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Micro-spectroscopy of a single quantum dot using a high-resolution Michelson interferometer

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Abstract

The coherent control of exitons in QWs and QDs is very attractive for application to novel ultrafast device such as ultrafast all-optical switches, and semiconductor quantum information devices. We developed a high-resolution Michelson interferometer with He-Ne laser positioning system, and measured the coherent carrier dynamics of a single InAs self-assembled quantum dot (SAQD) using a micro-spectroscopy system. Stabilization of phase locked double pulse was realized with the maximum deviation below 10nm.

1. Introduction

Ultrafast phase-locked spectroscopy using a coherent control technique has been reported for studies of the ultrafast carrier dynamics of excitons in semiconductor quantum wells (QWs) and quantum dots (QDs)[1][2]. The coherent control of exitons in QWs and QDs is very attractive for application to novel ultrafast device such as ultrafast all-optical switches, and semiconductor quantum information devices. We have already reported the coherent carrier dynamics of quantum well and quantum wire [3].

In the coherent control experiment, it is very important to stabilize a relative phase of double pulses correctly. In this paper, we developed a high-resolution Michelson interferometer with He-Ne laser positioning system, and measured the coherent carrier dynamics of a single InAs self-assembled quantum dot (SAQD) using a micro-spectroscopy system.

2. The high-resolution Michelson interferometer and Micro-spectroscopy System

Figure 1 shows the high-resolution Michelsin interferometer with He-Ne laser positioning system, where a mode-locked Ti:sapphire laser with a pulse duration of 2.7ps was used for the input pulse. Output pulse pair with a certain delay between them were generated by a high-resolution Michelson interferometer, where the pulse

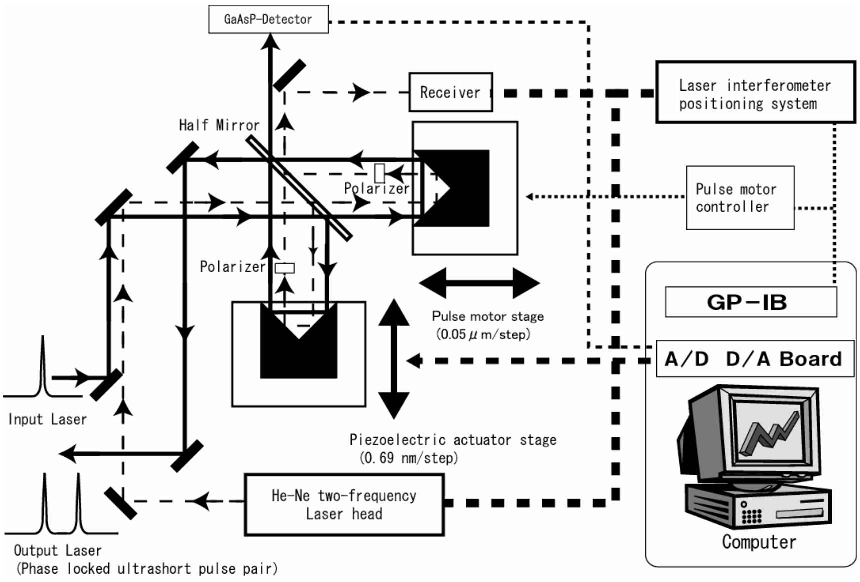

Fig.1 The high resolution Michelson interferometer with He-Ne laser positioning system.
A solid line shows the path from the modelocked laser. A dotted line shows the path from He-Ne two-frequency laser. To stabilize the relative phase of the pulse pair, we monitored the laser interferometer positioning system with He-Ne two-frequency laser, and the piezoelectric actuator stage was controlled by computer in real time.

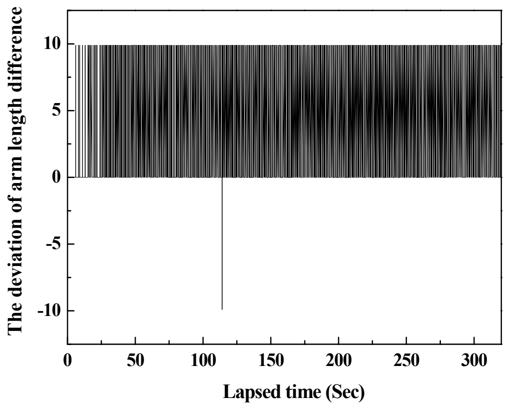

Fig. 2 The deviation of arm length difference in Michelson interferometer.

motor stage (0.05μm/step) and a piezoelectric actuator stage (0.69 nm/step) were used.

