High-power low-SWaP wavelength stabilized pumps

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ABSTRACT

With the development of fiber lasers, the weight, power and brightness of fiber coupled semiconductor lasers are increasingly required. Low SWAP (low size and weight and power-efficient) laser diode has been a major focus of research. This paper mainly introduces the latest development of BWT low-SWaP products. In 2023, BWT introduces products with a power to mass ratio of 2.3W/g. By optimizing the optical path, increasing the power of the single chip, optimizing the structural design, and changing the material, BWT has introduced a higher brightness low-SWaP wavelength stabilized pumps. relying on a proprietary architecture of spatial and polarization multiplexing with multi-emitters.

Keywords: Low-SWaP, Diode laser, High power, High brightness, Multi-emitters

1. INTRODUCTION

With the development of fiber lasers, the weight, volume, photoelectric efficiency and brightness of semiconductor pump sources are increasingly required. [1] There is also an increasing demand for low size, weight and power-consumption (SWaP) fiber-coupled diodes for compact High Energy Laser (HEL) systems for defense and industrial applications. [2] SWaP fiber-coupled achieve high electro-optical efficiency by optimizing structural and optical design to reduce weight and size, improve coupling efficiency, and reduce power loss.

In 2022, BWT reported a low SWaP 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-to-weight ratio 1.05W/g and a volume power ratio of 0.64 cm^3/W. [3] In 2023, BWT reported a lower SWaP laser diode which power-to-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%.[4] As fig.1 shows, BWT developed a 260W pump source with a 135um fiber which power-to-weight ratio is 2.9W/g, and a 480W pump source with a 200um fiber and a power-to-weight ratio of 1.5W/g.

In this paper, BWT will introduce a lower SWaP laser diode which power/weight ratio is 2.5W/g. The shell materials are mainly aluminum. Using spatial beam combination, polarization beam combination, a 130W wavelength-locked laser diode was achieved which fiber core is 105um, and the E-O efficiency is 50.4%.

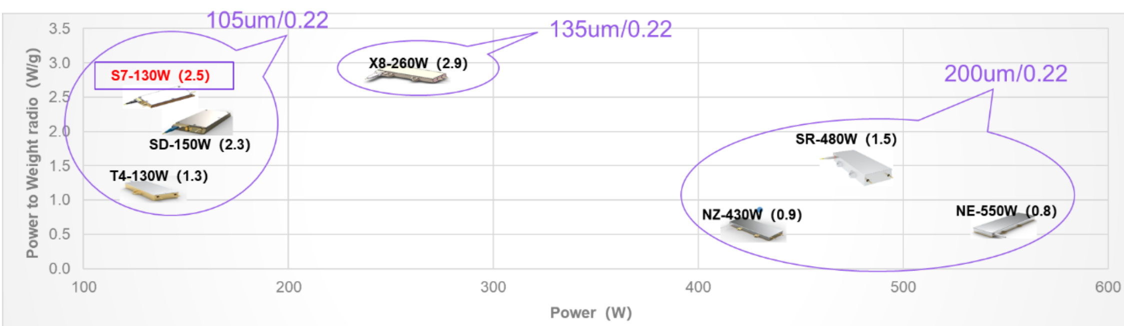

Fig. 1 BWT Lightweight Product Series

High-Power Diode Laser Technology XXII, edited by Mark S. Zediker,
Erik P. Zucker, Jenna Campbell, Proc. of SPIE Vol. 12867, 128670Q

2. SIMULATION AND DESIGN

The implementation path of SWaP is mainly to increase chip's E-O efficiency, optimize the structure design and optical path design, and reduce wastage as fig.2 shows.

