Self-seeded gain-switched operation of an InGaN MQW laser diode

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ABSTRACT

Self-seeded, gain-switched operation of an InGaN multi-quantum-well laser diode has been demonstrated for the first time. An external cavity comprising Littrow geometry was implemented for spectral control of pulsed operation. The feedback was optimized by adjusting the external cavity length and the driving frequency of the laser. The generated pulses had a peak power in excess of 400mW, a pulse duration of 60ps, a spectral linewidth of 0.14nm and maximum side band suppression ratio of 20dB. It was tunable within the range of 3.6nm centered at a wavelength of 403nm.

Keywords: gain switching, self seeding, InGaN, laser diode, external cavity

1. INTRODUCTION

Recent progress in gallium nitride technology has resulted in dramatic improvement of the quality of GaN-based laser diodes. Operation characteristics of these lasers are currently similar to or even better than those of GaAs-based laser diodes. Picosecond pulse generation from this type of lasers has been demonstrated some time ago, and soon proved to be of particular interest for applications in time-resolved fluorescence spectroscopy, biomedical analytics, metrology and other areas. Indeed, a range of picosecond pulse sources has been developed based on these lasers and is commercially available now. In some applications, the GaN-based lasers represent an attractive alternative to the traditional, frequency-doubled solid-state ultrafast laser sources, with the advantages of low cost, compact size, high efficiency, and good stability.

In practice, high power pulsed operation of InGaN laser diode has been reported in a gain-switched regime with a peak power in excess of 400mW[1]. However, pulse quality degradation became significant at high pumping levels. On the other hand, the spectrum was not controlled at all. In another study[2], mode locking of an anti-reflection (AR) coated InGaN laser with external cavity has been reported, producing 30ps-long pulses with a low duration-bandwidth product of 1.2. However, the laser output power was as low as 2mW, thus limiting the application range. As any other mode-locked laser, the system required precise adjustment of the cavity length, and its performance was very sensitive to environmental change.

Therefore, a robust technique for "pulsing" a GaN laser in order to provide good pulse quality both in time domain and in spectral domain would be a very attractive proposition.

Here, we present an alternative method, based on gain-switched operation of a commercial, unmodified InGaN laser, self-seeded in a non-resonant external cavity, thus implementing a technique previously demonstrated in the near infra-red (IR) spectral region[3-5].

2. EXPERIMENT

The laser used in the experiment was a NLHV3000E single mode device from Nichia Corporation. It produced a fundamental lateral mode across the whole range of operating current and was found to have a threshold current of 44.5mA, a CW output power of >30mW, and a resonance response frequency of 1.2GHz. The laser was driven by an amplified radio frequency (RF) signal imposed on a direct current (DC) bias. Temperature of the laser was maintained at a level of 25°C.

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Without the external cavity, the laser produced the shortest pulse duration of 49ps and the highest peak power of 460mW when driven by the maximum power of RF signal, approximately 1W. The driving frequency was 1.13 GHz, close to the laser resonance frequency of 1.2GHz. The DC bias was 80mA.

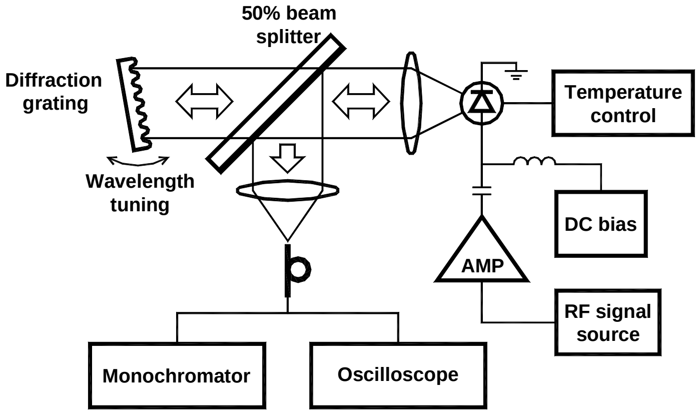

Fig. 1. Experimental set-up

The external cavity had Littrow geometry, as shown in Fig. 1. An aspheric lens with a numerical aperture of 0.5 was used to collimate the output laser beam, producing an elliptical beam with size of 9mm by 1mm, approximately. A diffraction grating with a blazing wavelength of 393nm and diffraction efficiency of 80% to the first order was placed at a distance of 240mm from the laser, so that the second harmonic of the external cavity round-trip frequency was close to the laser resonance frequency.

