Optically-pumped UV Lasing from a GaN-based VCSEL

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Motivation—Compact ultraviolet sources are required for advanced chemical and biological sensors, high density optical storage, and as pump sources for phosphors used in solid-state white lighting. Although GaN-based edge-emitting lasers operating near 400 nm are available commercially, shorter wavelengths as well as other lasing geometries have remained a challenge. In particular, electrically-injected vertical-cavity surface-emitting lasers (VCSELs) have not been demonstrated in the III-Nitrides. VCSELs have unique advantages due to their low cost, compact size, and well-defined circular output beam. Optoelectronic sources based on UV VCSELS will be the enabling component for many advanced sensor, display, and general illumination technologies.

Accomplishment—We have demonstrated a technique for producing epitaxial distributed Bragg reflectors (DBRs) with reflectivities greater than R = 99%. This resulted in the demonstration of a room temperature, quasi-continuous wave optically-pumped VCSEL operating at 383 nm. The optical resonator consisted of a lower epitaxial GaN/$Al_{0.20}Ga_{0.80}N$ DBR and an upper dielectric DBR. Using a standard nucleation layer, 1 µm of GaN was grown by metalorganic chemical vapor deposition on a sapphire substrate followed by a 135 Å thick AlN strain compensating layer. Due to the low index contrast between GaN and $Al_{0.20}Ga_{0.80}N$, a very thick DBR (~ 5 µm) of 60 alternating quarter-wave layers is required to achieve a reflectivity of R > 99%. AlN strain compensating layers were inserted every 20 layer pairs in order to avoid the stress-induced cracking which is normally observed when thick AlGaN is grown on GaN. The effective use of strain compensating layers was the key to achieving the crack-free, high reflectivity epitaxial DBRs.

An active region containing 20 $In_{0.03}Ga_{0.97}N$/GaN multiple quantum wells was grown to provide gain near 380 nm. A top dielectric DBR composed of SiO_2/HfO_2 was deposited to complete the optical cavity. The VCSEL structure was optically pumped using the third harmonic of high repetition rate (76 MHz) 100 ps YAG laser. Figure 1 shows the output power of the laser as a function of input pump power with a clear threshold observed near 30 mW of pump power. The inset shows the far field emission pattern of the UV light projected on a fluorescent screen. Figure 2 shows the emission spectrum of the laser above and below threshold. Note the narrow linewidth (< 0.1 nm) above threshold. The threshold behavior and linewidth narrowing are clear evidence of optically-pumped lasing.

Significance—The GaN/$Al_{0.20}Ga_{0.80}N$ DBR technology demonstrated here can be used in a variety of optoelectronic devices. For example, epitaxial DBRs used in resonant-cavity light emitting diodes (RC-LEDs) are known to improve the light extraction and hence device efficiency. For VCSELs, epitaxially grown DBRs provide a controllable, low cost means of producing high finesse optical cavities. Optically pumped lasing is one important step towards the realization of an electrically-injected UV VCSEL. Electrically-injected UV VCSELs will find applications in a wide array of chemical and biological sensors as well as in display and general illumination technologies.

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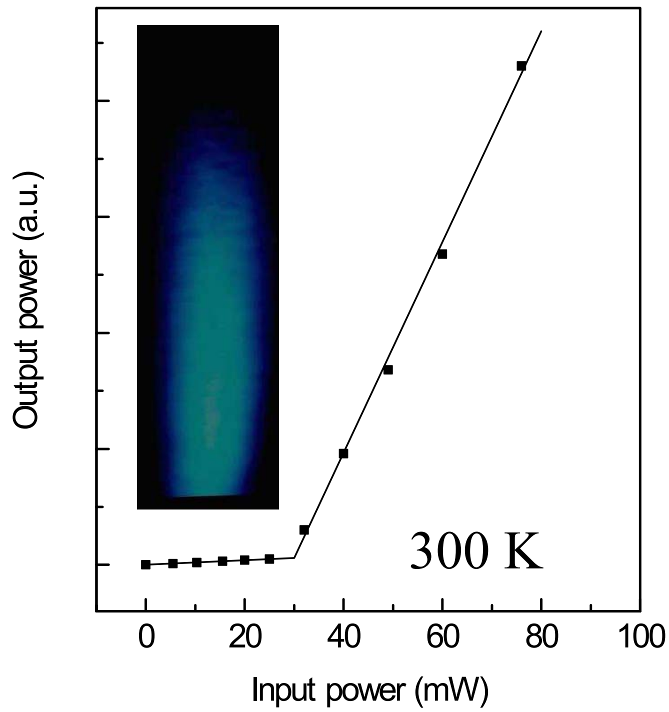

Figure 1. Average input power versus output power of a VCSEL device at room temperature. The inset shows the far field pattern of the VCSEL projected onto a fluorescent screen.

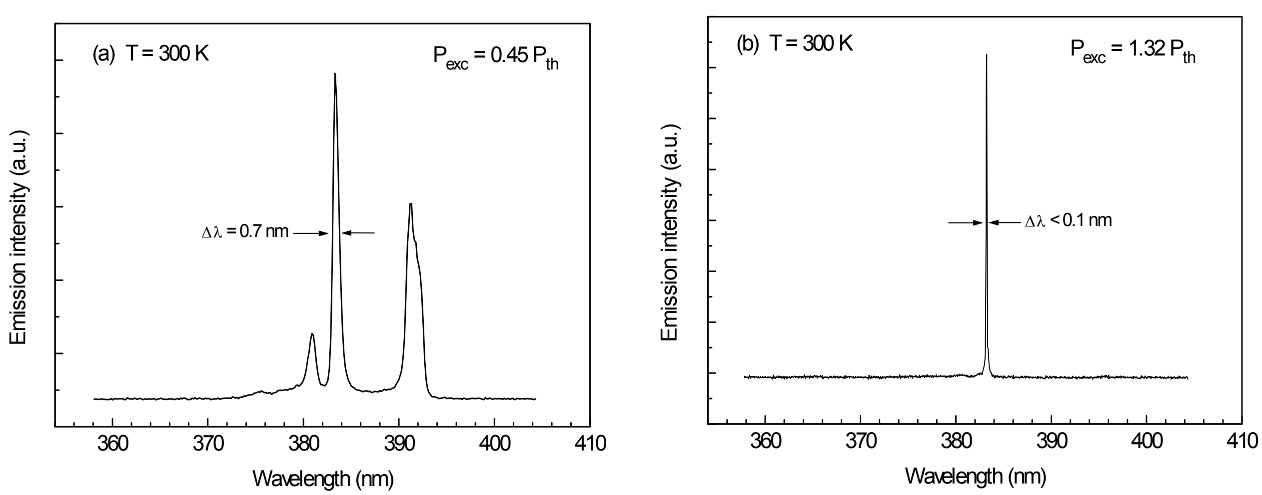

Figure 2. (a) Room temperature VCSEL emission spectrum below threshold. (b) VCSEL lasing sprectrum above threshold. Note the linewidth narrowing observed above threshold.