Firstly, the high electro-optical chip with beam quality and power meeting the requirements was selected according to the optical path simulation results. Finally, the chips shown in Fig.3 was selected;

Secondly, the optical design was carried out according to the selected chip, the optical parameters were optimized, and the operability was considered while reducing the space size. Due to the problem of the focal length of the SAC(slow axis collimator), the space between the chip and the SAC was wasted. Because the output of high electro-optical efficiency needs to be achieved by satisfying the high coupling efficiency at the same time, the SAC with short focal length cannot meet the demand of the optical path. As shown in Figure 4, through simulation comparison, it was found that the curved cylindrical mirror can not only shorten the distance between the chip and the SAC, but also meet the requirements of high coupling efficiency. Based on the simulation results in Figure 4, the optical path design in Figure 5 was finally determined, and the optical path simulation results shown in Figure 6 were obtained, with a coupling efficiency of about 96%.

Thirdly, the mechanical design was carried out according to the optimized optical path design. The relative position of the chip and the selection of shell material were determined by combining the heat dissipation simulation. Because the power of the chip is less than 15W and the thermal power is less than 10W, the aluminum shell can meet the requirements of heat dissipation. Finally, the shell structure was determined by combining the stress simulation.

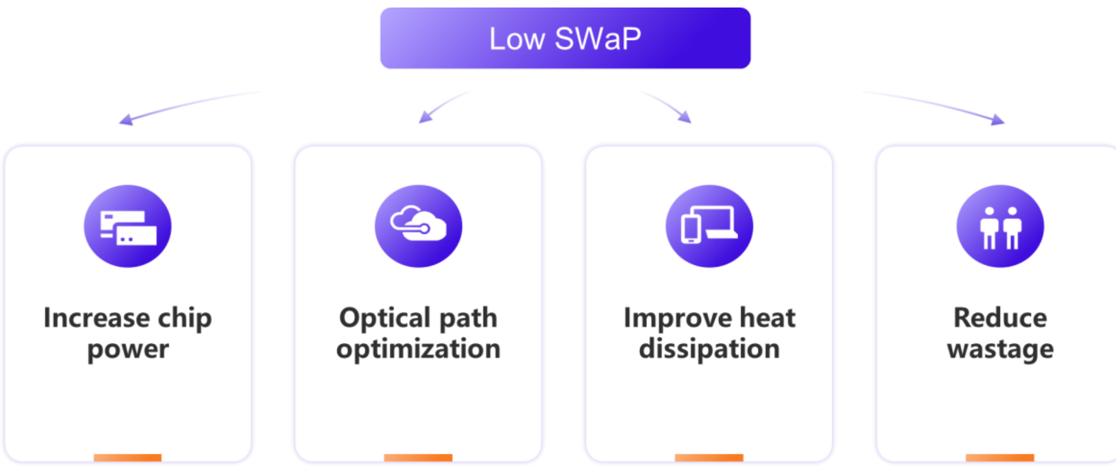

Fig. 2 The implementation path of SWaP

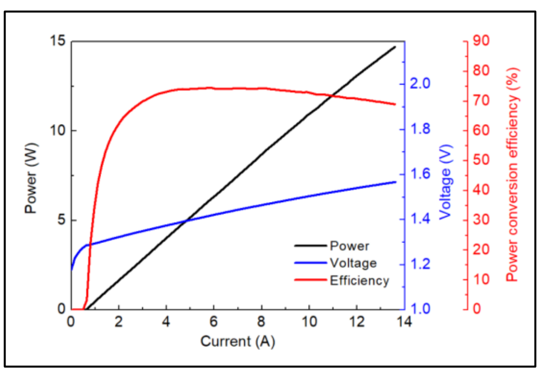

Fig. 3 Performance parameters of chips

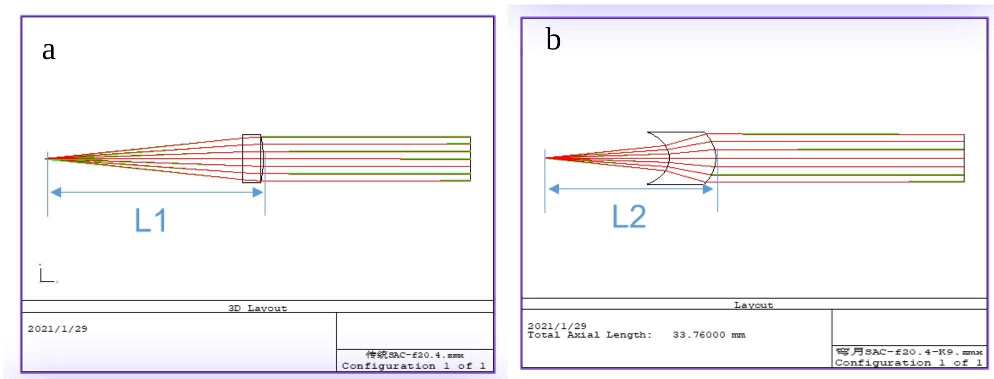

Fig. 4 Comparison of simulation results of curved cylindrical mirror and flat convex cylindrical mirror

a: Distance of work: 19.37mm. Lens thickness: 2mm,L1= 21.37mm

b: Distance of work: 10.6mm. Lens thickness: 4.18mm. L1= 14.78mm. The width direction can be reduced by 6.59mm

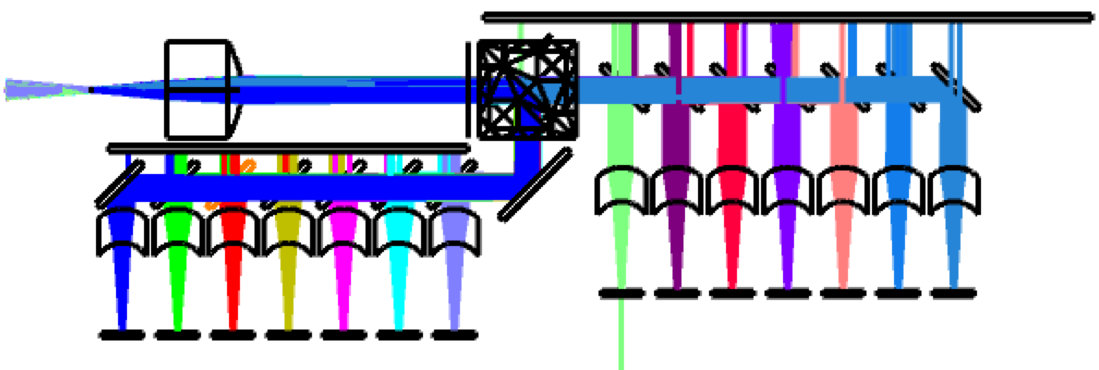

Fig. 5 Light path diagram

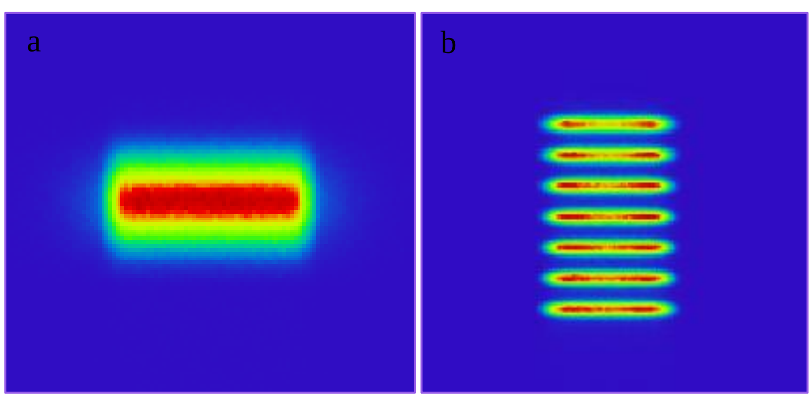

Fig. 6 Spot pattern of combined beam and spot pattern of optical fiber end face

a: Spot pattern of combined beam

b: Spot pattern of optical fiber end face

3. RESULTS

Fig. 7 shows that the output power of the diode laser at 11A is 130W from the 105um fiber. According to the electro-optical parameters, it can be concluded that the electro-optical efficiency outside the fiber is 50.4%. The central wavelength is 976.1nm which the half-height full width spectrum is 0.2nm. The appearance and weight of the component are shown in Fig. 6. The weight of the component is 52.3g and the power/weight ratio reaches 2.5W/g. Fig. 7 shows the dimension drawing of the module; the module's dimensions are 83mm*32.5mm*12mm, and the volume is 32370mm^3.

