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Dynamics of optical spin injection in self-assembled InGaAs quantum dots

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Highly efficient spin injection of carriers in quantum dots (QDs) is strongly motivated for realizing spin-functional devices such as spin-polarized lasing in QDs. Spin-injection dynamics including spin relaxation during the injection is a crucial subject to be clarified because the spin-injection efficiency can be largely affected by the injection dynamics. Therefore, we study the spin injection dynamics in self-assembled InGaAs QDs by circularly polarized, thus spin-resolved, time-resolved photoluminescence (TRPL) and PL excitation (PLE) methods.

The InGaAs/GaAs QDs were grown by molecular beam epitaxy. The average diameter, height and areal density are 24 nm, 5 nm and 3.3×10^{10} cm^{-2}, respectively. The dynamics of carrier-spin injection was probed by TRPL under circularly polarized pulsed excitation for GaAs barriers at a wavelength of 805 nm. The temperature was varied from 6 K to 250 K.

The PLE data shows directly optical spin injection from the GaAs barriers into QDs. The typical TRPL for the first excited states in the InGaAs QDs demonstrates the spin injection dynamics, such as, an injection time of 60 ps and spin conservation factor during the injection: $\eta = 0.66$ (0.5: full relaxation and 1: full conservation of spin states), as well as a spin lifetime in the QDs of 1 ns (Fig.1). The temperature-dependent spin-injection kinetics is shown in Fig.2. We find that the spin-injection time decreases from 70 ps to 10 ps with increasing temperature, while η initially increases from 0.65 to 0.75 in the range from 6 K until 150 K, then decreases down to 0.62 at 250 K. These trends will be discussed in terms of effects of energy and momentum relaxation of carriers on the spin injection.

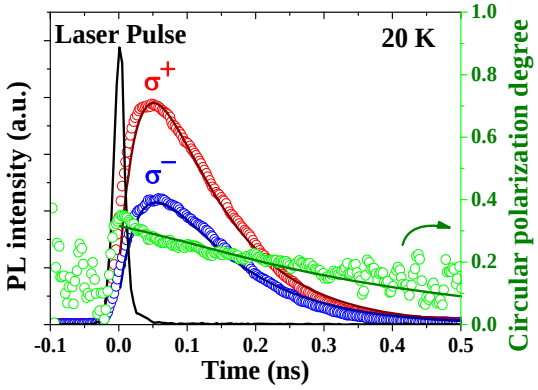

Fig.1 Circularly polarized time- resolved PL in InGaAs QDs under circularly polarized pulsed excitation at 20 K. Solid lines are rate equation calculations

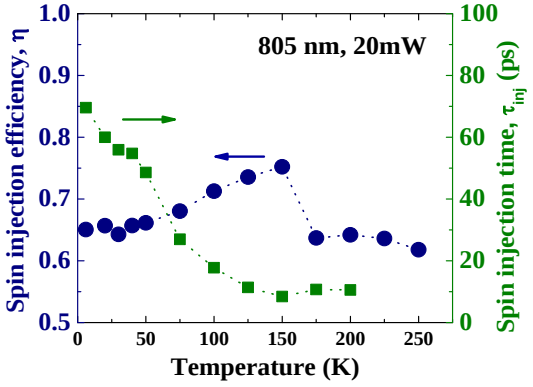

Fig.2 Temperature dependences of the spin injection dynamics, the injection time and spin conservation factor during the injection.