Time-resolved Magneto-Luminescence Measurements in Quantum Wells with Variable Well Widths for Optically Pumped NMR Experiments

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Introduction

We recently reported the photon energy dependence of the optically pumped NMR (OPNMR) in a strained Si-δ-doped 30 nm GaAs/$Al_{0.1}Ga_{0.9}As$ multiple quantum well (MQW) [1]. Prominent features in the data were assigned to specific electronic transitions with the aid of spin-dependent electronic band structure calculations. To systematically study the effects of quantum confinement on OPNMR, a series of GaAs/$Al_{0.25}Ga_{0.75}As$ MQWs with variable well widths were fabricated. Time-resolved photoluminescence (PL) experiments were performed. The electron spin polarization, and hence the nuclear spin polarization obtained in optically pumped NMR, depend strongly on the excited state lifetime τ when τ exceeds the electron spin lifetime.

Experimental

The MQWs were grown by MBE at the Center for Integrated Nano-Technology (CINT), Sandia Labs. Measurements were made in the Faraday geometry in SCM-3 at ~4.4 K. PL from the MQWs was collected by a microprism affixed to the edge of each sample and directed into a graded-index optical fiber to a monochromator and a streak camera. PL was excited with ~130 fs optical pulses with a center energy of 1.74 eV and 250 μW average power.

Results and Discussion

The PL peak energy at high field exhibits a linear dependence on field with a slope that decreases with decreasing well width, as shown in Fig 1. The field dependence of the PL peak energy in a 14 nm MQW is shown in the inset of Fig 1. Representative time-resolved PL data is shown in Fig. 2. Columns of the data presented in Fig. 2 show the temporal response of the PL at a given energy. After a rapid increase in PL intensity, the PL signal exhibits a single-exponential decay. Fitting the decay of the PL signal at different energies shows that the lifetime varies across the lineshape of the PL signal. The energy dependence of the PL lifetime depends on well width, showing longer lifetimes at higher energies for wider QWs (28 nm, 14 nm, and 7 nm) and at lower energies for the narrowest well (4 nm). The lifetimes at maximum and minimum energies are reported in Table I.

Conclusions

We have measured the magneto-PL and the PL lifetimes from a series of MQW samples at several magnetic fields (0, 3, and 9.4 T). The lifetimes are found to be independent of magnetic field and vary across the lineshape of the PL. Lifetimes decrease with decreasing well width. The lifetimes will be used as input parameters in simulations of the OPNMR photon energy dependence for this series of MQWs.

Acknowledgements

Samples were grown for OPNMR studies under a CINT/Sandia Labs user grant. A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy.

References

[1] Wood, R.M., *et al*., Physical Review B, **90**, 155317 (2014).

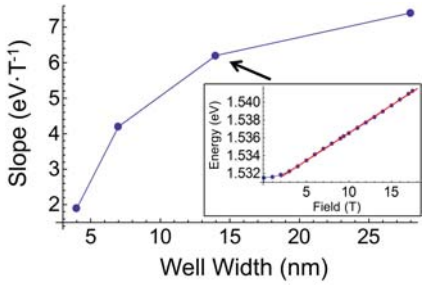

Fig. 1. Slope of the high-field magneto-PL versus QW width. (Inset) Magnetic field dependence of the PL peak energy for a 14 nm MQW. The solid red line is a linear fit of the data.

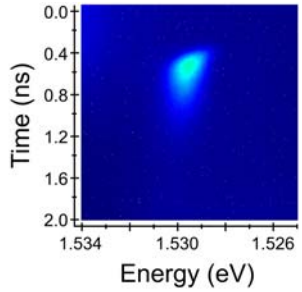

Fig. 2. Time-resolved PL signal from a 14 nm MQW at 0 T and 4.4 K.

Table I. Summary of low and high energy PL lifetimes for MQWs of different well widths.

Well Width	Low Energy τ (ps)	High Energy τ (ps)
28 nm	400	650
14 nm	230	420
7 nm	240	310
4 nm	250	150