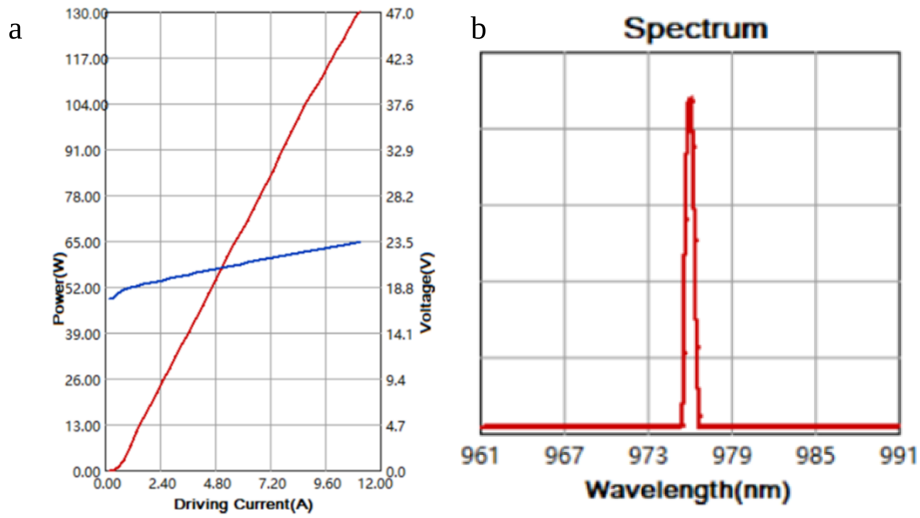

Fig. 7 PI curve and spectrum Diagram

a: Diagram of power and voltage variation with current. 130W was achieved at 11A from a 105um fiber.

b: Spectrum Diagram. The central wavelength is 976.1nm and the spectral width is about 0.2nm.

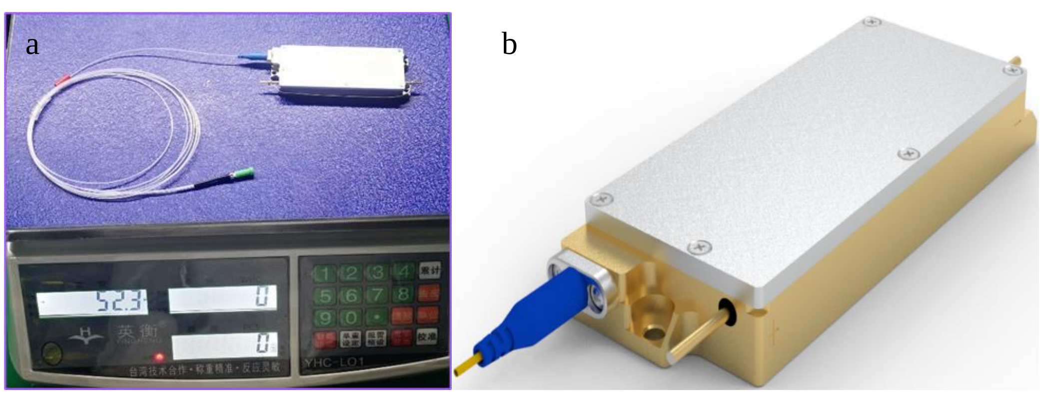

Fig. 8 Weight and schematic of the module;

a: the weight of the module is 52.3g, the power/weight ratio is 2.5W/g;

