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High brightness high power lightweight diode laser

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ABSTRACT

With continuously increasing output power of fiber lasers, small volume, lightweight, high electro-optic efficiency fiber laser is needed. The weight of the semiconductor laser accounts for half of the weight of the entire fiber laser. Therefore lower weight high brightness high power diode laser pump source has become the inevitable trend of development. Lightweight need small volume, low density material. Copper and aluminum are commonly used shell materials. Copper has excellent heat dissipation which density is three times that of aluminum. Lightweight need to balance the contradiction between heat dissipation and weight. BWT designed a diode laser pump source which power ratio is 2.3W/g. The shell materials are mainly copper and aluminum. Using spatial beam combination, polarization beam combination, together with 3-dimensional space dense arrangement, lower weight diode was achieved.

Keywords: Lightweight, Diode laser, High power, High brightness

1. INTRODUCTION

With continuously increasing output power of fiber lasers, small volume, lightweight, high electro-optic efficiency fiber laser is needed.[1] The weight of the semiconductor laser accounts for nearly half of the weight of the entire fiber laser. Therefore, lower weight high brightness high power diode laser pump source has become the inevitable trend of development. Lightweight need small volume, low density material. Copper and aluminum are commonly used as shell materials. Copper has excellent heat dissipation which density is three times than that of aluminum. Lightweight need to balance the contradiction between heat dissipation, stress deformation and weight.

In 2022, BWT reported a low SWaP (low size and weight and power-efficient) diode laser which is a wavelength-locking laser output within weight less than 190 g. The output power reaches 200 W at 11 A with E-O efficiency of over 50%. The leakage rate is controlled below 9.9×10-9 Pam3s-1 by a compact sealing structure with sealant. This product achieved a power weight ratio 1.05W/g and a volume power ratio of 0.64 cm^3/W. [2][3]

In this paper, BWT will introduce a lower SWaP laser diode which power/weight ratio is 2.3W/g. The shell materials are mainly aluminum. Using spatial beam combination, polarization beam combination, a 147.8W wavelength-locked laser diode was achieved which fiber core is 105um, and the E-O efficiency is 51.5%.

2. SIMULATION AND DESIGN

To develop a SWaP diode laser requires the following important factors: optimized optical path design, compact mechanical design with appropriate thermal management.

For multiple emitter semiconductor lasers, multiple optical paths can be matched according to chip power, chip beam quality, fiber parameters and output power from the fiber. And we chose the light path design with the least space with an appropriate process implementation difficulty.

Secondly, optimizing structural design. Structural design mainly includes thermal and stress simulation. The emitter of semiconductor laser generates a large amount of waste heat in the working process, which will affect the reliability of chip, lens, fiber, glue and so on. For thermal simulation, the main consideration is thermal power, heat conduction medium, chip spacing, thickness from the bottom plate, chip location, bottom plate material and other factors. We need to design a mechanical structure that is the smallest in terms of heat dissipation. The commonly used heat conducting medium is mainly copper and aluminum materials. Copper density is about 3 times that of Aluminum while thermal conductivity is about 2 times that of Aluminum. Combined with the designed optical path, the appropriate mechanical structure is selected

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through thermal simulation, which can not only meet the ability of heat conduction, but also achieve the effect of weight reduction. Fig. 1 shows the weight comparison of the two materials. Fig. 2 shows thermal simulation of copper and aluminum plates. The highest temperature of the chip with Aluminum base plate is 4.6℃ higher than that with copper base plate, and the highest temperature is 44.9℃. The central wavelength difference is close to 1.5nm, which is within the acceptable range.

