re-normalization. The almost unchanged peak Λ can be attributed to the mutual cancellation between the blue shift, which is due to the filling-up of the low band-gap regions and the shielding of piezoelectric field with increasing carrier density, and the red-shift, which is due to band-gap re-normalization.

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CWB3

8:30 am

Coherent control of acoustic phonon oscillations in InGaN/GaN multiple-quantum-wells

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Progress in femtosecond lasers and ultrafast spectroscopy technology has enabled us to generate and directly observe the coherent oscillations of phonon modes.¹⁻⁴ Oscillation changes in optical properties have been observed in GaAs,^{1,2} Ge,³ and a number of other materials.^{2,4} In semiconductors, carriers can be excited by ultrashort pump pulses in a spatial area much larger than one lattice unit cell and the excited carrier populations are coupled to the corresponding optical phonon modes with wave vector $q \approx 0$. This optically excited coherent optical phonon mode can behave like a classical oscillator and has non-zero time-dependent displacement. This is different from spontaneous emission of phonons which is an incoherent process that populates the phonon modes with the expectation value of each mode being zero. For acoustic phonons, semiconductor superlattices exhibit zone-folding of the acoustic branches within the mini-Brillouin zone due to the artificial coherent oscillations of the zone-folded acoustic phonons in AlAs/GaAs superlattices.^{5,6} However the observed reflection modulation was extremely small, on the order of 10^{-5} to 10^{-6} .

Recently we have reported our studies of the coherent acoustic phonon oscillation in InGaN/GaN multiple-quantum-wells (MQWs) with strain-induced piezoelectric field.⁷ Large coherent acoustic phonon oscillation can be easily generated with induced transmission/absorption modulation on the order of 10^{-2} to 10^{-3} . The oscillation frequency, on the order of THz, can be linearly varied by tuning the sample period width. With ultraviolet (UV) femtosecond pulse excitation, photogenerated carriers screened the piezoelectric field and initiated the dispersive oscillations of the co-

CWB3 Fig. 1. Measured transient transmission changes vs. probe delay for 62/43 Å InGaN/GaN MQWs.

CWB3 Fig. 2. Differential transmission changes vs. probe delay with both the initiation pulse and the control pulse.

herent longitudinal-acoustic phonon. The specific coherent phonon frequency was selected by the coupling between the periodic carrier distribution and the corresponding acoustic phonon mode. The induced acoustic phonon oscillation resulted in modulation of piezoelectric field and the then caused absorption variation through the quantum-confined Franz-Keldysh effect. The uncertainty of carrier distribution wavevectors due to the finite sample width was found to determine the observed dephasing time of the coherent oscillation.

In this presentation, we demonstrate the coherent control of the initiated coherent acoustic phonon oscillation using a separate control UV pulse. The experiments were performed at room temperature on 14 periods InGaN/GaN MQWs. The barrier-widths of all samples were 43 Å while the well-widths were varied from 12 to 62 Å. The experiments were performed using the frequency-doubled output from a Kerr-lens-modelocked Ti:sapphire laser. Figure 1 shows an example of the measured probe transmission change as a function of probe delay for the 62 Å well-width sample by using a standard pump-probe geometry without the second control pulse. The pump/probe wavelength was at 395 nm. After the pump excited carriers and caused transient transmission increase at zero time delay, a clear cosine-like oscillation could be observed due to the induced coherent acoustic phonon oscillation in InGaN/GaN MQWs. The differentiated transmission signal was also shown in Figure 2 as trace (a). After the initiation of the coherent phonon oscillation, we use a second femtosecond UV pulse to control the oscillation phase and amplitude. Trace (b) in Figure 2 shows an example of the oscillation amplitude suppression by using a second control pulse

with twice the optical fluence compared with the first initiation pulse exciting at a delay time when the acoustic phonons were at 180 degree of the induced cosine oscillation. Figure 2 also shows the examples of the oscillation phase control by the control pulses. For traces (c), (d), (e) of Figure 2, phase shifts of -20 , $+35$, and $+135$ degrees were demonstrated by exciting with the control pulses at delay time corresponding to -90 , $+90$, and 180 degrees of the first induced cosine oscillations. To theoretically model the control of the coherent phonons, we use an oscillator model with both dispersive and impulsive forcing terms and include the effects of damping and dephasing. We solve the model exactly for two pump pulses to obtain qualitative agreement with the experimental results. To obtain more quantitative agreement with the experiments, one must put in more detailed effects including (1) a background signal due to carrier phase space filling, (2) saturation nonlinearities associated with the screening of the piezoelectric field by the photoexcited carriers and saturation of the optical transitions.

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CWB4

8:45 am

Photogenerated carrier dynamics in GaN

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A clear understanding of recombination mechanisms is crucial to optimize GaN based III-V semiconductors for optoelectronic devices, especially for consumer applications requiring room temperature operation. For the study of carrier dynamics in optical processes, time resolved photoluminescence (TRPL) represents a powerful tool combining temporal and spectral resolution capabilities. We studied GaN grown by Hydride Vapor Phase Epitaxy (HVPE) by TRPL measurements at a variety of optical excitation power levels. We observed a significant increase in the carrier lifetime with increasing excitation power. This is attributed to the saturation of the defect centers associated with the yellow luminescence in GaN.

The sample studied was grown by HVPE¹ on a patterned sapphire substrate using the