To stabilize the relative phase of the pulse pair, we monitored the laser interferometer positioning system with He-Ne two-frequency laser, and the piezoelectric actuator stage was controlled by computer in real time. Figure 2 shows the deviation of arm length difference in Michelson interferometer. Stabilization of phase locked double pulse was realized for a long time. The maximum deviation was 10nm which is limited by the resolution of this He-Ne laser positioning system.

The output pulse pair passed through the spatial filter were reflected at a half mirror and collimated by an object lens onto a sample. The beam diameter was 1.7μm on the sample.

The photoluminescence (PL) from the sample passed through the half mirror and was detected by a monochromator and a liquid nitrogen cooled CCD camera.

3. Experimental Result

Figure 3 shows the micro photoluminescence excitation (PLE) spectra of a single InAs SAQD which grown by MBE. The detected PL photon energy of a Q-dot is E_{DET}=1.337eV. The PLE peak attributed to 1LO phonon was located at the relative energy of E_{EX}-E_{DET}=34meV. In the coherent control experiment, the mode-locked laser energy was turned to the 1LO phonon energy level.

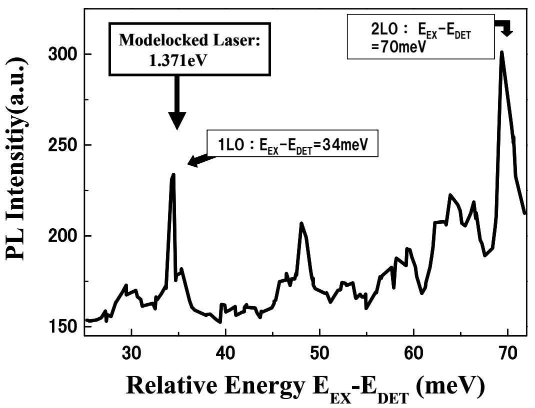

Fig.3 Micro photoluminescence excitation (PLE) spectra of a single InAs SAQD. The detected PL photon energy of a Q-dot is E_{DET}=1.337eV.

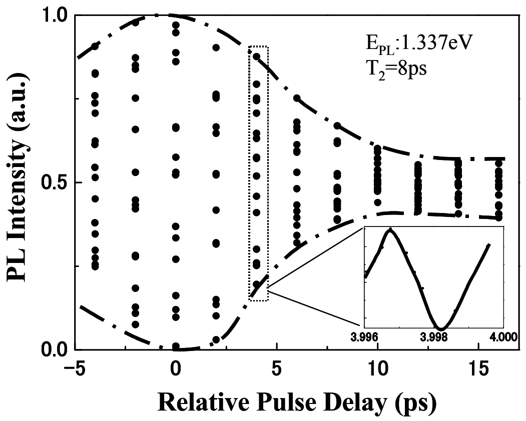

Fig.4 Oscillation amplitude of the time integrated PL as a function of relative time delay. The inset shows an expanded view around 4ps.

Coherent control of an InAs SAQD was demonstrated by the micro-spectroscopy system with the high-resolution Michelson interferometer. Figure 4 shows the amplitude of oscillation in integrated PL as a function of relative time delay. The exponential fit yields the decay time of resonance to be about T_2=8ps, which is close to that estimated from the homogeneous linewidth in the PLE spectrum.

4. Conclusions

We developed a high-resolution Michelson interferometer with the He-Ne laser positioning system, and measured the coherent carrier dynamics of a single InAs SAQD using the micro-spectroscopy system.

Stabilization of phase locked double pulse was realized with the maximum deviation below 10nm.

The amplitude of oscillation in integrated PL as a function of relative pulse delay was observed. The exponential fit yields the decay time of resonance to be about 8ps, which is close to that estimated from the homogeneous linewidth in the PLE spectrum.

References

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