Compact 532 nm microchip laser array utilizing optical contact Nd:YVO_4/PPMgOLN

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Abstract: In order to produce laser projectors in large quantities, a green laser with compact structure stable performance and low cost as the green light source was need. In this paper, a compact microchip laser array was obtained, utilizing optical-contact Nd:YVO_4/PPMgOLN bar as gain media and frequency doubler, combined with soldering packaging technology. Three green beams of the laser were obtained with the total output power of 223.7 mW, each laser beam had good spot profile and stability, the microchip laser array had compact size of 47 mm×35 mm×25 mm. It had a fluctuation of less than ±2.5% for 2.5 h. Various performances of the laser would fully meet the requirements of laser projector as the green light source, and it could be mass-produced in low cost.

Key words: microchip laser array; PPMgOLN; green laser; laser display

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基于 Nd:YVO_4/PPMgOLN 的 532 nm 紧凑型阵列激光器

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摘 要:为更适用于批量生产激光投影仪,需要一种具有结构紧凑、性能稳定与低成本等特点的绿色激光器作为绿光光源。采用光胶合的 Nd:YVO_4/PPMgOLN 晶体棒作为增益介质和倍频晶体,结合一种新型焊接封装工艺,最终得到了一种紧凑型微片阵列激光器。该激光器 3 个激光光束共得到了 223.7 mW 的功率输出,每个激光光束都有良好的光斑分布和稳定性,且激光器包含两个内置 TEC 在内具有 47 mm×35 mm×25 mm 的紧凑尺寸。激光器连续工作 2.5 h 波动小于±2.5%。各项性能可以充分满足激光投影仪绿光光源的要求,并便于低成本批量生产与后期维护。

关键词:微片阵列激光器; 掺杂氧化镁的周期极化铌酸锂; 绿色激光器; 激光显示

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0 Introduction

Laser display has been accessing to a rapid development, benefiting from the development of laser technology. The advantages of laser display are wider color gamut of NTSC, higher contrast and resolution, and better color saturation compared with the traditional lamp projectors [1-2]. And it's also easy to get larger screen (>100 inches) display in a lower cost than LCD/LED televisions. Compact laser sources have been developed for laser display. A 7.2 W line beam $Nd:YVO_4$/PPSLT green laser[3] and a 7.6 W planar-waveguide green laser[4] have been developed. But small mobile laser projector demands more compact laser source. With the rapid progress of Periodically-Polled MgO doped Lithium Niobate (PPMgOLN), microchip green lasers (532 nm) over hundreds of milliwatts output power can be obtained by utilizing optical-contact $Nd:YVO_4$/PPMgOLN[5-6]. Microchip green laser has the advantage of small size, high efficiency and easy to mass production at very low cost.

In this paper, we experimentally demonstrated a compact one-dimensional microchip laser array of wavelength 532 nm, utilizing optical-contact $Nd:YVO_4$/PPMgOLN bar as gain media and frequency doubler, for mobile laser projection. Three arrayed laser beams with the total output power of 223.7 mW are achieved by pumping three independent laser diodes directly into microchip. By combining the 3 output beams, the coherence length of the laser source can be reduced for better laser speckle reduction[7]. The fluctuation of the green output power is less than ±2.5% for 2.5 h. By using soldering packaging technology, the robust of the microchip laser array can be improved. Thus the microchip laser array can be mass produced with high productivity at a lower cost. With more compact size, it's suitable for mobile laser projector.

1 Designing and experiments

Microchip laser array consists of a monolithic flat-flat cavity formed by a $Nd:YVO_4$ bar and a PPMgOLN bar with dielectric cavity mirrors deposited directly on the surfaces. The $Nd:YVO_4$ bar and PPMgOLN bar are optical-contacted, with their polished and uncoated surfaces faced together. Two Silicon pads are used for firmly fixing them, as shown in Fig.1. A 2 mol% doped $Nd:YVO_4$ bar and a 5 mol% MgO doped PPMgOLN bar are used as the gain and frequency doubling medium, respectively. The size of the $Nd:YVO_4$ bar is 11.0 mm×1.0 mm×1.0 mm, and 11.0 mm×1.0 mm×1.5 mm for the PPMgOLN bar. The input facet of the microchip is coated for high transmission(HT) at the 808 nm pump wavelength, and high reflection (HR) at both 1 064 nm and 532 nm wavelengths(R>99.8%). The output facet of the microchip is coated for high reflection (HR) at 1 064 nm and anti-reflection (AR) at 532 nm.

