Single/multiple wavelength generation in green laser diode

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Abstract: Single and two-stage self-injection locking in InGaN/GaN laser diode is presented demonstrating multiple/single wavelength emission. Simultaneous locking of up to four Fabry–Perot modes with appreciable (<2.5 dB) peak power ratio was achieved.

OCIS codes: (140.3520) Lasers, injection-locked; (140.5960) Semiconductor lasers; (140.7300) Visible lasers

1. Introduction

Single and multiple wavelength tunable lasers in the visible wavelengths are demanding for various multi-disciplinary applications in medical imaging, atomic clocks, ion trapping, sensing, communication, and terahertz/microwave generation. Single frequency generation in semiconductor laser is usually carried out by using a diffraction grating in an external cavity diode laser (ECDL) system, typically known as Littrow configuration. Chen *et al.* used this configuration in a green laser diode and demonstrated emissions with a linewidth of ~10 MHz [1]. On the other hand, multiple wavelength generation is still under the realm of high intensity nonlinear optic fiber systems. In this report, a grating-less solution is presented in free space medium to obtain single/multiple wavelength emission from a green laser diode. We have employed single and two stage self-injection locking technique in an ECDL configuration. The extended cavity is formed from the laser facet to the partial reflector(s) wherein the collimated light beams resonate at certain frequencies. The modes of the laser diode whose frequency matches with any of the allowed frequencies of the external cavity(ies) sync themselves suppressing the neighboring longitudinal modes. With proper tuning of the external cavity length, we have achieved simultaneous locking of up to four Fabry-Perot longitudinal modes with peak ratio, the ratio of the peak powers of the locked longitudinal modes, to be < 2.5 dB.

2. Experimental setup

Fig. 1. Experimental configuration of (a) single and (b) two stage self-injection locking scheme. (c) Normalized spectrum of a single wavelength longitudinal mode generated from two-stage self-injection locking configuration.

Single and two stage self-injection locking system for multiple and single longitudinal mode generation are shown in Figs.1 (a) & (b), respectively. Commercially available InGaN/GaN TO-can laser diode (Thorlabs L520P50) was employed in the system to ensure self-injection locking by allowing part of its emitted light to be re-injected with the help of external reflectors. In both of these configurations, the laser diode was placed inside a laser diode mount (Thorlabs TCLDM9) on a translational stage and an aspheric lens L₁ (Thorlabs, A110TM-A) was placed in front of it to collimate the emitted light beam. A 92:8 % beamsplitter (BS, Thorlabs BP108) was placed in the external cavity which transmits 92% of the light beam that travels a distance, d₁=26 cm in the free space until it reaches the 30% reflector (polka dot beamsplitter, Edmund Optics) as shown in Fig. 1 (a). In the second configuration of Fig. 1 (b), a two-stage self-injection locking is demonstrated where an additional reflector of 97.5 % reflectivity

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(Thorlabs, PF10-03-P01) was placed after the 30% reflector forming a three-cavity laser system. The overall length of the external cavity was kept $d_1 + d_2 = 26$ cm by moving the 30% reflector nearer to the laser diode at a distance of $d_1 = 15$ cm. The other 8% of the light beam from the external cavity BS was used as the diagnostic beam and sent to an optical spectrum analyzer (Yokogawa AQ6373B, resolution 0.05 nm) via an optical fiber after passing through a bi-convex lens (L_2 , Thorlabs LB1471-A-ML) and a free space-optical fiber coupler. During the experiment, the temperature of the laser diode mount was kept at 20°C.

3. Results and discussions

Fig. 1 (c) shows a spectrum having a very narrow linewidth of 34 pm which was generated from the two-stage self-injection locking system of Fig. 1 (b). Since the optical feedback reduces the threshold current, the operating injection current of the laser diode was set just below the threshold of the free running laser diode (36 mA). Lower mode competition in lower injection allowed a stable single wavelength emission at 524.05 nm. It is notable that the linewidth of 34 pm is almost as half as the free running laser diode mode spacing (~ 60 pm). Fig. 2 (a), (b), and (c) represents the spectra of two, three, and four simultaneous longitudinal mode which was generated using a single stage self-injection locked laser diode as shown in Fig. 1 (a). The operating point of the laser diode was set at different injection currents and we observe higher probability of multiple wavelengths at higher injections. In Fig. 2 (a) the dual wavelengths were observed at the free-running threshold current at 36 mA and they are 0.6 nm (0.65 THz) apart with a peak ratio of 0.25 dB. At an injection current of 43 mA, we began to see three simultaneous modes; an example of which is shown in Fig. 2 (b) having less than 0.4 dB of peak power ratio. The mode spacing of the locked modes are ranged from 0.60 nm to 0.92 nm, which is equivalent to 0.65 THz to 0.92 THz in the frequency domain. Further increase of injection current allowed four longitudinal modes. At an injection of 100 mA we observe such locking with a minimum peak ratio of ~ 2.5 dB as shown in Fig. 2 (c). The emission wavelengths and the mode spacing of the locked modes can be tuned by varying the length of the external cavity, injection current, and temperature of the system [2,3].

Fig. 2. Simultaneous generation of (a) dual, (b) triple, and (c) quadrupole longitudinal mode in an external cavity based self-injection locked laser diode system operated at an injection current of 36 mA, 43 mA, and 100 mA, respectively, in a controlled 20°C temperature.

4. Conclusions

In this work, a simple and cost-effective single and multiple wavelength generation system has been presented using single and two stage self-injection-locking technique in the green emission region. An appreciable peak power ratio of < 2.5 dB was achieved. A free space system with single laser diode and grating less configuration greatly simplifies the single and multi-wavelength generation in semiconductor laser diodes.

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