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

Prashant R. Ramesh[1,2], N. Margaria[3], D.A. Fioretto[1,3], S.C. Wein[3], A.Pischagin[3], M.Morassi[1], A.Lemaitre[1], M.F.Doty[2], P.Senellart[1], L.Lanco[1,4], N.Belabas[1], O.Krebs[1]

[1]*C2N-CNRS, 10 Boulevard Thomas Gobert, 91120 Palaiseau, France*

[2]*University of Delaware, 210 S. College Ave, Newark, DE 19716, United States*

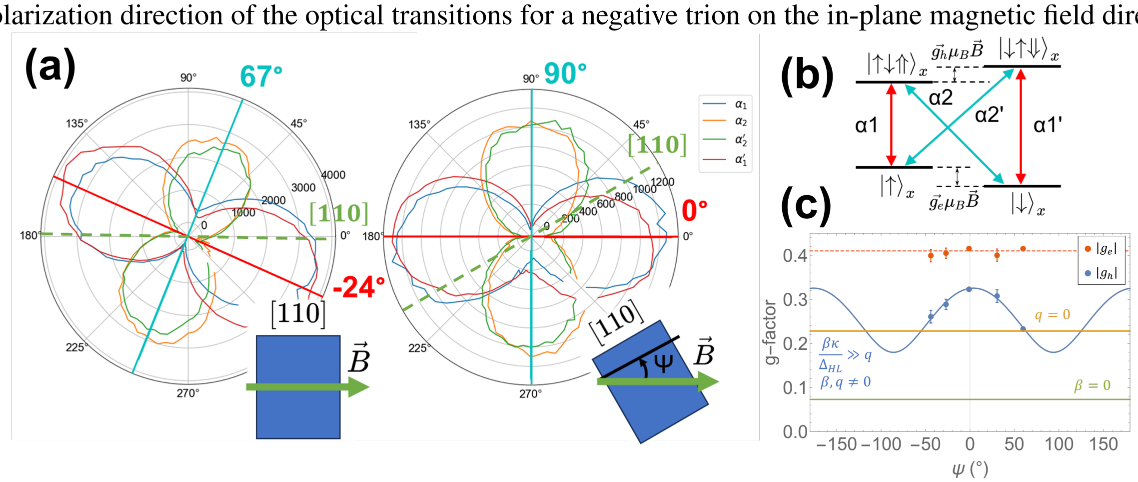
[3]*Quandela SAS, 7 Rue Léonard de Vinci, 91300 Massy, France*

[4]*Université Paris Cité, 75013 Paris, France*

rameshpr@udel.edu

Self-assembled InGaAs/GaAs quantum dots (QDs) are of unique importance to photonic quantum computing. Single photon sources using these QDs have been used for the deterministic generation of photonic cluster states via the Lindner-Rudolph protocol [1, 2]. Notably, this relies on the Larmor precession of a spin in a transverse magnetic field, which is governed by the in-plane g-factors of the QD electron and valence band heavy-hole, with a maximum efficiency likely reached when $|g_e| = |g_h|$. To satisfy this condition, we seek to harness the heavy-hole g-factor anisotropy with respect to the in-plane magnetic field direction [3]. This involves elucidating the origin of the heavy-hole in-plane g-factor.

The non-vanishing in-plane g-factor leading to the effective Larmor precession of the heavy-hole spin in a transverse magnetic field can be attributed to two effects. The most invoked effect in the context of individual spin manipulation is the heavy-hole light-hole mixing induced by QD structural anisotropy [4]. Another contribution is described by a confinement-renormalized cubic Luttinger parameter q as reportedly observed to be predominant for an ensemble of annealed QDs [5]. We assess the contributions of these two effects by investigating the dependence of the polarization direction of the optical transitions for a negative trion on the in-plane magnetic field direction.



We find that the linear polarization of the four Zeeman-split transitions (fig b) remain mostly attached to the sample axes [110] when the sample is rotated by an angle ψ with respect to the magnetic field direction (fig a, ψ= 0 (left) ψ=30° (right)). This demonstrates that valence-band mixing is the dominant contribution in our annealed QDs. We further observe a dependence of the magnitude of the hole g-factor g_h on the magnetic field direction (fig c), which we fit using a simple spin model including both valence band mixing captured by $\beta\kappa/\Delta_{HL}$ [4] and the Luttinger q parameter. We thus demonstrate that the hole g-factor anisotropy is tunable by the magnetic field direction, which opens the promise of post-growth control of the hole g-factor and further optimization of spin-photon cluster state generation.

References

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