CTuU2 **4:45 pm**

Structural asymmetry effects in the optical gain of indium gallium nitride quantum wells

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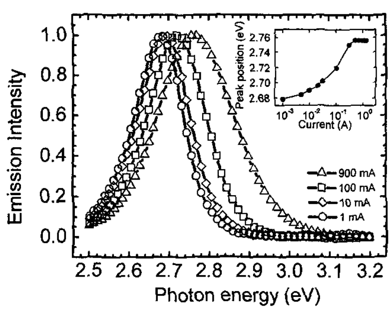
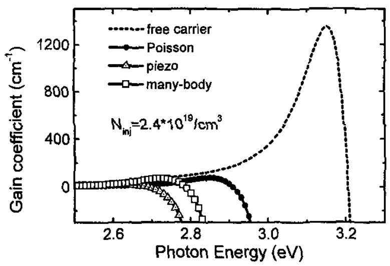
Recent progress in the epitaxial growth and device process on wide bandgap III-V nitrides have made possible the indium gallium nitride (InGaN) quantum well (QW) emitters spanning the spectral range from amber to violet.[1] From the device application point of view, it is desirable to have an active region designed such that a larger QW optical gain and wider wavelength tunability can be achieved with a medium carrier injection. In this work, we present a use of pulsed current excitation technique to study the structural asymmetry effects in the optical properties of strained InGaN QWs. Our study indicates a gain competition process between the piezoelectric and many-body effects are responsible for the spectral blue shift as the carrier injection increases. When operated over the transparency regime, it is found the structural asymmetry in a 3.0 nm GaN/InGaN/AlGaN QW results in a 35% enhancement of the TE-polarized optical gain compared with the symmetric InGaN/AlGaN QW case.

Samples used in this study were grown by MOCVD on (0001) sapphire substrates;[2] the active region of the QW emitter consisted of an undoped 3.0 nm strained $In_{0.2}Ga_{0.8}N$ epilayer sandwiched between a n-type Si:GaN and a p-type $Mg:Al_{0.2}Ga_{0.8}N$ layer of a thickness of 2 μm and 100 nm, respectively. The experiments with pulsed current injection were conducted at a 1 μs width with a repetition rate of 10 Hz. In Fig. 1 we illustrate the normalized electro-luminescence (EL) spectra of the InGaN QW at various injection currents. A spectral blue shift as large as 80 meV is clearly resolved as the injection currents increase from 1 mA to 1 A.

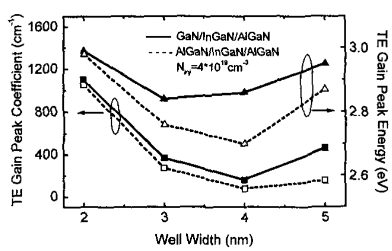
Since the effects of bandgap renormalization scale with a reduced dimension, the spectral blue shift in the strained InGaN QW represents an interesting phenomenon to be resolved. In Fig. 2 we present a calculated optical gain spectra of the asymmetric 3.0 nm



CTuU2 Fig. 1. Normalized EL spectra of a 3.0 nm asymmetric $GaN/In_{0.2}Ga_{0.8}N/Al_{0.2}Ga_{0.8}N$ QW at various injection currents.



CTuU2 Fig. 2. Calculated optical gain spectra of the asymmetric 3.0 nm InGaN QW.



CTuU2 Fig. 3. Structural asymmetry effects in the TE-polarized optical gain spectra of InGaN QW.

InGaN QW at $N_{inj} = 2.4 \times 10^{19}$ cm^{-3} which corresponds to a current injection of 900 mA in Fig. 1. By gradually incorporating the effects of piezoelectric, carrier induced screening (Poisson), and many-body bandgap renormalization in the analysis, we are able to quantify the contribution of each perturbation to the optical gain of InGaN QW. In particular, it is noted the resultant QW gain spectrum reveals a competition between the piezoelectric induced spectral red shift, many-body and charge screening effects induced blue shift. On the other hand, it is found a simple free-carrier model calculation not only can exaggerate the QW optical gain but also erroneously shift the peak gain to a shorter wavelength.

In Fig. 3 we compare the well width dependence of the TE-polarized optical gain in the asymmetric and symmetric InGaN QWs at $N_{inj} = 4 \times 10^{19}$ cm^{-3}. By engineering the piezo-electric and quantum confinement effects, a two-order of magnitude increase in the InGaN QW optical gain can be achieved as the well width decreases. The increase of optical gain at relatively large well width (>4 nm) is due to the band-filling effects. Moreover, by introducing a structural asymmetry in the QW active region, more than 35% enhancement in the TE-polarized optical gain can be achieved in asymmetric GaN/InGaN/AlGaN QW compared with the symmetric InGaN/AlGaN QW case.

In summary, it is shown by suitable engineering of the piezoelectric effect and designing of the structural asymmetry in the InGaN gain region, one can achieve a wider range of wavelength tunability and more than 35% enhancement in the QW optical gain compared with the symmetric QW case.

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CTuU3 **5:00 pm**

Determination of electron-hole transport in InGaN QW heterostructures by near-field optical microscopy

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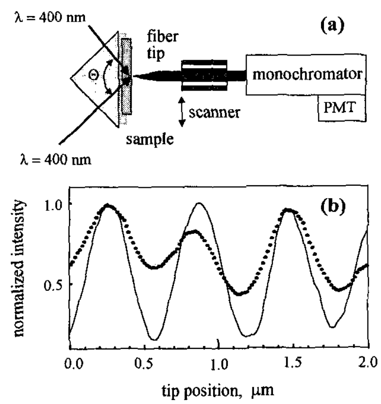
All-optical methods can be very useful for transport measurements of excess carriers in semiconductor structures. Application of these methods becomes problematic, however, when diffusion lengths become shorter than the light wavelength. To overcome this limit, we have adapted near-field optical methods to investigate electron-hole diffusion and recombination InGaN and GaN QW light emitting heterostructures. One particular motivation was on establishing a correlation between the complex crystalline microstructure of the non-random InGaN alloy and the optimal QW design/growth parameters for laser devices.

The idea of the experiment is sketched in Fig. 1(a). Two excitation laser beams interfere and are absorbed resonantly in a nitride heterostructure to create a sinusoidally varying electron-hole population grating whose concentration gradient provides the driving force for diffusive (and related dynamical) processes. The spatial photoluminescence (PL) profiles created e-h pair recombination are spatially and spectrally imaged with a near-field optical probe and provide direct input to the evaluation of diffusion lengths on a submicron scale. We were able to produce a popula-



CTuU3 Fig. 1. (a) Experimental schematic discussed in text. (b) Excitation grating at λ = 400 nm (solid line) and corresponding PL profile at λ_{PL} = 440 nm (dots) for a InGaN epilayer sample.