Origin of the heavy-hole in-plane g-factor in individual annealed InGaAs/GaAs quantum dots

Prashant R. Ramesh[1,2]

N. Coste,[1] N. Margaria,[1,3] N. Somaschi,[3] M. Morassi,[1] M. Pont,[1] A. Lemaitre,[1] L. Lanco,[1,4] M.F. Doty,[2] N. Belabas,[1] P. Senellart,[1] O. Krebs[1]

1 – Centre of Nanosciences and Nano-technology, CNRS, Université Paris-Saclay, 10 Boulevard Thomas Gobert, 91120 Palaiseau, France
2 – University of Delaware, 210 S. College Ave, Newark, DE 19716, United States
3 – Quandela SAS, 10 Boulevard Thomas Gobert, 91120 Palaiseau, France
4 – Universite Paris Cite, 75013 Paris, France

rameshpr@udel.edu

Self-assembled InGaAs/GaAs quantum dots (QDs) are of unique importance to photonic quantum computing as platforms for entangled spin qubits [1], quantum receivers [2] and spin-photon cluster states [3]. Some of these quantum protocols and notably deterministic cluster state generation for measurement-based quantum computing rely on the optical selection rules under a transverse magnetic field, which are related to the actual spin eigenstates (Fig.1b). Notably, the linear polarization axes of the optical transitions for a given in-plane magnetic field orientation are determined by the g-factor of the QD valence band ground state - a so-called heavy-hole - which in general must be represented by a second order tensor. It has been recently reported that for an ensemble of annealed QDs, the components of this tensor are dominated by a confinement-renormalized Luttinger parameter *q*, associated to *valence band warping* [4], rather than to the *valence band mixing* induced by the QD structural anisotropy [5]. Using polarization-resolved photoluminescence (PL) measurements of *individual* QDs for different angles of the applied magnetic field, we assess the respective contribution of the valence band warping and mixing to the heavy-hole in-plane g-factor tensor.

Under a strong transverse magnetic field (B = 5T), we excite individual QDs off-resonantly and find that the linear polarization of the four Zeeman-split PL lines, remain essentially parallel to the directions <110> of the crystal (Fig.1-a), regardless of the in-plane field angle. We also observed a significant anisotropy in PL intensity, with eigenaxes along the same directions <110>, and essentially independent of the magnetic field strength (Fig. 1-c) and direction (not shown). Both observations point to a valence band mixing as the origin of the heavy-hole in-plane g-factor despite annealed (hence likely less anisotropic) QDs. For a more quantitative analysis, we also performed simulations with a simple spin model including both valence band mixing and warping. With respect to Ref. [4], our results point to the criticality of the annealing procedure to control the effective heavy-hole in-plane g-factor tensor in such QDs.

References

[1] R. Stockill *et al.*, PRL, **119** 010503 (2017)
[2] H. Kim *et al.*, Nat. Photon. 7, 373 (2013)
[3] N. Coste *et al.*, Nat. Photon. (2023)
[4] A.V. Trifonov *et al.*, PRB, **104**, L161405 (2021)
[5] K. Kowalik *et al.*, PRB **75**, 195340 (2007)

Figure 1

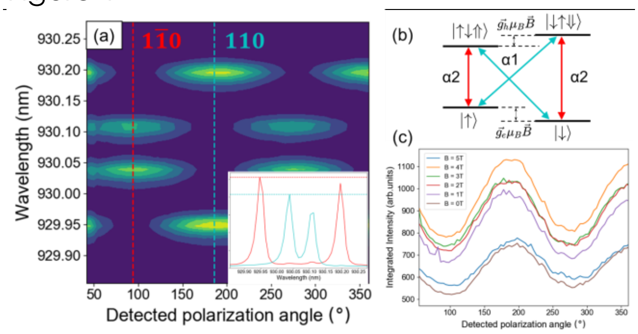

Figure 1: a) Contour plot PL intensity as a function of emitted light polarization and wavelength at B = 5 T. Inset shows spectra associated to <110> directions. b) Energy level diagram of the system. c) Integrated PL intensity vs emitted light polarization at varying magnetic field strength