Time Resolved Spectroscopy of InMnAs III-V Magnetic Semiconductors

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Introduction
The recent emergence of III–Mn–V magnetic semiconductors, such as InMnAs and GaMnAs has led to a number of exciting results relevant to the new field of spintronics. The discovery of carrier-induced ferromagnetism in III-V semiconductors has not only opened up the possibilities to develop devices but also provided unique opportunity to study the interaction of itinerant carriers with localized spins. Several theoretical models have been proposed but the mechanism of carrier-induced ferromagnetism is still a matter of controversy. One of the open and interesting questions is the nature of the carriers mediating the exchange interaction between Mn ions.

In this project, we used the time resolved optical facility at the NHMFL in collaboration with Dr. McGill, to probe the dynamical response of InMnAs structures with the Curie temperature of ~ 293 K. The samples were grown on GaAs substrate with Mn contents ranging from 1 to 4%. Exactly how a laser pulse can effectively change the collective magnetization in an ultrafast manner is still an open question. The motivation of the studies at high magnetic field is due to the complex nature of the valance bands in ferromagnetic semiconductors. In the presence of high magnetic fields one can provide an environment to reduce the band mixing in the valance band, significantly. The band structure of InMnAs in the presence of external magnetic field has been probed by cyclotron resonance measurements and modeled theoretically [1]. Our goal has been to understand the (1) spin relaxation of nonequilibrium photo-excited carriers, (2) transient modifications of ferromagnetic order, and (3) photo-induced dynamic phase transitions.

Experimental
During the visit, we employed several time-resolved differential reflectivity and transmission schemes at room temperature and 4.2 K, using excitation pulses in mid-infrared with the probe pulses fixed at 775 nm. During a week of the experimental efforts we couldn’t observe any signal suggesting the relaxations of the photo-excited carriers/spins in the sample. The accuracy and the functionality of the experimental setup were tested using a non-linear crystal out the magnet’s cryostat. We attributed the lack of data to the samples’ structure and new structures will be provided before the next visit.

Conclusions
Time-resolved magneto-optical spectroscopy can provide direct time-domain information about magnetic properties of excited states with high temporal resolution and fine control. We plan to visit the facility in a near future when more samples are provided for the study.

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References