Hole Spin-Relaxation in Quantum Wells from Saturation of Inter-Subband Absorption

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Optical orientation using far-infrared (FIR) light has been shown to create spin-polarized subband populations in doped quantum wells (QW) (monopolar spin orientation) [1]. Here we demonstrate how the inter-subband excitation in p-(113)GaAs QWs with circularly polarized FIR light in the nonlinear regime [2] can be exploited to extract hole spin relaxation times.

Resonant excitation of p-doped QW with far-infrared light results in direct inter-subband transitions which depopulate the lowest valence subband. The absorption coefficient is proportional to the population difference of the initial and final states involved in the transitions. At hight intensities the photoexcitation rate becomes comparable to the relaxation rate into the initial state and the absorption saturates. In contrast to excitation with linear polarized light, this saturation is spin-sensitive for circularly polarized light due to monopolar spin orientation and provides information about the spin relaxation of holes in the lowest spin-split subband. The saturation behavior can be quantified by a characteristic saturation intensity I_{ss}, which is given by $I_{ss} = \hbar\omega p_s/(\alpha_0 L_W \tau_s)$, where α_0 is the linear absorption coefficient, $\hbar\omega$ is the energy of the exciting light, L_W is the width of the quantum well and τ_s the spin relaxation time.

Spin-sensitive saturation of the absorption has been measured in p-type (113) MBE-grown GaAs QWs with well widths between 7 and 20 nm in the temperature range of 4.2 K up to 120 K. Spin relaxation times can be obtained from the experiment by making use of calculated (linear) absorption coefficients α_0 for inter-subband transitions. Our calculations are based on the self-consistent multi-band envelope function approximation (EFA) [3], that takes into account the crystallographic orientation of the QW and the doping profile.

In this abstract we show the results for a sample with a QW width of 15 nm. The experimental saturation intensities for excitation with linear and circular polarization are depicted in Fig. 1 in dependence on the temperature. Their difference demonstrates the sensitivity to spin relaxation. In Fig. 2 we present the linear absorption coefficient $\alpha_0(\hbar\omega)$ for different temperatures and the absorption coefficient $\alpha_0(T)$ at the excitation energy $\hbar\omega = 8.4\,\mathrm{meV}$ ($\widehat{=}148\,\mu\mathrm{m}$). Finally in Fig. 3 the extracted hole spin relaxation time is shown in dependence on the temperature. The experiments show a significant reduction of I_{ss} with decreasing width of the QW. This observation indicates longer hole spin relaxation times for narrower QWs.

References

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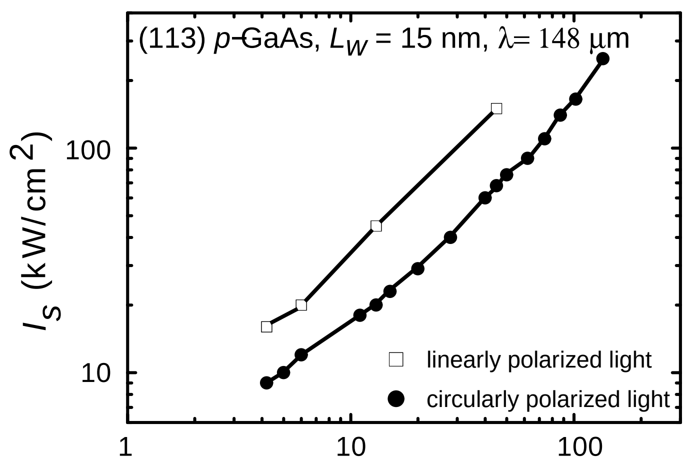

Figure 1: Temperature dependence of the saturation intensities for $L_W = 15\,\mathrm{nm}$ for linear (squares) and circular (circles) polarized light, respectively.

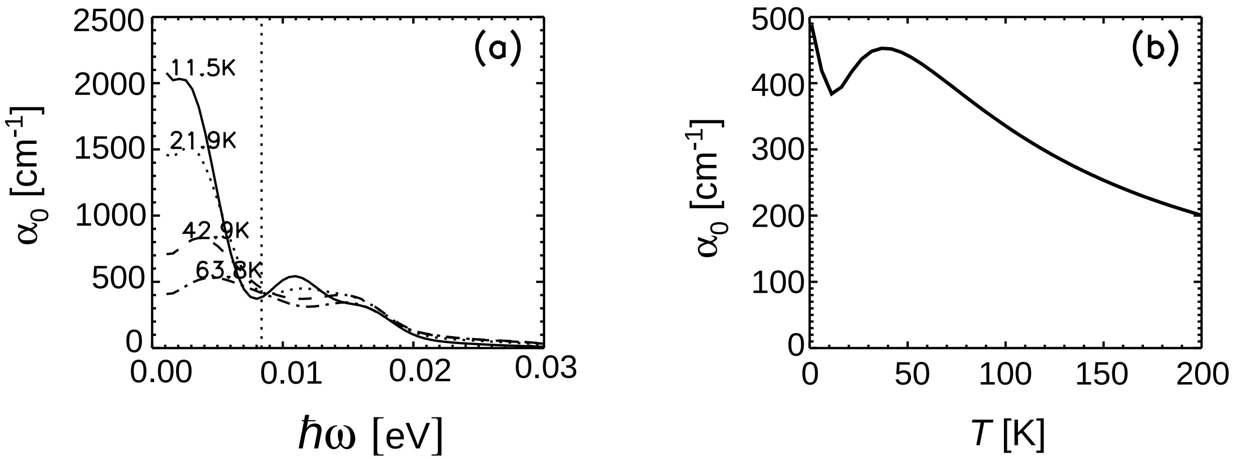

Figure 2: (a) Absorption coefficient as a function of photon energy $\hbar\omega$ for various temperatures T and (b) as a function of T for $\hbar\omega = 8.4\,\mathrm{meV}$ (vertical dotted line in (a)). The parameters of the calculation were chosen for a (113)-grown 15 nm GaAs-AlGaAs QW with carrier density $2 \cdot 10^{11}\,\mathrm{cm}^{-2}$.

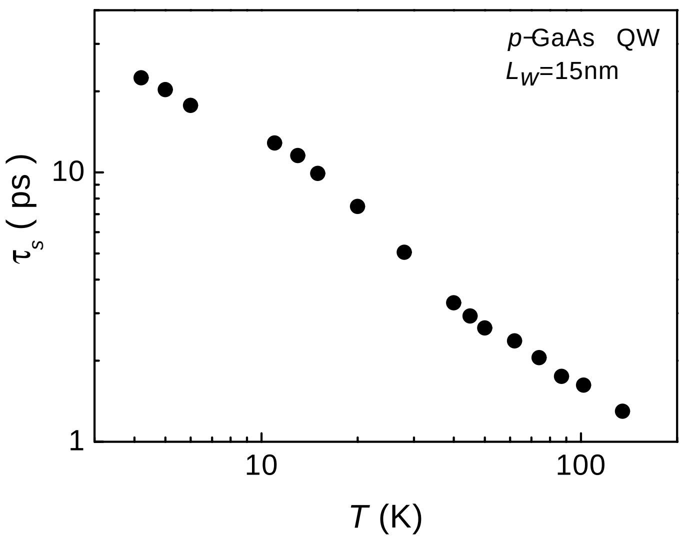

Figure 3: Spin relaxation times obtained for a p-type GaAs sample with a QW width of L_W=15 nm, $p_s = 1.66 \cdot 10^{11}$ cm^{-2} and mobility μ of about $5{\cdot}10^5$ cm^2/(Vs).