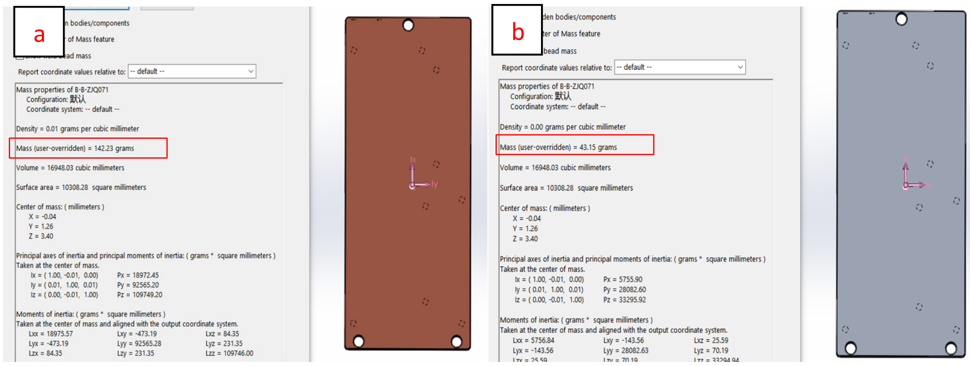

Fig. 1 Weight diagrams of copper and aluminum base plate;

a: The weight of the copper base plate is 142.3g;

b: The weight of the aluminum base plate is 43.15g, which is 0.3 times that of copper bottom plate;

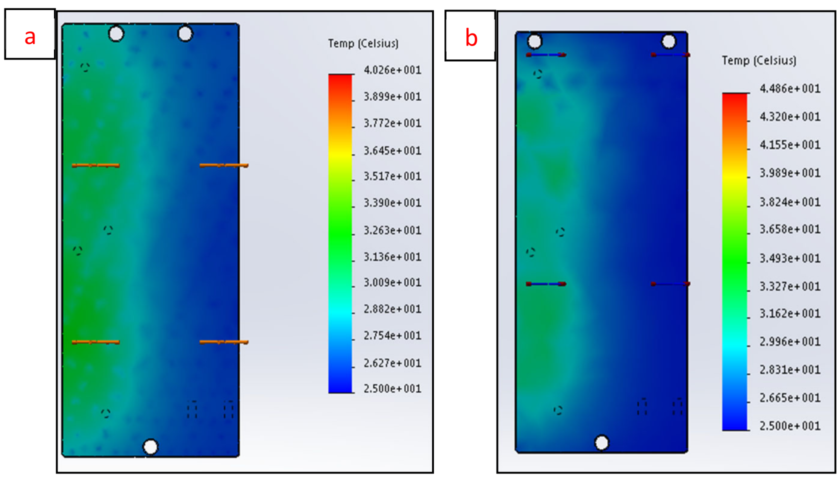

Fig. 2 Thermal simulation of copper and aluminum plates;

a: The highest junction temperature of the chip simulated by the copper shell peaked at 40.3℃;

b: The highest junction temperature of the chip simulated by the aluminum shell peaked at 44.9℃, and the temperature is within the acceptable range

The multi-emitters semiconductor laser are composed of multiple single emitter, multiple groups of optical lenses, fiber, etc. The core diameter size of optical fiber is micron, small optical path changes will cause the optical path offset, and then make part of the energy can not output from the optical fiber, resulting in low output power, low efficiency of E-O, and even burned the fiber and other problems. The stress simulation can simulate the position of the maximum deformation of the bottom plate after the stress is applied, and ensure the reliability of the laser by designing the position far away from the optical deformation requirement of high precision. In order to prevent the deformation of the key position, the stress of the bottom plate is simulated, and the deformation of the high-precision position is avoided by increasing the reinforcement and adjusting the positiont. A variety of screw fixation numbers and their stress at different hole positions were simulated. Figure 3 shows the number of two kinds of screw holes and the optimal positions of different numbers. Combined with the accuracy requirements of optical components, the fixed position in Figure b is finally selected.

