Ultrafast Absorption and Emission Dynamics of Dense, Quantized Magneto-plasmas in High Magnetic Fields

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Introduction

A strong magnetic field applied perpendicular to the plane of a semiconductor quantum well generates a series of Landau levels (LL), resulting in a highly degenerate δ-like 0D density of states. Intense ultrafast laser excitation results in a highly-quantized and dense electron-hole plasma which can occupy the LLs for short times before recombining [1,2]. Time-resolved transient absorption (TR-TA) and time-resolved photoluminescence (TR-PL) experiments exhibit similar temporal signatures and multiple bursts of emission.

Experimental

MBE-grown samples cooled to 10 K consisting of 15 layers of 8 nm In$_{0.2}$Ga$_{0.8}$As QW separated by 15 nm GaAs barriers and a 10 nm GaAs cap layer were excited by a 150 fs, 800 nm intense laser pulses in a 17.5 T superconducting magnet at normal incidence. For TR-TA experiments, collinear pulses tuned to the LL energies probed the transmission as a function of time delay laser for a range of laser fluences and magnetic fields. For the TR-PL measurements, a Hamamatsu streak camera was used to temporally-resolve light emission from the plane of the QW, collected by using a micro-prism mounted at the side of the sample.

Results and Discussion

Fig. 1 displays the normalized TR-TA pump-probe data at 0 T and 17.5 T. Compared with the 0 T data, a dramatic and qualitative change in dynamic response occurs at 17.5 T – all LLs exhibit an initial fast increase in transmission (as seen at 0 T), however the LL transmission signals exhibit abrupt, non-exponential reductions after the initial excitation. Fig. 2 (a-c) presents the corresponding in-plane TR-PL signal for 17.5 T at various excitation fluences. Multiple bursts of PL separated in time appear from each LL, with temporal signatures that correlate with abrupt reduction in transmission (Fig 1.) The presence of multiple bursts from the LLs suggests a complicated relaxation process mediated by the magnetic field whereby the photo-excited carriers initially relax into the LLs, followed by subsequent e-h recombination and emission. Because the densities are so high, a relaxation bottleneck occurs until the emission takes place, and LLs can subsequently ‘reload’ from higher occupied LL states.

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References