

Oscillating longitudinal-mode control of a microchip green laser by injection current

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Abstract: We describe a simple method of controlling the oscillating longitudinal mode of a diode-pumped-microchip green laser by changing injection currents to the laser diode. We observed the dependence of the oscillating longitudinal modes on the injection current and operation temperature in the microchip green laser, and demonstrated that the stable oscillating longitudinal-mode operation under the single mode, two and three modes can be achieved by only controlling injection currents from 850 to 1050 mA. The maximum output power of the microchip green laser as high as 105.5 mW was obtained under the single longitudinal-mode operation pumped by an 810 mW pumping power. The corresponding long-term power stability was better than 0.47 % for the measuring time interval of 12 hours.

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OCIS codes: (140.3570) Lasers, single-mode; (190.2620) Frequency conversion; (140.3480) Lasers, diode-pumped.

References and links

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1. Introduction

Microchip green lasers are applied to many fields due to their advantages of good transverse mode, compact, low cost. However, the output power is generally varying with time due to the coupling of oscillating longitudinal modes, which is called green noise problem [1]. The longitudinal mode of the microchip green laser can be operated under the single mode by inserting an optical element in the cavity such as an etalon, a wave plate, a Brewster plate, or using a very shorter-length cavity and a short cavity involving an electro-optic modulator [2-

7]. In addition, the optimization of the concentration and thickness for the Yb^{3+} :YAG crystal microchip laser has been used to improve the laser performance [8]. Furthermore, the oscillating longitudinal modes of microchip lasers can be suppressed by introducing the optical feedback and optimizing the external cavity length [9]. We have reported a novel method of controlling the number of oscillating longitudinal modes in a microchip green laser by using the index-temperature dependency of laser and nonlinear optical crystals [10]. In this paper, we describe a simple method to control the oscillating longitudinal modes of the microchip green laser by optimizing the injection current and crystal temperature without requirements of inserting any optical elements in the cavity. We use directly commercial products as the laser and nonlinear optical crystals so that the longitudinal mode selection and stable operation can be achieved at a low cost.

The oscillating longitudinal modes of the microchip green laser are primarily determined by gain, loss, cavity length and subsequently oscillating frequency in the cavity. We control the oscillating longitudinal modes by adjusting slightly the gain, which is achieved by optimizing the injection current to the laser diode. As the increase in the injection current, the output power for pumping becomes large, and the central wavelength of laser diode is shifted to the long wavelength. If the central wavelength of the pumping laser is brought close to absorption wavelength of the laser crystal with the increase in the injection current, the corresponding gains of the possibly oscillating longitudinal modes grow subsequently. The oscillating longitudinal mode with a high gain is amplified while other longitudinal modes with relative low gains are restrained. Therefore, the oscillating frequency with respect to the peak gain can be fine-tuned by adjusting the injection current. Figure 1 shows spectral distributions of the laser diode for injection currents from 800 to 1050 mA. The corresponding central wavelength of laser diode varies slightly from 805.69 to 806.95 nm, which is near the absorption wavelength of 808 nm in a neodymium doped vanadate ($\text{Nd}:\text{YVO}_4$) crystal when the injection current is increased. Such variations in the central wavelength and pumping power can satisfy the purpose of the fine tuning in the gain and subsequently the oscillating longitudinal modes of the microchip green laser. We can select the oscillating longitudinal mode and control the number of oscillating longitudinal modes by adjusting the gain throughout the injection current.

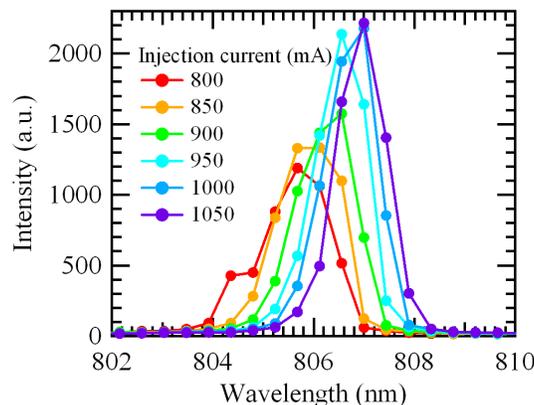


Fig. 1. Spectral distributions of the laser diode under different injection currents.

2. Experimental setup

Figure 2 is the scheme of our diode-pumped-microchip green laser designed based on conventional configurations. An 808 nm laser diode is used as the pumping source of the microchip green laser, which provides the maximum continuous-wave pump power up to 1 W. A ball lens with 4 mm diameter is used for condensing the pumping laser into a $\text{Nd}:\text{YVO}_4$ crystal. The $\text{Nd}:\text{YVO}_4$ crystal has an Nd^{3+} concentration of 3 at % to get absorption