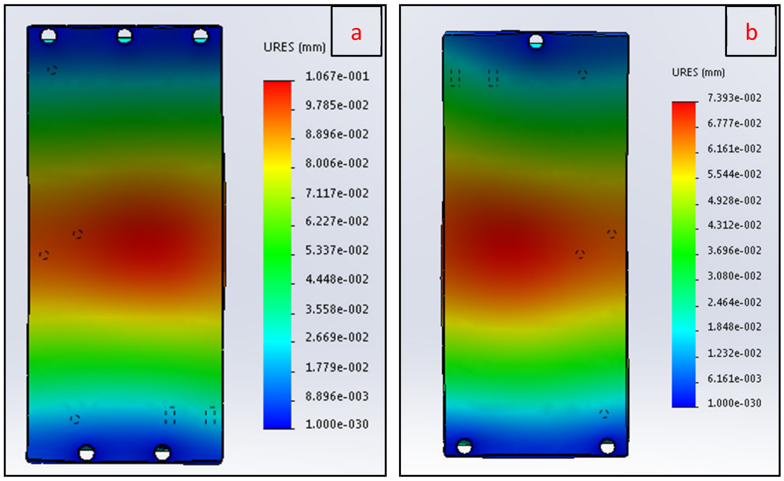

Fig. 3 Stress analysis diagram of the module;

a: The module has 5 positioning holes for installation;

b: Replaced the 5 positioning holes with 3 positioning holes. Optimizing the position of mounting holes to obtain the best position

3. RESULTS

Fig. 4 shows that the output power of the diode laser at 15A is 147.8W from the 105um fiber. According to the electro-optical parameters, it can be concluded that the electro-optical efficiency outside the fiber is 51.5%. The central wavelength is 975.9nm which the half-height full width spectrum is 0.5nm. The locking temperature ranges from 15 ℃ to 35℃ which can bring customers a good experience. The diode laser is stilling aging. It has been aging for more than 170h, and there is no obvious attenuation of power. Long-term aging is still being further accumulated, as shown in Fig. 5. The appearance and weight of the component are shown in Fig. 6. The weight of the component is 65.6g and the power/weight ratio reaches 2.3W/g. Fig. 7 shows the dimension drawing of the module; the module's dimensions are 84mm*36mm*12mm, and the volume is 36288mm^3. The volume/power ratio is 245.5mm^3/W.

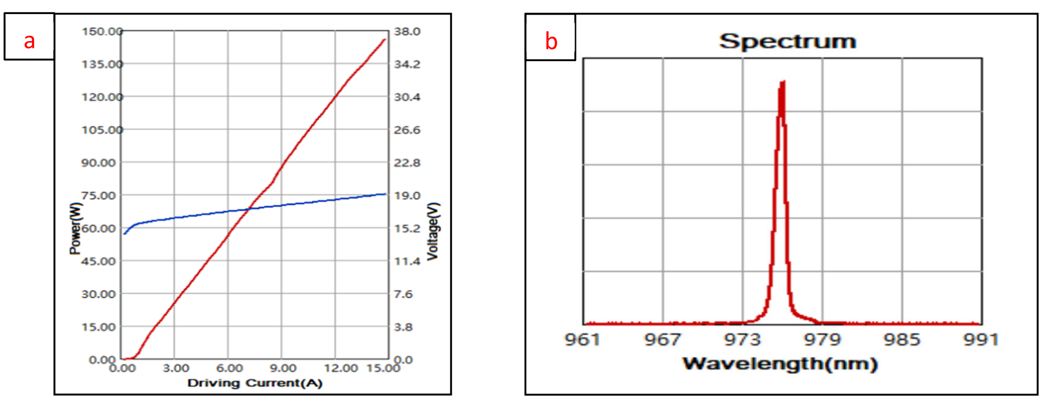

Fig. 4 PI curve and spectrum Diagram

a: Diagram of power and voltage variation with current. 147.8W was achieved at 15A from a 105um fiber.

b: Spectrum Diagram. The central wavelength is 975.9nm and the spectral width is about 0.5nm.

