Intersubband Electroluminescence from GaN/Al₀.₆₅Ga₀.₃₅N

Quantum Cascade Emitters

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For the past couple of decades, Quantum Cascade (QC) devices have garnered increased interest due to their broadband capabilities, high power operation and operating speed. These qualities have allowed them to become widely successful at applications such as trace gas sensing and medical diagnostics. However, the physical limitations in conventional material systems, mainly the limited conduction band offsets (CBOs) (≤ 0.7 eV) and small longitudinal optical (LO) phonon energy (~34 meV), restrict the wavelength range and temperature performance of the devices. In contrast to the conventional designs such as in the GaAs/InGaAs system, GaN/AlGaN offers a better broadband performance due to its large CBOs (~2 eV) and large LO phonon energy (~90 meV), enabling the device to achieve emission wavelengths that are not possible with GaAs/InGaAs designs, notably on short wavelengths below 4 µm and long wavelengths beyond 20 µm. Additionally, GaN/Al₆Ga₄N devices offer a great potential for operations in a wide temperature range (~230°C to 500°C) [1]. Recently, intersubband (ISB) emission in the short wavelength range (926 cm⁻¹ to 1450 cm⁻¹) from GaN/AlGaN multi-quantum well structures at 80 K have been observed [2]. It is therefore of interest to demonstrate ISB emission in GaN/Al₆Ga₄N QC devices.

The design, shown in Fig. 1 (A), comprises 50 periods of alternating Al₆Ga₄N and GaN layers in thicknesses of 4.4 / 6.6 / 4.4 / 6.6 / 4.4 / 6.6 / 4.6 / 6.8 / 4.4 / 6.8 / 4.8 / 10.2 / 3.8 / 6.8 / 4.0 / 6.6 / 4.2 / 6.6 monolayers (ML) of the respective material, with ≤ 0.6 ML uncertainty, and Si doping of 1.8 x 10¹⁸ cm⁻³ is introduced into the underlined wells. A diagonal ISB transition in the active region is indicated with the red arrow in Fig. 1 (A), peaking at 4.9 µm [3]. Transverse-magnetic (TM) and Transverse-electric (TE) polarized spectra of the device are shown in Fig. 1 (B). Both the TM and TE spectra, taken at 80 K in pulsed mode, have a clearly distinguishable peak centered at 1000 cm⁻¹, indicating the unpolarized blackbody radiation. Due to the internal polarization bias in the Fourier transform infrared spectrometer, an apparent but spurious TM over TE ratio of 2:8:1 is observed in the blackbody radiation. As a result, the two spectra are normalized with respect to the blackbody radiation for a strict comparison of the signals. As shown in Fig. 1 (B), a separate emission peak at around 2000 cm⁻¹ is observed only in the TM-polarized spectrum and is absent in the TE-polarized spectrum. This contrast confirms the ISB nature of the emission signal. Furthermore, the emission wavelength centered at 5 µm matches closely to our predicted value of 4.9 µm from the design.

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