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

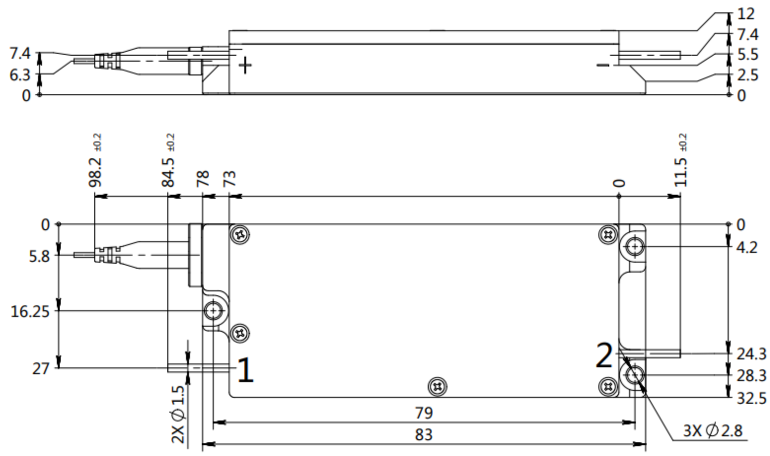

Fig. 9 Dimension drawing of the module; the module's dimensions are 83mm*32.5mm*12mm, and the volume is 32370mm^3.

Table 1 shows the module qualification test plan. The module has passed the low temperature storage test and temperature cycle test, and the aging test has been carried out for 500h. The power changes before and after the test are shown in fig.10, the power change rate is less than 3%, the test passed. The aging test and mechanical integrity will be continued in the future.

Table 1. module qualification test plan

Group	Test	Conditions	Current situation
Endurance	Low Temperature Storage	-40℃, 72hrs	YES
	Aging	-	500h
	Temperature Cycling	-40℃ to 85℃ for 200X	YES
	Damp Heat	85℃/85%RH for 1000hrs	To be completed
Mechanical Integrity	Mechanical Shock	500G, 1ms, 5times/axis	
	Vibration	20G, 20Hz~2000Hz, 4min/cy, 4cy/axis	
	Thermal Shock	ΔT = 100℃, 0℃ to 100℃, 15cycles	

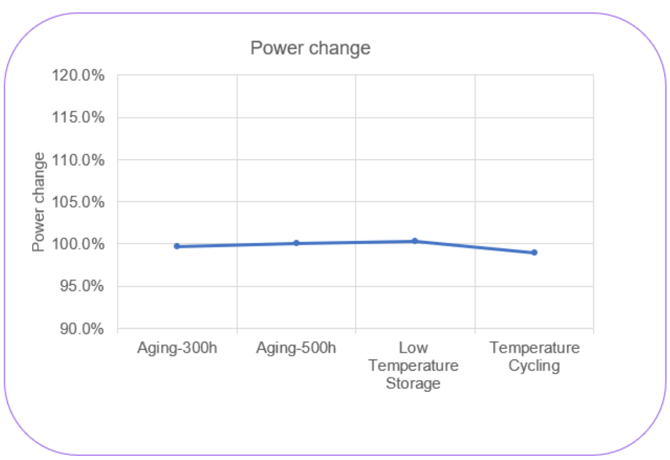

Fig. 10 The power changes before and after the test.

4. CONCLUSIONS

This paper reported a wavelength-locked low SWaP diode laser emitting 130W from a 105um, 0.22NA fiber which E-O efficiency is 50.4%. Through statics thermal simulation, optimizing optical path, the weight of module reduced to 52g. And the power/weight ratio become to 2.5W/g. The module has passed the low temperature storage test and temperature cycle test, and the aging test has been carried out for 500h. In the next, the aging test and mechanical integrity will be continued. With the increase of chip power, combined with higher thermal conductivity materials, and the use of composite materials, which can further improve heat dissipation and reduce weight, the power to weight ratio will be improved.

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