High Power GaN-based Blue Superluminescent Diode Exceeding 450 mW

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Abstract:

We demonstrate a high-power blue emitting superluminescent diode (SLD) with a tilted-facet configuration. An optical power of 457 mW with a broad spectral bandwidth of 6.5 nm was obtained under pulsed current injection of 1 A, leading to a large power-bandwidth product of ~ 2970 mW·nm.

Keywords: superluminescent diode (SLD), amplified spontaneous emission (ASE), gallium nitride, laser diode.

1. INTRODUCTION:

Since their first demonstration, group III-nitride light emitters, including light-emitting diodes (LEDs) and laser diodes (LDs) [1, 2], have evoked a wider range of industrial applications such as solid state lighting, visible light communications, and high capacity data storage [3, 4]. The development of superluminescent diodes (SLDs) has recently attracted increasing research interests due to their unique features such as broadband emission, large modulation bandwidth, and being free of both efficiency-droop and speckle noise [5, 6]. The working principle of SLDs is based on electrically driven pn-junction that generates amplified spontaneous emission through a single-pass or dual-pass gain medium [7]. SLD combines the advantages of both LD and LED, making it a promising light source for various applications, including lighting, optical coherent tomography (OCT), and pico-projections [7]. Moreover, shorter wavelengths of nitride SLDs have higher impact on enhancing in-plane resolution which is crucial for OCT, sensors, and fiber optic gyroscopes applications [8]. In this work, we report a high-power blue emitting SLD using a tilted-facet configuration. The electrical and optical characteristics were measured and compared with these of other previously reported SLDs in violet-blue regime. Our SLD shows a large power-bandwidth product (PBP) of ~ 2970 mW·nm, which is calculated from the obtained optical power of 457 mW and spectral bandwidth of 6.5 nm at a current injection of 1 A. To the best of our knowledge, this is the first blue SLD with optical power exceeding 450 mW with wall-plug and slope efficiencies of 7.9% and 0.9 W/A, respectively.

2. EXPERIMENTS AND RESULTS

The fabricated SLD utilizes a 12° tilted-facet waveguide (Fig. 1a) to suppress feedback of light in the resonating cavity under high current injection. The 15- μ m-wide ridge waveguide SLD was etched to ~ 1000 μ m in length and the facet was polished by focused ion beam (FIB) milling processing (Fig. 1b). The SLD was tested in a customized tester with a Keithley 2520 diode laser testing system and a thermoelectric cooler (TEC) to stabilize the operating temperature at 22 °C. Light-current -voltage (L-I-V) characteristics were measured under a pulsed operation (duty cycle of 2%, 9.8 kHz) and plotted in Fig. 1c. A superlinear L-I characteristic was observed (above 500 mA), which indicates the superluminescent behavior of the device. An optical output power of 457 mW at 1 A of injected current was measured without showing significant thermal roll over in the L-I curve.

Fig. 1 SLD device and performance: (a) Schematic of SLD and angled-facet. (b) Scanning electron micrograph of etched facet on the polished ridge section. (c) L-I-V curve of the SLD. The device has a peak power of 457 mW at a 1 A injected current and the corresponding voltage is ~ 5.8 V.

To further study the optical performance of the SLD, we measured the electroluminescence (EL) spectra using an Ocean-Optics HR4000 spectrometer at different currents ranging from 100 mA to 1 A (Fig. 2a). A peak emission wavelength of ~ 445 nm was obtained from the SLD. Fig. 2b depicts the current-dependence of the full width at half maximum (FWHM) and peak wavelength of the SLD device. It reveals that the FWHM value decreases from ~ 18 nm at 100 mA while under spontaneous emission, to 6.5 nm at 1 A due to the higher amplification of spontaneous emission (ASE) near the optical gain maximum [9]. Due to band-filling effects, a blue-shift tendency in the current-dependent peak position is observed, which is later turned into a red-shift due to increased heating associated with high driving currents. We have compared the emission wavelength, device design, optical power, and spectral bandwidth of our device with those from other previously reported violet-blue-SLDs in Table 1. Our SLD shows a promising large PBP of 2970 mW·nm, which is the highest value, to the best of our knowledge, compared to other devices in violet-blue regime. A high-resolution EL spectrum was measured by guiding the emitted light into a single-mode optical fiber and characterized using Yokogawa AQ6373B optical spectrum analyzer (Fig. 2c). This spectrum illustrates a ripple period of ~ 26 pm at 800 mA, which further confirms the amplified spontaneous emission characteristics of the reported device.

Fig. 2 Characterization of SLD: (a) Electroluminescence spectra of the SLD at different current injection. (b) Plot of FWHM and peak position as a function of driving current. (c) High resolution EL spectrum of the SLD showing the oscillating ripples at 800 mA.

TABLE I. SUMMARY OF DEVICE DESIGN AND PERFORMANCE OF VIOLET-BLUE SLDs.

Wavelength (nm)	Substrate	Device Design	Optical power	Bandwidth (nm)	PBP (mW·nm)	Reference
420	c-GaN	Tilted waveguide, 2 μ m ridge	100 mW (pulse)	5	500	[10]
439	m-GaN	Facet roughening, 4 μ m ridge	5 mW (pulse)	9	45	[11]
443	c-GaN	Curved waveguide, 2 μ m ridge	100 mW (cw)	2.6	260	[12]
447	semipolar-GaN	Passive absorber, 7.5 μ m ridge	256 mW (cw)	6.3	1612.8	[4]
445	c-GaN	Tilted facet, 15 μ m ridge	457 mW (pulse)	6.5	2970	Our work

3. CONCLUSION

In conclusion, we have demonstrated a record high-power blue emitting SLD of 457 mW at an injection current of 1 A by utilizing a 12° tilted-facet design. A large FWHM of 6.5 nm was measured, resulting in a record high power-bandwidth product of above 2970 mW·nm with wall-plug and slope efficiencies of 7.9% and 0.9 W/A, respectively.

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