Electron spin coherence in long wavelength $Hg_{1-x}Cd_xTe$

C. R. Pidgeon[1], P.Murzyn[1], J-P. R. Wells[1], N. T. Gordon[2], T. Ashley[2], J. H. Jefferson[2], T. M. Burke[2] , C. D. Maxey[3] and B. N. Murdin[4]

[1]*Department of Physics, Heriot-Watt University, Edinburgh EH14 4AS, UK.*
[2]*QinetiQ, St Andrews Road, Malvern, Worcs WR14 3PS, UK.*
[3]*BAE SYSTEMS Infra Red Ltd., Southampton SO15 0EG, UK.*
[4]*Department of Physics, University of Surrey, Guildford GU2 7XH.*

We have used the Dutch free electron laser (FELIX) to measure spin coherence times in long wavelength $Hg_{1-x}Cd_xTe$ at wavelengths between 4 and 10μm and from 4 - 300K. In particular, we measure remarkably long spin coherence times at 300K. We have obtained similar results for InSb near 7 μm. These first results are being extended to a range of compositions, mobilities and temperatures, both to explore the physics determining spin relaxation in narrow gap semiconductors (NGS), and to establish conditions required to optimise the spin lifetime.

In bulk semiconductors three main spin relaxation processes have been found to be important: the Elliott-Yafet (EY) [1], D'yakonov-Perel (DP) [2] and the Bir-Aronov-Pikus (BAP) [3] mechanisms. The BAP mechanism is thought to be important in wide gap materials and is based on the electron-hole Coulomb interaction, but is not expected to contribute in intrinsic or n-type NGS.

The EY mechanism results from the fact that in real crystals Bloch states are not spin eigenstates because of the strong spin-orbit coupling induced by the lattice ions. In this case spin-independent interactions with impurities, boundaries, phonons etc., can connect spin up and down electrons, leading to a relaxation whose rate $1/T_1$ is proportional to $1/\tau$ where τ is the orbital momentum (mobility) scattering time. This process is thought to be important in NGS samples and/or at high temperature.

The DP mechanism is expected to dominate in large gap n-type semiconductors that lack inversion symmetry so that the **k**-dependent spin-orbit interaction lifts the spin degeneracy even in the absence of a magnetic field. Somewhat counter-intuitively, and in contrast with EY, the spin relaxation rate $1/T_1$ is subject to motional narrowing, and is therefore directly proportional to the orbital (mobility) scattering time, τ [2]. In NGS both the EY and the DP mechanisms may be important, and indeed conflicting reports of spin relaxation in InSb [4] and InAs [5] - the former being interpreted in terms of EY and the latter of DP - show that the subject is still controversial. It is therefore presently unclear whether enhancement of the spin lifetime may be achieved with higher or lower mobility samples, which is affected by e.g. layer thickness through interface scattering, as well as by sample temperature. Additional factors may influence the spin relaxation, and we report its measurement as a function of doping, mobility, and temperature in order to investigate systematically the dominant mechanisms. We find, in accord with the earlier work [4], that at least for long wave HgCdTe and InSb it is indeed the EY mechanism that dominates.

We have used both the polarization pump-probe method [5] and the Faraday rotation method [6,7] in the 5 - 10μm region in

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order to examine the spin relaxation times of bulk epilayers of long wavelength $Hg_{1-x}Cd_xTe$ and InSb as a function of temperature, doping, mobility and bandgap. Results are shown in Fig. 1 for lightly doped p-$Hg_{0.7}Cd_{0.3}Te$ at two different temperatures. It is clear from the results that the spin lifetime increases with sample mobility in accord with the EY mechanism, and in contrast with the DP mechanism.

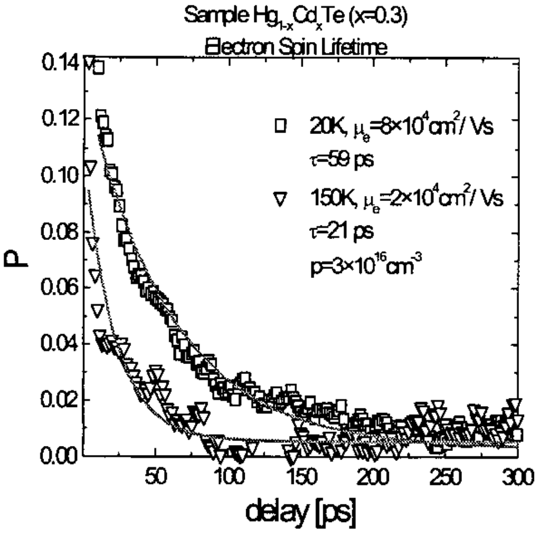

Fig. 1 Spin polarisation of the probe beam as a function of delay after the "same polarized" pump, for $Hg_{0.7}Cd_{0.3}Te$ at two different temperatures.

A key step in controlling spin relaxation has been the observation of a large enhancement of the spin memory of electrons by n-type doping in both bulk (GaAs) semiconductor and QWs (ZnCdSe) - T_1 is found to increase by several orders of magnitude over corresponding intrinsic material [6, 7]. We have found a similar effect in n-HgCdTe and n-InSb, where we obtain more than an order of magnitude enhancement of T_1 (from ~ 20ps to ~ 500ps) between intrinsic and n-type material ($N = 2x10^{17}cm^{-3}$). The present tentative explanation for this is that in intrinsic samples, photo-excited spin-polarised holes efficiently scatter electron spins and themselves have a short spin relaxation time (picoseconds), which dominates the measured value. In the presence of a degenerate Fermi sea, the photo-excited holes are removed, and the true electron spin relaxation time is measured.

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