at liquid nitrogen temperature. The sample is mounted on a cold finger made of a sapphire tube and cooling is made by a separate conventional helium-flow cryostat for optical microscopic spectroscopy. The two cryostats are jointed together by a flexible joint sharing the isolation vacuum, and the total optical path is about 12 cm. This short distance is advantageous in performing ultrafast and nonlinear laser spectroscopy experiments. Use of fiber optics is common in spectroscopic studies in high magnetic fields, but it deteriorates time resolution by elongating short light pulses through fnite dispersion. Our system avoids his problem by using free space optics with direct access to the sample via a window.

The specs of the capacitor bank are 5.6 mF capacitance and 2 kV charging voltage with a total energy of 11.2 kJ. Figure 2 show the waveforms of the generated pulsed field at different charging voltages. The raising time is about 2 msec, and the total pulse width is about 10 msec. A magnetic field of 30 T is generated at 1800 V charging voltage; the current is 5.2 kA at 30 T, and the interval of successive pulse is about 5 minutes. We have not found any interference with the spectroscopy setup, and the effect of the leakage field was not detected.

While a number of groups and laboratories in the world have expertise in ultrafast optics and pulsed high magnetic fields separately, no facilities currently exist which combine the two. National high magnetic field facilities in different countries have some limited capabilities of performing time-resolved optical experiments, but fields used in such experiments are DC fields, which naturally limit the highest field available. Our system will allow us to investigate an entirely new class of phenomena in the magnetic quantum limit with a unique table-top environment in a university laboratory setting.

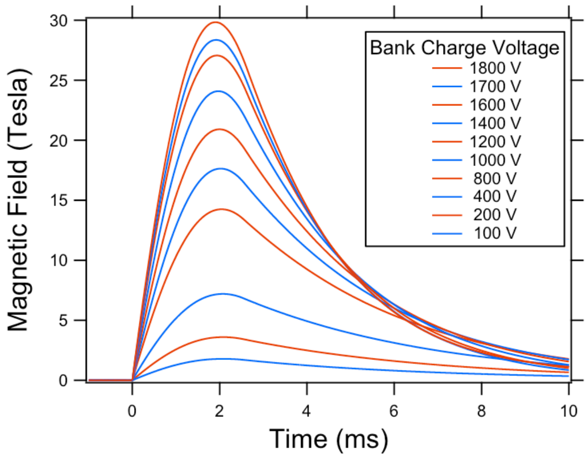

Fig. 2 Waveform of pulsed magnetic fields at different charging voltages of the capacitor bank.

Key Words

High Magnetic Fields, Ultrafast and Nonlinear Optical Spectroscopy, High-Field Magneto-optics

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