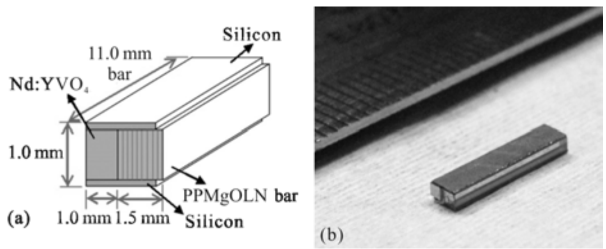

Fig.1 Schematic and photo of the microchip laser array

Optical-contacted $Nd:YVO_4$/PPMgOLN microchip array has the advantages of compact size, easy to use and low cost. However it cannot be pumped by high power laser diode of the power over 1 000 mW for too long(>2 h) due to the thermal issue, otherwise the optical-contact microchip would break down. The most important parameter of the array structure is the gap between pump LDs. The two neighboring pump beams will be partially overlapped if the gap is too narrow[8]. And the array microchip will be damaged due to the high quantity of heat concentrated in the middle after long-term operation, as shown in Fig.2 from reference [8]. Therefore, after a precise calculation and designing according to the actual condition, the microchip bar is directly pumped by 3 mini-mount laser. The gap between each other is 3 mm, as shown in Fig.3. The bar is cooled by a miniTEC to keep temperature of PPMgOLN stable at 27 ℃, which is the optimum temperature of the PPMgOLN [9]. The microchip was fixed in a brass fixture, which was soldered onto the miniTEC. Then they were aligned and soldered on the heat sink. This soldering packaging technology we developed can improve the robustness of the laser array module.

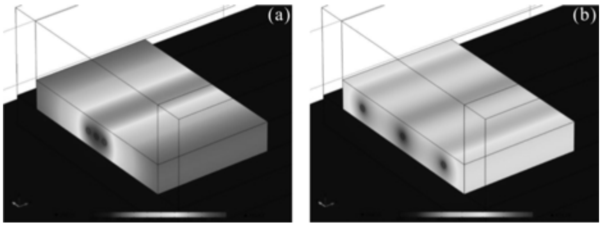

Fig.2 Finite element simulation results of the thermal distribution in the gain slab pumped by 3 emitters at different intervals, from the reference[8]

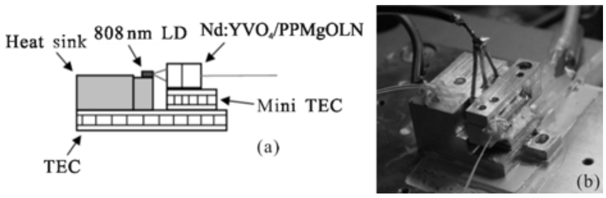

Fig.3 Schematic and the experimental setup of microchip laser array

2 Experimental results and analysis

At first, the microchip was pumped by single LD in turn to characterize each laser output, with the injection current changing from 0–0.9 A. Figure 4(a) shows each 532 nm laser output power, numbered from 1 to 3, as a function of LD current. With the increase of power, the shape of the output spot of the semiconductor will change, which will lead to the fluctuation of the pump efficiency. The No.3 laser beam has poorer output power characterization than the other two laser beams, due to its poor pump beam shape of 808 nm LD. The maximum output powers of 135 mW, 156 mW and 107 mW, respectively, are obtained at the current of 0.85 A for each LD.