coefficient of 111cm^{-1} , which absorbs 808 nm pumping light and generates 1064 nm fundamental light. A potassium titanyl phosphate (KTP) crystal cut for a type II phase-matching configuration with $\theta=90^\circ$ and $\Phi=23.5^\circ$ at 1064 nm, is used to convert the wavelength from 1064 nm fundamental light to 532 nm second-harmonic light. The Nd:YVO₄ and KTP crystals are bounded together by an optical contact. The sizes of the Nd:YVO₄ and KTP crystals are $1.5\times 1.5\times 0.5\text{ mm}^3$ and $1.5\times 1.5\times 2\text{ mm}^3$, respectively. The incident surface of the Nd:YVO₄ crystal and output surface of the KTP crystal are coated to provide two cavity mirrors. The incident surface has a high transmissivity at the pumping wavelength of 808 nm ($T>95\%$), and high reflectivities at 1064 nm ($R>99.8\%$) and 532 nm ($R>99\%$). The output surface has a high transmissivity at 532 nm ($T>95\%$), and a high reflectivity at 1064 nm ($R>99.8\%$), respectively. The laser diode and crystals are inserted in aluminum holders and the corresponding temperatures are efficiently controlled with peltier elements, respectively. The temperature of the laser diode is set to $24.5\text{ }^\circ\text{C}$ at an accuracy of $\pm 0.05\text{ }^\circ\text{C}$ to prevent the thermal effect in the laser diode, and the bounded Nd:YVO₄ and KTP crystals are controlled at an accuracy of $\pm 0.1\text{ }^\circ\text{C}$.

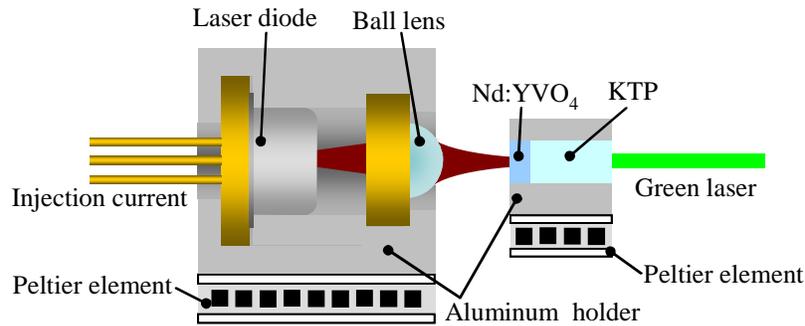


Fig. 2. Configuration of the microchip green laser.

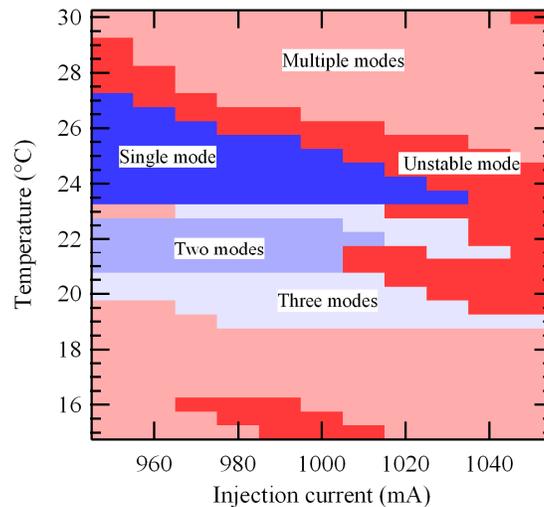


Fig. 3. The distribution of the oscillating longitudinal mode for injection currents of 950-1050 mA and crystal temperatures of 15-30 $^\circ\text{C}$.

3. Experimental results

Figure 3 shows the distribution of the oscillating longitudinal modes for injection currents of 950-1050 mA and crystal temperatures of 15-30 °C, respectively. The stable oscillation of single longitudinal mode (blue region), two (dove gray region) and three (gray region) longitudinal modes are observed for crystal temperatures of 19-27 °C. The oscillating longitudinal modes vary cyclically with the injection current and crystal temperature. The oscillating longitudinal modes are operated under the unstable mode (red region) when the output powers are modulated by the green noise and varying with the time.

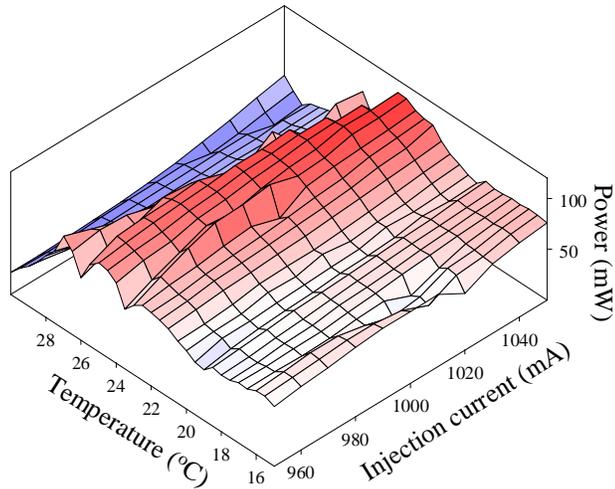


Fig. 4. The output power distribution of the microchip green laser for injection currents of 950-1050 mA and crystal temperatures of 15-30 °C.

