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1.38 W Tunable High-Power Narrow-Linewidth External-Cavity Tapered Amplifier at 670 nm

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Abstract: A diffraction-limited narrow-linewidth diode laser system based on a tapered amplifier in external cavity is demonstrated. 1.38 W output power is obtained. The laser system is tunable from 659 to 675 nm.

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1. Introduction

Diffraction-limited high-power narrow-linewidth red diode lasers are attractive for many applications, such as photodynamic therapy, laser display, and as pump source to generate UV light by second harmonic generation. High-power, diffraction-limited diode lasers can be realized by the introduction of the technology of lasers with a tapered gain-region [1]. In order to improve the spectral quality of a tapered laser, different techniques are applied. Up to 1 W output power at 668 nm from a Fabry-Perot tapered diode laser was obtained with a beam quality factor of 1.7, and the spectral width was smaller than 0.2 nm [2]. Around 670 nm, tunable high-power narrow-linewidth output was achieved from a master oscillator power amplifier system [3]. A 670 nm micro-external cavity tapered diode laser system was demonstrated with a volume reflection Bragg grating as a feedback element; in CW mode, more than 0.5 W output power was obtained, in pulse mode 5 W peak power was obtained with the beam quality factor of 10, and the spectral width below 150 pm [4]. External cavity feedback based on a bulk diffraction grating in Littrow configuration is a useful technique to achieve a tunable narrow-linewidth, high-power, and diffraction-limited tapered diode laser system [5]. Recently, we have demonstrated such a tapered laser system around 670 nm with output power up to 810 mW, a beam quality factor of 3.4 was obtained with an output power of 600 mW [6].

Here we present the experimental results of a 670 nm external cavity diode laser system based on an improved tapered amplifier. An output power up to 1.38 W is obtained, the laser system is tunable from 659 to 675 nm. To our knowledge, this is the highest output power from the tunable diode laser system in this wavelength range. The emission linewidth is less than 0.07 nm, and the beam quality factor M^2 is 2.0 with the output power of 1.27 W.

2. Experiment

The laser structure of the 670 nm tapered amplifier used in the experiment was grown using metal organic vapor phase epitaxy. The tapered gain device had a total length of 2 mm, a 0.5 mm long index guided ridge-waveguide section and a 1.5 mm long flared section. The tapered angle is 4°, and the output aperture is 110 μm. The rare facet was anti-reflection coated with a reflectivity of 5×10^{-4} , whereas the front facet had a reflectivity of 1%.

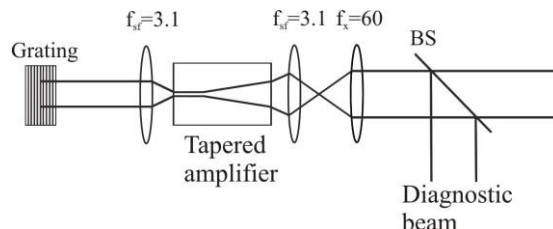


Fig. 1. Experimental set-up of the tapered diode laser system using external cavity feedback. BS: beam splitter, (the units are in mm).

The external cavity configuration employed is depicted in Fig. 1. An aspherical lens of 3.1-mm focal length with a N.A. of 0.68 is used to collimate the beam from the back facet in both fast and slow axes. The bulk grating is ruled with 1200 grooves/mm and has a blazed wavelength of 750 nm. The grating is mounted in the Littrow configuration and oriented with the lines in the grating parallel to the active region of the amplifier. The laser cavity is formed between the diffraction grating and the front facet of the tapered amplifier. Another aspherical lens of 3.1-mm focal length with a N.A. of 0.68 is used to collimate the beam from the output facet in the fast axis. Together

with a cylindrical lens of 60-mm focal length, these two lenses collimate the output beam in the slow axis and compensate the astigmatism simultaneously. All the lenses are antireflection coated for the red wavelength.

The temperature of the amplifier is controlled with a Peltier element and it is operated at 15°C in the experiment. The emission wavelength of the laser system is tuned by rotating the diffraction grating. The tapered device is lasing without the grating feedback. The power/current characteristics for the laser system with or without the external cavity feedback are shown in Fig. 2. Without feedback, the threshold current is around 0.7 A, the slope efficiency is 0.63 W/A, the emission wavelength is around 667.1 nm, the roll-over takes place around 1.5 A, an output power of 0.65 W is achieved with the injected current of 2.0 A. With the external cavity feedback, the maximum power is obtained at the wavelength around 668.4 nm, the threshold current of the laser system is 0.5 A, the slope efficiency is increased to 1.05 W/A, the roll-over takes places around 1.7 A, an output power of 1.38 W is obtained with the operating current of 2.0 A. The output power at different wavelength is shown in Fig. 3 at an operating current of 1.8 A, a maximum output power of 1.27 W is obtained with the wavelength of 668.38 nm, the output power is higher than 800 mW in the tuning range from 659 to 675 nm.

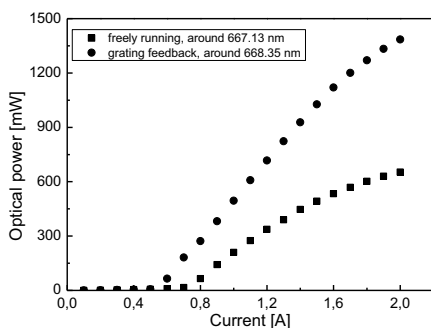


Fig. 2. The power/current characteristics for the tapered diode laser system with and without external cavity feedback.

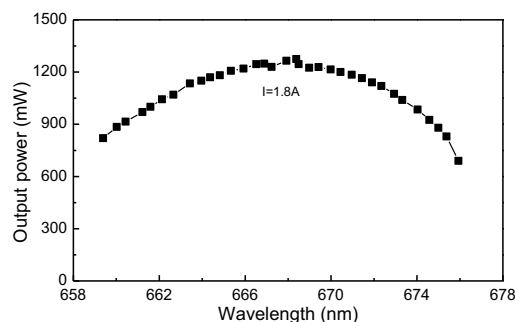


Fig. 3. Tuning curve of the tapered diode laser system at an operating current of 1.8 A.

The beam quality of the output beam along the slow axis is estimated by measuring the beam quality factor M^2 for the external cavity laser system. A spherical lens with a 100-mm focal length is used to focus the diagnostic beam. Then the beam width, W ($1/e^2$), is measured at various recorded positions along the optical axis – on both sides of the beam waist. The value of M^2 is obtained by fitting the measured data with a hyperbola. The estimated M^2 values are 1.39 ± 0.01 and 2.00 ± 0.01 with the output power of 277 mW and 1275 mW respectively.

The optical spectrum characteristic of the output beam from the tapered diode laser system is measured using a spectrum analyzer (Advantest Corp. Q8347). The linewidth of the output beam is less than 0.07 nm during the tunable range, and the amplified spontaneous emission intensity is more than 20 dB suppressed.

3. Conclusion

A diode laser system based on a tapered semiconductor optical amplifier in external cavity is demonstrated. An output power of 1.38 W is obtained with injected current of 2.0 A, and the laser system is tunable from 659 to 675 nm with output power over 800 mW. The M^2 value is 2.00 ± 0.01 with the output power of 1275 mW. The linewidth of the output beam is less than 0.07 nm.

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