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Multi-Wave-Mixing Photon-Echo in Strain-Compensated Quantum Dots

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Coherent transfer between light and the two-level system plays an important role in implementing quantum memory, which is an indispensable tool for quantum information processing and quantum communications. Recently, a new scheme for quantum memory using photon-echo processes in the inhomogeneous two-level system was proposed. For the proof-of-principle of the photon-echo-based quantum memory using an inhomogeneous semiconductor quantum dot (QD) ensemble, we try to demonstrate the coherent transfer, retrieval and manipulation of the relative phase of incident pulses using a phase-controlled multi-wave-mixing photon-echo technique (Fig. 1 (a)). In this presentation we show the first experimental demonstration of multi-wave mixing in the three excitation pulse configuration using a QD ensemble.

The sample used in this study is 150-layer-stacked InAs QDs fabricated using the strain compensation (Fig. 1(b)). We recently succeeded in observing photon-echo signals with a high signal-to-noise ratio using the same sample [1]. As a result, we found that the coherence time of an exciton in our QD is extremely long, which is over 1 ns [2, 3]. Figure 1 (c) shows the pulse area dependence of the intensities of multi-wave-mixing signals in the three excitation pulse configuration (I_{3pulse}) and in the two excitation pulse configurations (I_{2pulse}). All experimental results are in the good agreement with the calculations using the two-level model taking into account the inhomogeneous distribution of pulse areas (see the solid lines in Fig. 1(c)). The intensity I_{3pulse} is equivalent to the intensity I_{2pulse} for small pulse areas, which implies that the time-bin pulses can be retrieved as photon-echo signals. On the contrary, I_{3pulse} is much different from I_{2pulse} for large pulse areas due to the contribution of higher-order multi-wave-mixing signals. I also demonstrate the ultrafast coherent control of excitons in our QDs using Rabi oscillations. We found that ensemble effect is partly cancelled out in case of FWM signal only [4].

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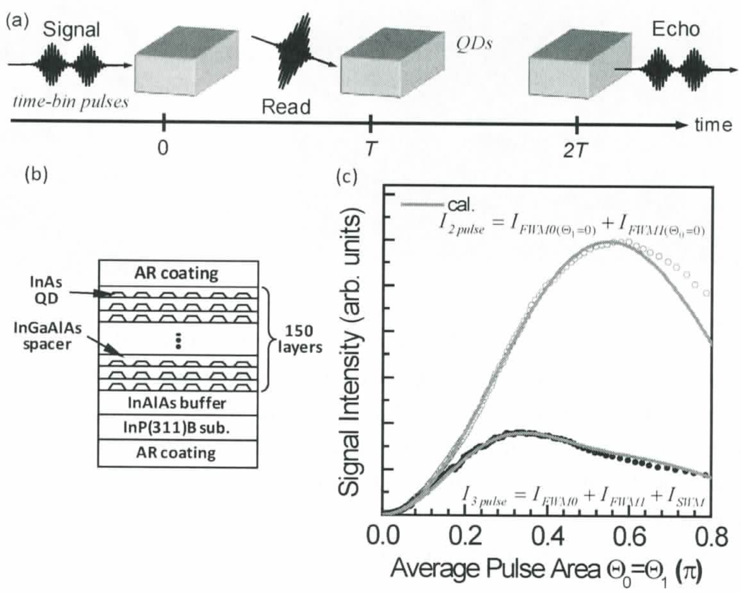

Fig. 1: (a) A scheme of photon-echo-based quantum memory (b) A schematic of our sample structure (c) The pulse area dependence of the intensities of multi-wave mixing signals in the three excitation pulse configuration (I_{3pulse}) and in the two excitation pulse configurations (I_{2pulse}). The area of read pulse was ~ π. Solid gray lines represent the theoretical curves calculated the two-level model.