Figure 4 shows the output power of the microchip green laser at the same injection current and crystal temperature shown in Fig. 3. The maximum power under the single longitudinal-mode operation up to 105.5 mW is obtained at the crystal temperature of 23.5 °C and the injection current of 1030 mA, which corresponds to the pumping power of 810 mW.

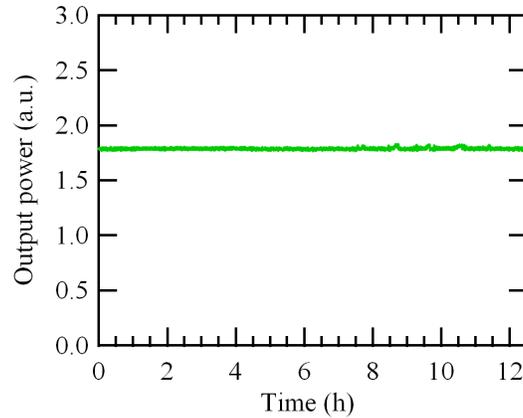


Fig. 5. The long-term stability of the microchip green laser for the measuring time interval of 12 hours.

Figure 5 shows the long-term power stability of the microchip green laser under single longitudinal-mode operation at the crystal temperature of 23.5 °C and the injection current of 1000 mA. The power ratio of standard deviation to average is 0.47 % for the measuring time interval of 12 hours. Thus a good long-term stability is achieved under the optimized injection current and crystal temperature.

The number of the oscillating longitudinal modes can be effectively controlled with injection currents from 850 to 1050 mA at the crystal temperature of 22.5 °C. Figure 6 shows interference signals of the oscillating longitudinal modes of the microchip green laser measured by a 125 GHz scanning Fabry-Perot interferometer. At relative low injection currents of 850-870 mA, the microchip green laser is operated under the stable single longitudinal mode [Fig. 6(a)]. As the injection current is increased gradually, the corresponding number of the oscillating longitudinal mode is changed from the single mode to two or three modes. The stable operations of two- and three-longitudinal modes are observed for injection current ranges of 880-1000 mA [Fig. 6(b)] and 1000-1020 mA [Fig. 6(c)], respectively. The separation of adjacent longitudinal modes is 33 GHz, which is the same as the intermode frequency spacing of the microchip green laser. For injection currents of 1020-1050 mA, the microchip green laser is operated under unstable longitudinal mode, in which the green noise is included in the output power [Fig. 6(d)]. In addition, the microchip green laser is operated under single mode, two and three modes with the long-term power stability better than 0.5 %.

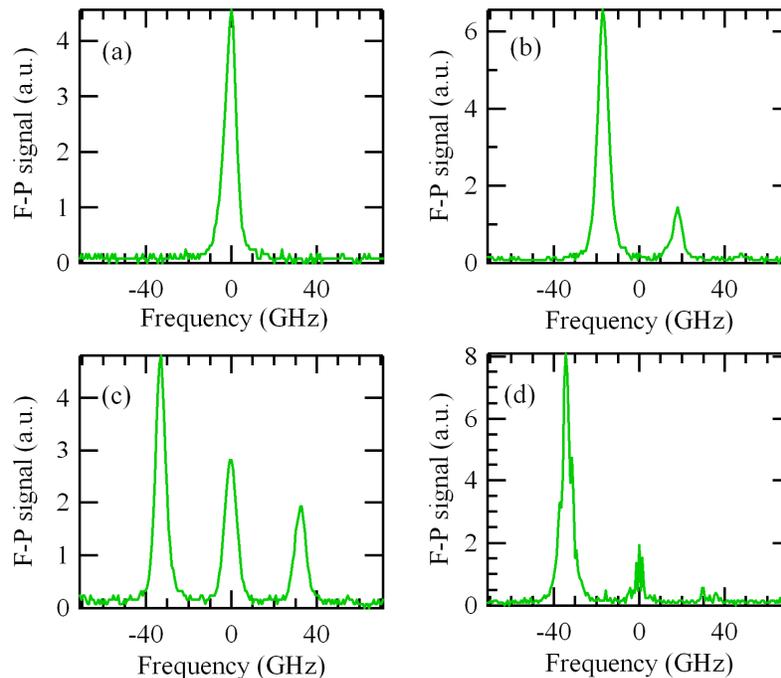


Fig. 6. Interference signals of the oscillating longitudinal modes of the microchip green laser measured with a scanning Fabry-Perot interferometer. (a) Single-longitudinal mode operation at 850 mA; (b) Two-longitudinal mode operation at 950mA; (c) Three longitudinal mode operation at 1020mA. (d) Unstable longitudinal mode operation at 1050mA.

4. Conclusion

We described a simple method to control the number of the oscillating longitudinal modes of the microchip green laser by optimizing the injection current and crystals temperature. We have achieved stable the longitudinal mode operations of single mode, two and three

longitudinal modes. The maximum output power of the microchip green laser was 105.5 mW at the pumping power of 810 mW. The long-term power stability under single longitudinal-mode operation was 0.47 % for the measuring time interval of 12 hours. The method can be simply achieved at a low cost by using commercial crystals without any requirements of inserting optical elements in the cavity.