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Excitation Wavelength Dependence of Terahertz Electromagnetic Wave Generation from Quantum Wire

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1. Introduction

Terahertz (THz) electromagnetic wave technology have been studied towards the application to imaging, and spectroscopy. THz electromagnetic wave generation by ultrashort pulse excitation of semiconductor can be applied to not only for new THz emitter but also to the measurement of ultrafast carrier dynamics in semiconductor. As a matter of fact, quantum beats and Bloch oscillations of semiconductor coupled quantum wells and superlattices have been studied using THz spectroscopy[1],[2]. Therefore, it is important to apply THz spectroscopy for the study of ultrafast carrier dynamics in quantum wire structure.

In this paper, we have investigated excitation wavelength dependence of THz electromagnetic wave generation from a semiconductor quantum wire.

2. Sample Structure

The GaAs/AlGaAs quantum wire sample used in our experiment was fabricated on a V-groove GaAs substrate by metalorganic chemical vapor deposition (MOCVD) growth with flow rate modulation epitaxy (FME) technique[3],[4]. Fifteen periods of very small crescent-shaped quantum wires with a central thickness of 11nm and a lateral full width of 46nm were formed at the bottom of the V-groove. Fig. 1 shows Photoluminescence (PL) and Photoluminescence excitation (PLE) spectra. In the PLE experiment, the polarization of the excitation laser was set in a parallel (PLE//) and a perpendicular (PLE⊥) to the quantum wire. Sharp 1e-1hh exciton peaks (at 799nm) with linewidth of 5-6meV was observed by PL measurement. While 1e-1hh and 2e-2hh exciton states were observed at 1.5525 and 1.5559 eV in PLE//, and 1e-1lh 1e-2lh exciton states were observed at 1.5593 and 1.5624 eV in PLE⊥.

3. Experimental Results

The THz electromagnetic wave generated from the quantum wire sample was measured by the free-space electrooptic (EO) sampling method[4],[5]. The experimental setup is schematically shown in Fig. 2. The quantum wire sample was held in a cryostat at a temperature of 14 K, and THz electromagnetic wave pulse was generated by ultrashort optical pulse excitation. The ultrashort optical pulse from a mode-locked Ti:sapphire laser with a pulse duration of about 140 fs was used for optical excitation. The THz electromagnetic wave generated from the quantum wire was collected with a pair of off-axis parabolic mirrors, and was incident on an EO crystal (ZnTe) with a delayed probe beam. The probe beam passed through the EO crystal was analyzed by a Wollaston polarizer, and detected by a balanced photodetector.

Fig. 3 shows the time-resolved THz waveforms. A THz electromagnetic wave resulted from the instantaneous polarization was observed. The magnitude of this THz electromagnetic wave was measured with variation of excitation laser wavelength. An excitation wavelength dependence of THz electromagnetic wave generation from the quantum wire sample is shown in Fig. 4. This represent that the THz electromagnetic wave generation is resulted from the instantaneous polarization in quantum wires, because the magnitude of the THz electromagnetic wave decrease at higher energy than fundamental absorption edge of the bulk GaAs. A peak of magnitude of the THz electromagnetic wave slightly shift from 1e-1hh excitation peak observed by PLE measurement. We consider that this shift is caused by the rise in temperature of the sample due to high power excitation.

4. Conclusion

We have studied excitation wavelength dependence of a THz electromagnetic wave generation from a quantum wire. THz electromagnetic wave was generated by a ultrashort optical pulse excitation, and was detected by free-space EO sampling method with the ZnTe as the EO crystal. Consequently, magnitude of THz electromagnetic wave generation exhibits excitation wavelength dependence. This represent that THz electromagnetic wave generation is resulted from the instantaneous polarization in the quantum wires.

