Electron spin-dynamics in GaAs quantum wells

R. Harley
School of Physics and Astronomy, University of Southampton, United Kingdom

The possibilities for application of the spin degree of freedom in addition to (or instead of) the charge of electrons in semiconductor devices are attracting increasing attention [1]. Semiconductor quantum wells and two-dimensional electron gases (2DEGs) are likely to play an important role in these developments. To exploit the behaviour of electronic spins it is necessary to understand the fundamental physics of spin dynamics in such quantum structures and learn how to control it. In this lecture I will give a brief general introduction and then describe some recent and continuing optical experiments aimed at elucidating these important goals.

Experiments on GaAs quantum wells grown on substrates with (100) and (110) crystallographic orientations show, as predicted theoretically, that the spin relaxation rate for electrons in (110)-oriented quantum wells is much lower than in (100)-oriented quantum wells [2–4]. We also find that the spin relaxation rate may be strongly enhanced by application of electric field [4]. Both these phenomena have great potential for spintronic applications.

Investigation of 2DEGs in GaAs samples, where the electron mobility approaches the state of the art and therefore the momentum relaxation rate is minimised, have given new insights into the role of scattering in the spin dynamics [5–7]. For example, it was long expected that the electron spin-relaxation rate should be proportional to the electron mobility [1, 2], suggesting that high mobility and long spin memory, each potentially desirable properties for spintronic applications, are not compatible. The experiments [7] show this expectation to be incorrect. All the qualitative features of the D'jakonov–Perel mechanism [8, 2] of spin dynamics in both collision-dominated and collision-free regimes are observed but theoretical analysis [6] shows that the spin dynamics are dominated by electron-electron scattering which does not contribute to the mobility.

Bibliography

[1] See: D. D. Awschalom, D. Loss, and N. Samarth (ed.) *Semiconductor Spintronics and Quantum Computation* (Berlin, Springer), particulary Chapter 4 by M. E. Flatte *et al.*.
[2] M. I. D'jakonov and V. Yu. Kachorovskii, Sov. Phys. Semicond., **20**, 110 (1986).
[3] Y. Ohno *et al.*, Phys. Rev. Lett., **83**, 4196 (1999).
[4] O. Z. Karimov *et al.*, Phys. Rev. Lett., **91**, 246601 (2003).
[5] V. N. Gridnev, JETP Lett., **74**, 380 (2001).
[6] M. M. Glazov and E. L. Ivchenko, JETP Lett., **75**, 403 (2002); M. M. Glazov and

E. L. Ivchenko, Journal of Superconductivity: Incorporating Novel Magnetism **16**, 735 (2003); M. M. Glazov, Physics of the Solid States, **45**, 1162 (2003).
[7] M. A. Brand *et al.*, Phys. Rev. Lett., **89**, 236601 (2002).
[8] M. I. D'jakonov and V. I. Perel', Sov. Phys. JETP, **33** 1053 (1971).