Low Temperature Optical Absorption Studies on Semi-Insulating GaAs: Implications for Optically-Pumped NMR

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The large NMR signal enhancements afforded by the optical orientation of nuclear spins in semiconductors has enabled the study of rare (1) and dilute (2) spin systems. Interestingly the maximum signal intensity of optically-pumped NMR (OPNMR) signal intensity is observed below the bandgap energy. Although the optical pumping mechanism for OPNMR was well established (3), the physical origin for the dependence of OPNMR signal intensity with photon energy was not clear.

Figure 1 shows ^{71}Ga OPNMR signal intensity dependence on photon energy for excitation with σ+ and σ– for 400 μm and 175 μm thick GaAs wafers (see legend). The figure clearly shows that the maximum OPNMR signal intensity occurs approximately 20 meV below the bandgap energy (1.52 eV). Recently, we have developed a numerical model which incorporates the combined roles of optical absorption, photon energy and polarization, and the corresponding penetration depth to explain this maximum (4). In these initial simulations (see Figure 2), we utilized optical absorption coefficients adapted from Ref. (5) which were obtained at 21 K. We were able to qualitatively explain the experimental features shown in Figure 1.

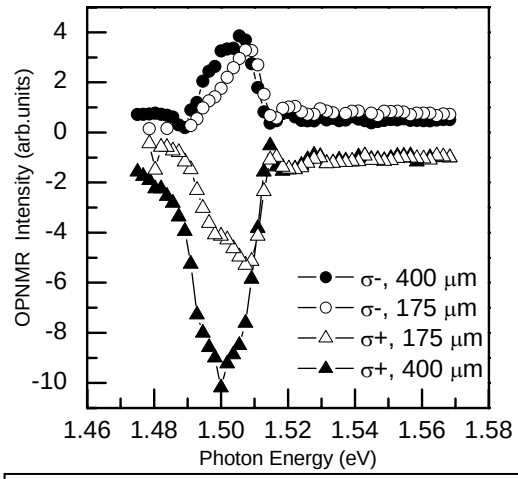

Figure 1 – ^{71}Ga OPNMR signal intensities of GaAs for σ+ and σ- polarized light and two sample thicknesses.

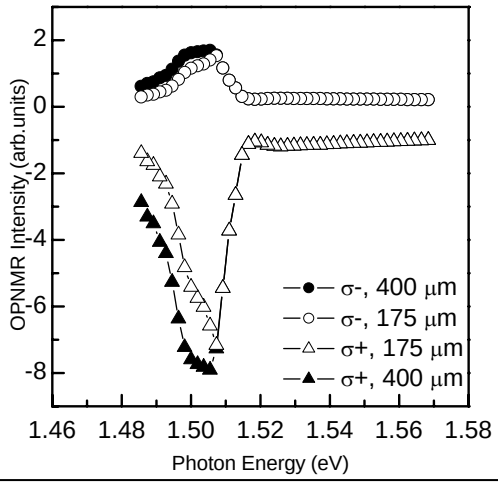

Figure 2 – Simulated ^{71}Ga OPNMR signal intensities in GaAs for σ+ and σ- polarized light and two sample thicknesses

In order to quantitatively describe the experimental data, we have performed optical transmission measurements on the same GaAs samples used in our OPNMR experiments. These optical measurements were performed at NHFML (Los Alamos, NM), in the superconducting split-coil magnet having direct optical access and a peak field of 8 T. The samples were mounted, strain-free, in the variable-temperature insert, and the sample temperature was kept constant at 6 K (the same sample temperature used in OPNMR experiments). The output of a 100 W white-light source was spectrally filtered to less than 0.5 nm using a 0.3 nm scanning monochrometer. The light was then linearly polarized, and then circularly polarized (σ+ or σ–) with a quarter-wave plate before being focused onto the sample. Transmitted light was detected by an avalanche photodiode.

An improved analysis of the OPNMR signal intensity profile employing the newly acquired optical absorption coefficients is underway.

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