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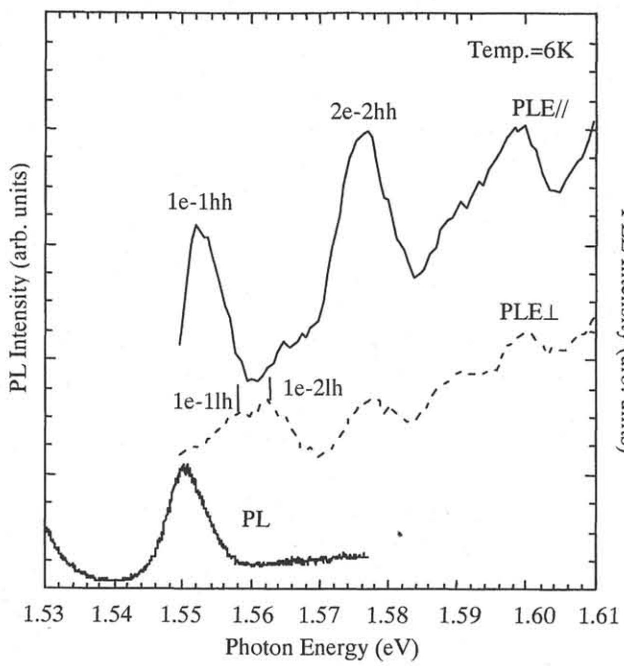

Fig. 1 PL and PLE spectra of the quantum wire sample with the polarization of excitation laser parallel (PLE//) and perpendicular (PLE⊥) to the quantum wire.

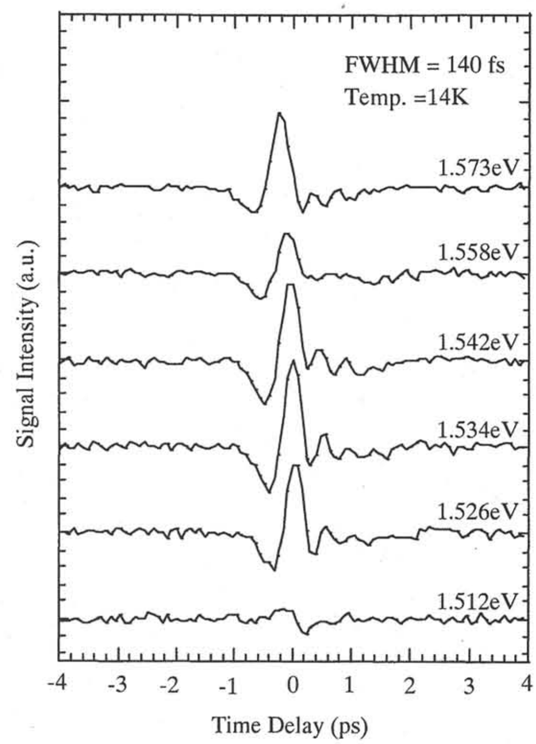

Fig. 3 Observed THz electromagnetic wave from the quantum wire sample

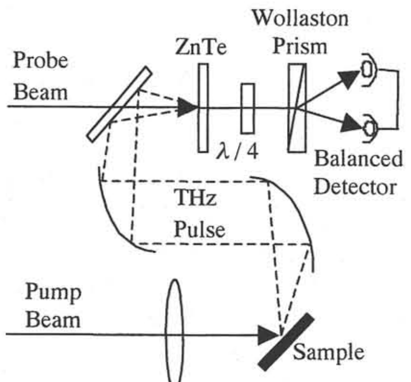

Fig. 2 Schematic diagram of experimental setup with free-space EO sampling system

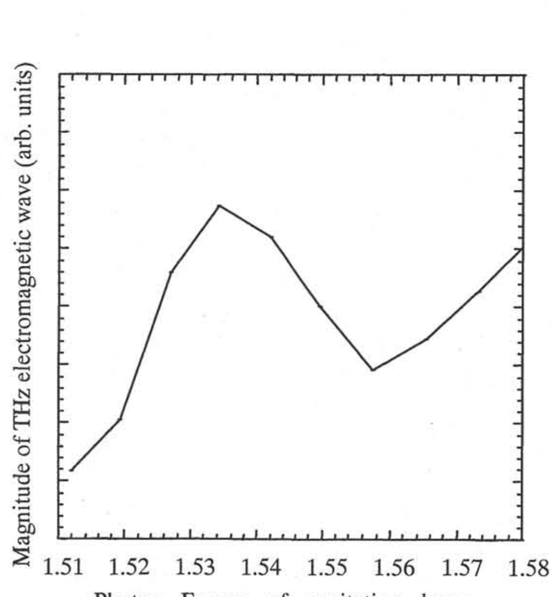

Fig. 4 Excitation laser wavelength dependence of the magnitude of THz electromagnetic wave generation