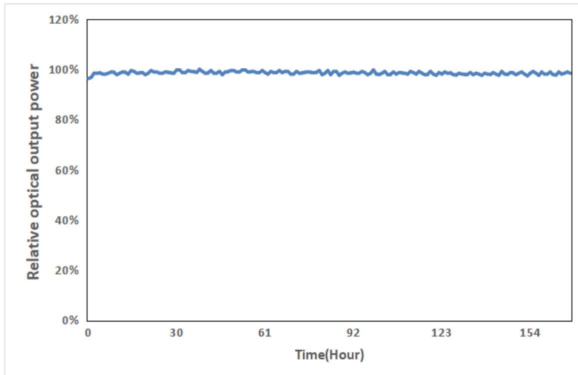

Fig. 5 Aging time of the module.

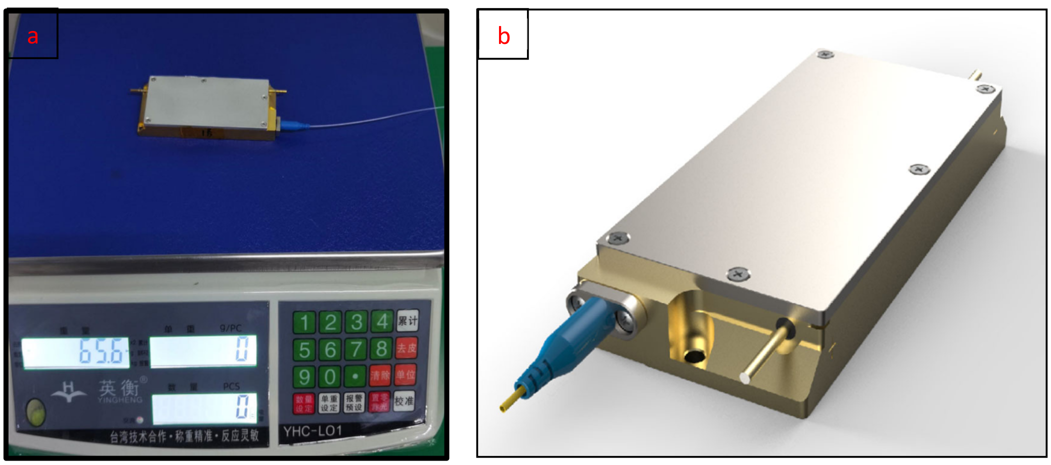

Fig. 6 Weight and schematic of the module;

a: the weight of the module is 65.6g, the power/weight ratio is 2.3W/g;

b: the schematic of the module. The shell in the figure can choose gold plated or nickel plated.

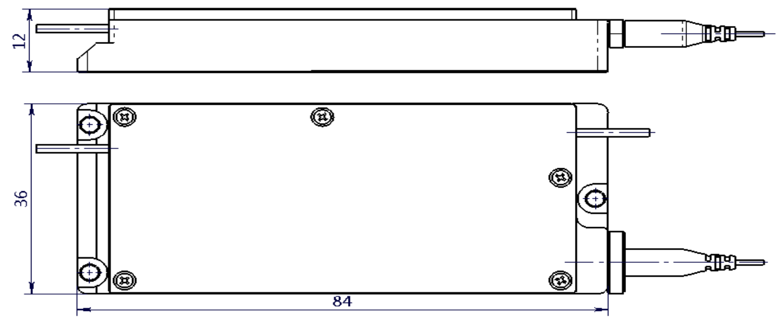

Fig. 7 Dimension drawing of the module; the module's dimensions are 84mm*36mm*12mm, and the volume is 36288mm^3. The volume/power ratio is 245.5mm^3/W.

4. CONCLUSIONS

This paper reported a wavelength-locked low SWaP diode laser emitting 147.8W from a 105um, 0.22NA fiber with one end coated. Through statics thermal simulation, optimizing optical path, the weight of module reduced to 65.6g. And the power/weight ratio become to 2.3W/g while the volume/power ratio is 245.5mm3/W. The power/weight ratio is twice that of the module we present in 2022.In the next, in order to better meet the customer's demand for low SWaP diode lasers, we will further optimize the optical path and structure design and improve the power/weight ratio to about 3W/g.

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