The total output power of three laser beams is shown as a function of total injection current in Fig.4(b), with the 3 LDs in parallel connection. The threshold current of the microchip laser array is 0.65 A. And the maximum output power is 223.7 mW at the total current of 1.8 A. When the microchip is pumped by 3 LDs at the same time, Higher output power cannot be obtained by increasing the total current, due to much more heat accumulation in the microchip. It's difficult to remove the heat by miniTEC. Certainly it is realizable to obtain higher power by improving the heat radiation and pumping structure. Figure 5 shows the beam profile of the three laser spots, numbered from 1 to 3, which is measured at total current of 1.8 A. As we can see, the 3 laser spots have similar profile, due to more homogeneous thermal distribution in the microchip.

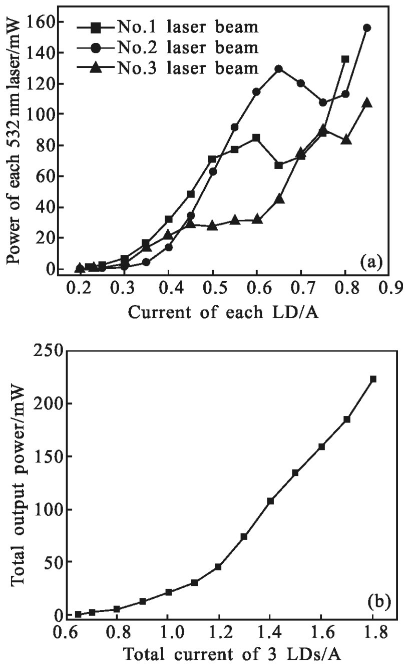

Fig.4 Characterization of laser output power

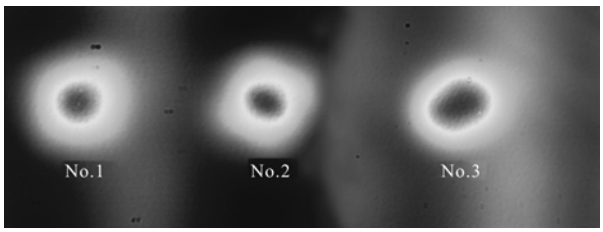

Fig.5 Beam profile of three laser spots, they are numbered from 1 to 3

The laser array module is packaged with the volume of 47 mm×35 mm×25 mm, as shown in Fig.6.

The laser array has a fluctuation of the green output power less than 2.5% for 2.5 h, as shown in Fig.7.

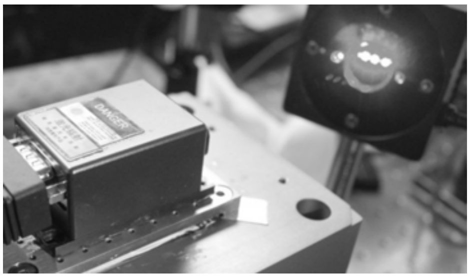

Fig.6 Microchip laser array system

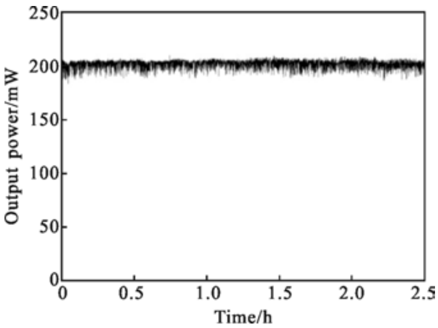

Fig.7 Output power versus working time

Due to the independent pumping laser diodes of the three green laser beams, their speckle patterns are independent of and incoherent with each other [10]. Hence the drastic laser speckle of the projection is eliminated by the low coherence [7]. The mobile laser projector will have a lower speckle contrast by using laser array as illumination source.

3 Conclusions

A compact continuous-wave microchip laser array of 532 nm is developed for mobile laser display. Three laser beams with total output power of 223.7 mW was obtained. By utilizing soldering packaging technology we developed for mass production, the robustness of the laser can be improved. So does the productivity, lower cost can be achieved for mobile laser display. Optimization work will be carried on to achieve higher output power, efficiency, and stability in the future.

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