Optical Generation and Detection of High Frequency Coherent Acoustic Phonons in $In_{0.1}Ga_{0.9}As/GaAs$ Quantum Wells

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The absorption of ultrashort light pulses of sub-picosecond temporal width in a medium may generate GHz-THz coherent acoustic phonon pulses therein, and the propagation of the generated phonon pulses may be monitored using the delayed light pulses through the transient optical reflectivity change caused, for example, by the photoelastic effect. The technique is called picosecond laser ultrasonics [1], and has been applied to investigate micro- and nano-scale material properties as well as the structure and defect in the same spatial scale. It has also been applied to semiconductor quantum wells to investigate the phonon generation mechanisms as well as to explore the possibility of generating broad band acoustic phonon pulses up to or beyond 1 THz [2–4]. In Ref. [3], the $Al_{0.3}Ga_{0.7}As/GaAs$ quantum wells have been studied using the picosecond laser ultrasonics. The obtained result has been analyzed using the model of coherent phonon generation based on the deformation potential and the quantitative light scattering theory. Although the experimental results agree well with the theory, it is important to point out that the use of mixed crystal $Al_{0.3}Ga_{0.7}As$ as the barrier layer may cause ultrasonic absorption due to the randomness of the atomic structure and is not very appropriate for the high frequency phonon application.

In this paper, we investigate the coherent phonon pulse generation and detection in $In_{0.1}Ga_{0.9}As/GaAs$ quantum wells with picosecond laser ultrasonics using an interferometer. On top of a (100) GaAs substrate, 1 μm GaAs buffer layer, 14.9 nm $In_{0.1}Ga_{0.9}As$ quantum well layer, 100 nm GaAs barrier layer, 5 nm $In_{0.1}Ga_{0.9}As$ quantum well layer, and 39.5 nm GaAs layer (the topmost layer) were grown using molecular beam epitaxy. A pair of synchronized mode-locked Ti-sapphire lasers generating light pulses with a temporal width < 100 fs with a repetition frequency of 80 MHz is used as the light sources. One output is used for the probe light at a fixed wavelength of 415 nm which is obtained by the frequency doubling. The other output is used for the pump light with the variable wavelength from 780 nm to 970 nm. An interferometer setup [3] is used to monitor both the real and imaginary parts of the complex reflectance change as a function of the delay time between the pump and probe light pulse arrival to the sample surface. Figure 1 shows a typical result of the real (ρ) and imaginary ($\delta\phi$) part of the reflectance change obtained with the pump light wavelength of 830 nm. The wiggling patterns are observed around the delay time from 20 to 50 ps. These are caused by the arrival of the coherent acoustic phonon pulse generated at the quantum well of thickness of 14.5 nm to the sample surface. The pump wavelength dependence of the signal will be discussed. This work would form a foundation for the application of quantum well structures for the high frequency coherent acoustic phonon generation.

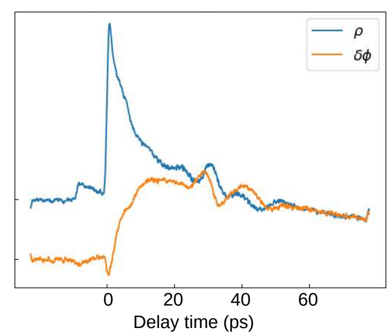

Fig. 1. Real (ρ) and imaginary ($\delta\phi$) parts of the transient complex reflectance change. The wavelength of the pump light is 830 nm.

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