Evidence for spin memory in photoluminescence of room temperature vertical-cavity quantum dot gain structure

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Spin-optoelectronics is a rapidly developing field with promises to provide extra functionalities in communication and spectroscopy via ultrafast polarization modulation [1]. We are addressing the question of spin memory in InAs/GaAs quantum dots (QD) which can serve as gain structures for vertical-external cavity lasers (VECSELs), whereas most previous investigations focused on monolithic VCSELs. VECSELs offer possibilities not only for power scaling but also for additional flexibility as polarization controlling elements can be introduced into the free space sections [2,3]. Moreover QDs extend the wavelength coverage of GaAs based materials to the 1300 nm telecomm band with long spin lifetimes having been reported [4]. However, previous investigations concentrated on low temperatures and/or charged/doped dots and we are not aware of results on structures at strong excitation for lasing at room temperature.

The sample consists of 5 groups of 3 InGaAs/$In_{0.12}Ga_{0.88}As$ dot-in-a-well (DWELL) layers separated by GaAs barriers and spacers. The half-cavity is closed by a 25 layer GaAs/AlAs Bragg stack. In these structures spin-polarized lasing emission using the spin amplification around threshold has been demonstrated [3]. In this work the sample is excited using a 905 nm laser at 30° from normal with a maximal power of 190 mW. The resulting normal photoluminescence (PL) is collected with an f =50 mm lens, coupled to a multi-mode fibre and analysed with an optical spectrum analyzer. In the collimated region between collimator and fibre coupler, a Glan-Thompson polarizer and an achromatic quarter-wave plate (QWP) are used to measure the Stokes parameter S_3 of the PL.

Emission of the QD is centred at 1295 nm (inset of Fig. 1b). For spin polarized pumping (S_3=±1) the PL shows a small helicity with clearly separated curves (Fig. 1a) with the S_3 values obtained for linear pump polarization in between. The total effect is very small and sensitive to drifts of laser intensity and fibre coupling as the polarization sensitive measurements are done in sequence and not parallel but are overall consistent with a spin memory of 0.006-0.008. Further evidence is obtained by continuously varying the spin polarization of the input beam by rotating a QWP controlling the polarization of the pump beam. This yields a linear relationship between PL S_3 and pump S_3 (Fig. 1b). From the slope m the spin lifetime τ_s can be estimated via $m= 1/(1+\tau/\tau_s)$. For a typical carrier lifetime of $\tau = 1$ ns this results in $\tau_s \approx$ 5-8 ps. This is quite short but might be influenced by the shape anisotropy of the quantum dots leading to birefringence and reducing the optically detected S_3 compared to the fundamental spin polarization present in the sample. The demonstration and quantification of a finite spin memory under strong excitation provide a promising starting point for the implementation of high power spin-VECSELs.

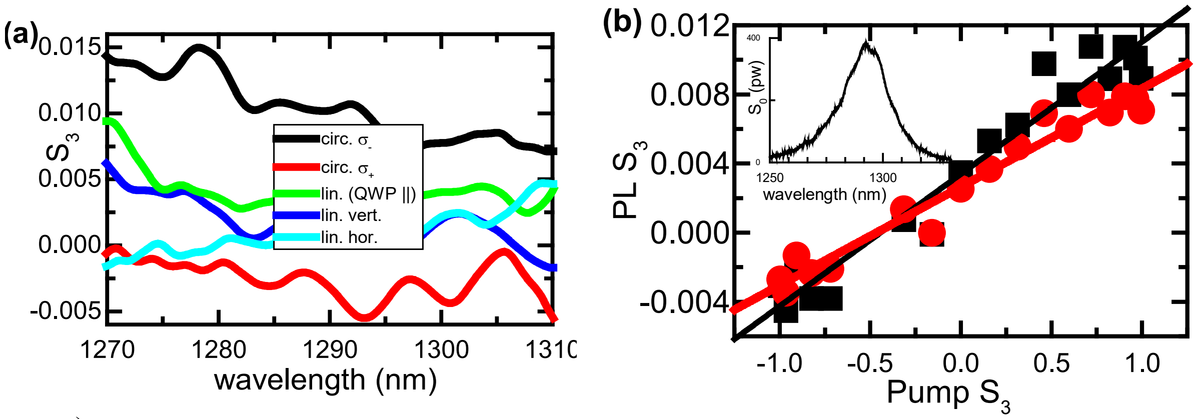

Fig. 1 a) Spectrally resolved S_3 of PL for different excitation conditions smoothed over 4 nm. b) S_3 of PL vs. S_3 of pump. Black data averaged over central 1285-1302.5 nm. For the red data the average is weighted by S_0 (see inset). Straight lines: linear fits to data.

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