With the external cavity feedback, the output pulse duration broadened to 60ps, and the peak power reduced to 360mW, whilst the average power slightly increased from 45mW to 47mW (Fig. 2a). The pulse spectrum changed dramatically from a broad, 1.5nm wide band to a line as narrow as 0.14nm, with the sideband suppression in excess of 20dB (Fig. 2b).

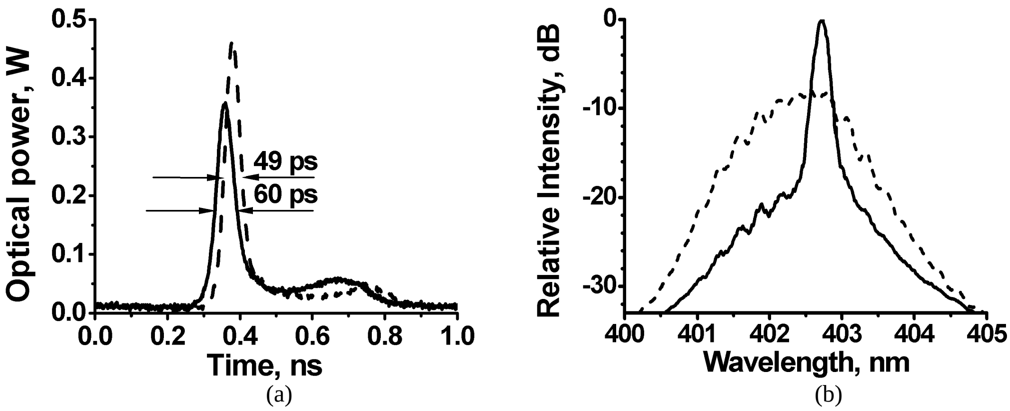

Fig. 2. (a) Oscilloscope traces of the laser output without (dashed line) and with (solid line) self-seeding. (b) Spectra of laser output without (dashed line) and with (solid line) self-seeding.

By adjusting the grating, it was possible to continuously tune the laser wavelength within a 3.6nm range, from 401.1nm to 404.7nm, as shown in Fig. 3. At the edges of the tuning range, a broad, low intensity side band appeared close to the peak of the gain curve of the laser.

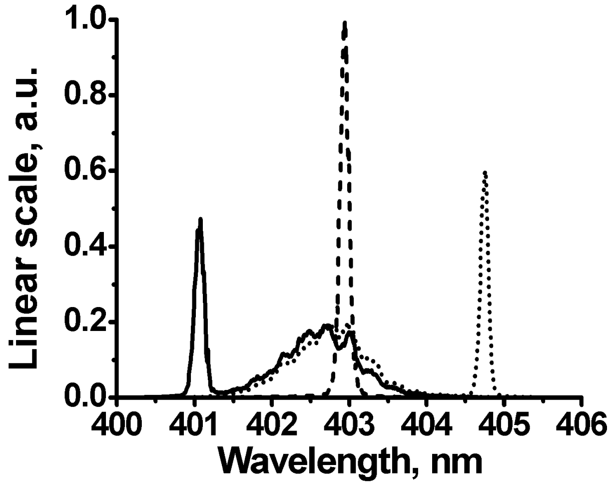

Fig. 3 Wavelength tuning of self-seeded gain-switched pulses

The system showed a stable performance even with the considerably detuned external cavity. We varied the external cavity length between 235mm and 250mm, corresponding to a maximum of 50ps time offset between the feedback signal and the main laser signal. This variation did not induce any noticeable changes in the temporal and spectral characteristics of the laser output, and the system showed stability similar to that reported for the near-IR systems[3-5].

3. CONCLUSION

Stable operation of a self-seeded, gain-switched commercial InGaN laser diode has been demonstrated. The output laser pulses were characterized by high peak power of 0.4W, narrow linewidth of 0.1nm, and good side band suppression ratio in excess of 20dB and wavelength tuneability over 3.6nm.

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