InGaN LED 구조에서 결맞는 bulk phonon과 folded acoustic phonon의 생성

Generation of coherent bulk and folded acoustic phonon oscillations in InGaN light-emitting diodes structure

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Recently, there has been much interests in InGaN/GaN multiple-quantum-well (MQW) structures due to their applicability as optoelectronic devices such as light-emitting diodes (LEDs) and laser diodes [1]. Their ultrafast and physical properties are also of significant interests. Anomalously large acoustic phonon oscillations have been observed using ultrafast lasers in InGaN MQWs [2].

In this study, we have performed femtosecond pump-probe experiments in the reflection geometry on 5 periods InGaN/GaN MQW LED structure with well width of 20 Å and barrier width of 100 Å at room temperature.

Figure 1 shows the pump-probe signal as a function of probe delay for various pump wavelengths. Two types of oscillations exist: (a) short period oscillations which quickly disappear with time (Fig. 1a), and (b) long period oscillations with very long lifetime (Fig. 1b). It is very interesting to note that, for the short period oscillation, the period is independent of the pump wavelength. In contrast, the long period oscillations show a significant change in period: the longer the wavelength, the longer the oscillation period.

The short period oscillation has already been observed by Sun *et al.* [2], attributed to the folded acoustic phonon oscillation enhanced by strong piezoelectric field in this class of materials. The observed oscillation period of about 1.4 ps at pump wavelength of 398 nm roughly agrees with what is expected from the phonon velocity in InGaN.

On the other hand, the long period oscillation, which is even stronger in amplitude than the short period oscillation, has never been observed before. We note that the period of long oscillations is proportional to the pump beam wavelength (Fig. 2), which is consistent with the equation: $\tau = \lambda/2\upsilon n$, where λ is the pump beam wavelength, υ the sound velocity for GaN, and n the refractive index [3]. We, therefore, attribute this strong, long period oscillation to the coherent phonons generated by the impulsive Brillouin backscattering at the p-n GaN epilayers sandwitching intrinsic MQW layers.

In conclusion, we have observed folded acoustic phonon and bulk acoustic phonon simultaneously in InGaN/GaN MQW LED structure. The folded phonon oscillation is independent of pump beam wavelength but the bulk phonon period is proportional to the laser wavelength, indicating that impulsive Brillouin scattering is responsible for this long period oscillations.

Reference

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[2] Chi-Kuang Sun, Jian-Chin Liang, and Xiang-Yang Yu, Phys. Rev. Lett. **84**, 179 (2000).

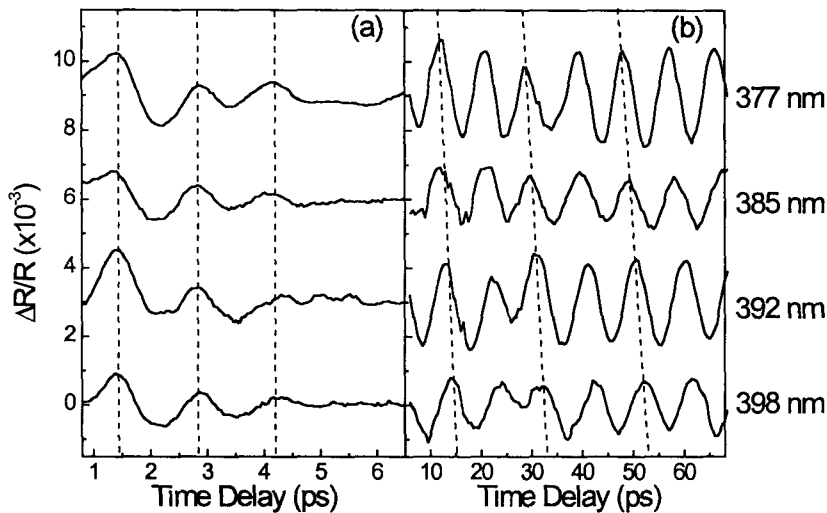[3] C. Thomsen, H. T. Grahn, H. J. Maris, and J. Tauc, Phys. Rev. B **34**, 4129 (1986).

Fig. 1 Measured reflection changes as a function of probe time delay for InGaN/GaN MQW LED structure for various pump wavelengths. Acoustic folded phonon oscillations are observed in short time delay (a) and bulk phonon oscillations are observed in long time delay (b). Dashed lines are guide to the eye.
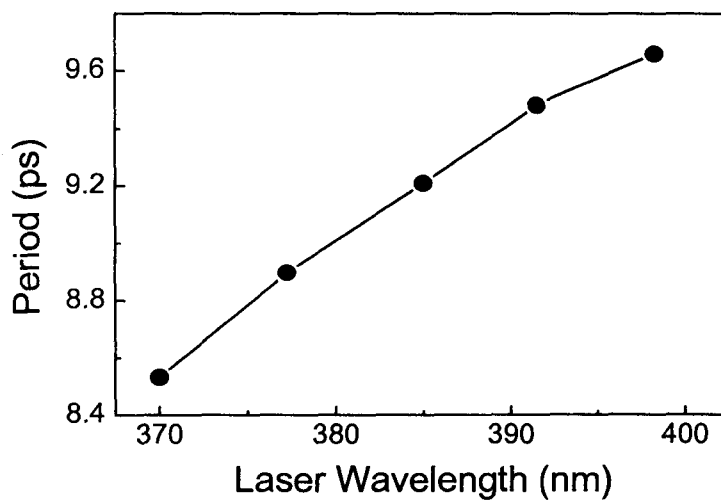
Fig. 2. Bulk phonon oscillation periods as a function of laser wavelength.