PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

High-power, high-brightness, high-efficiency, small-volume, low-weight, high-gas-tightness semiconductor laser-diode pump module

Yixiang Zhang, Zhenkun Yu, Dan Xu, Jianqiang Zhang, Jiangyun Wang, et al.

Yixiang Zhang, Zhenkun Yu, Dan Xu, Jianqiang Zhang, Jiangyun Wang, Xiaopeng Hu, Shaojie Shi, Jack Chen Sr., "High-power, high-brightness, high-efficiency, small-volume, low-weight, high-gas-tightness semiconductor laser-diode pump module," Proc. SPIE 11982, Components and Packaging for Laser Systems VIII, 1198202 (4 March 2022); doi: 10.1117/12.2608570

Event: SPIE LASE, 2022, San Francisco, California, United States

High-power, high-brightness, high-efficiency, small-volume, low-weight, high-gas-tightness semiconductor laser-diode pump module

Yixiang Zhang, Zhenkun Yu, Dan Xu, Jianqiang Zhang, Jiangyun Wang, Xiaopeng Hu, Shaojie Shi, Jack Chen*
BWT Beijing Ltd., No.4A Hangfeng Rd., Fengtai High-Tech Park, Beijing 100070, P.R. China

ABSTRACT

Low SWAP (low size and weight and power-efficient) laser diode has been a major focus of research in the laser industry. However, achieving high output power by a wavelength-stabilized laser diode with low SWaP and high airtightness is still challenging. Herein, using lightweight aluminum material and a compact structure design, BWT has developed a laser diode that outputs 200 W from 105 μm core diameter NA 0.22 fiber with the weight of 190 g and size of $144\times52\times17$ mm^3. The leakage rate of the diode laser is lower than 9.9×10^{-9} Pam^{3}s^{-1}. At 11 A, the electro-optical efficiency is higher than 50% with 200 W power output. The module's mass-to-power ratio is lower than the commercially available 200W laser diode from BWT. It is a relatively low-cost approach to low SWaP laser diode applications without complex structural design.

Keywords: Single emitter diode laser, SWaP diode laser, high airtightness, wavelength-stabilized

1. INTRODUCTION

The diode laser has been widely used due to its high efficiency, compact structure, low cost, and high reliability [1]. Low SWaP diode lasers have attracted increasing interest as the development of mobile industrial applications. Industrial diode lasers mostly have approximately >1 g/W specific mass, and specific volumes are too high to be acceptable for advanced applications [2]. Conventionally, the structure of the diode laser module is fabricated by Cu due to its high thermal conductivity [3-4]. However, it is relatively hard to reduce the excess weight and volume of diode laser while maintaining sufficient structural strength. By applying a complex structure design, a low SWaP laser diode could be realized with high cost.

In this work, we presented a low-weight and low-size diode laser with a relatively low-cost approach developed by BWT Beijing Ltd. With a compact design of $144\times52\times17$ mm^3 shown in Fig. 1, this diode laser reached 200 W out of a 105 μm core diameter NA 0.22 fiber. By utilizing an optimized aluminum structure and optical designs, the weight was lowered to 190 g. This diode laser can be applied in applications that require a low mass-to-power ratio and low leakage rate.

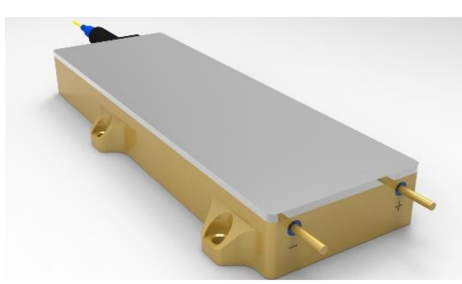

Fig. 1 Schematic of the module

Components and Packaging for Laser Systems VIII, edited by Alexei L. Glebov, Paul O. Leisher,
Proc. of SPIE Vol. 11982, 1198202 · © 2022 SPIE · 0277-786X · doi: 10.1117/12.2608570

*xiaohua.chen@bwt-bj.com; phone 86 010 8368 1054; www.bwt-bj.com

2. SIMULATION AND DESIGN

The laser diode is designed with a spatial and polarization combination of multiple single emitters. The chips are stacked in two rows on both sides of the package to shorten the optical path and maximum heat dissipation by conduction cooling. Thermal and statics simulation was performed to optimize the mechanical design. To reduce the weight of the module, we chose aluminum to fabricate the module body. Because the thermal conductivity of aluminum is significantly lower than copper, it is necessary to optimize the critical size of structure design by conducting thermal and statics simulations, aiming to obtain sufficient heat-sinking capacity and maintain adequate mechanical strength at the same time.

Structural strain related to mounting the module to a cold plate was the key parameter to be evaluated as modifying the size of the module. External factors such as the low flatness of the cold plate could lead to the structure of the module deforming under installation stress, resulting in laser beam shifting and degradation of coupling efficiency. The principle is to keep the maximum deformation at a low level and keep the light path away from the spot of the maximum deformation. Approaches to optimize structural distortion were restricted by weight limit. Fig. 2 shows the statics analysis results of the module with different thicknesses of the base plate. In the current design, the maximum deformation of the module is about 4.3×10^{-2} mm. And deformation of the light path was below 4.0×10^{-2} mm. As the thickness of the base plate decreases, the weight of the module could be lowered, and the deformation of the module increases. And the spot of the maximum deformation moves from the corner of the module to the center of the light path. This would increase the risk of degradation of coupling efficiency. As the thickness of the base plate increased, the deformation of the module was lowered to below 3×10^{-2} mm. But the mass-power ratio is over 1 g/W on account of the weight increment. Fig. 3 shows the effect of adjusting the thickness of the base plate on the deformation and weight of the module. The thickness of the base plate was set to the current design as a compromise between weight and structural strength.

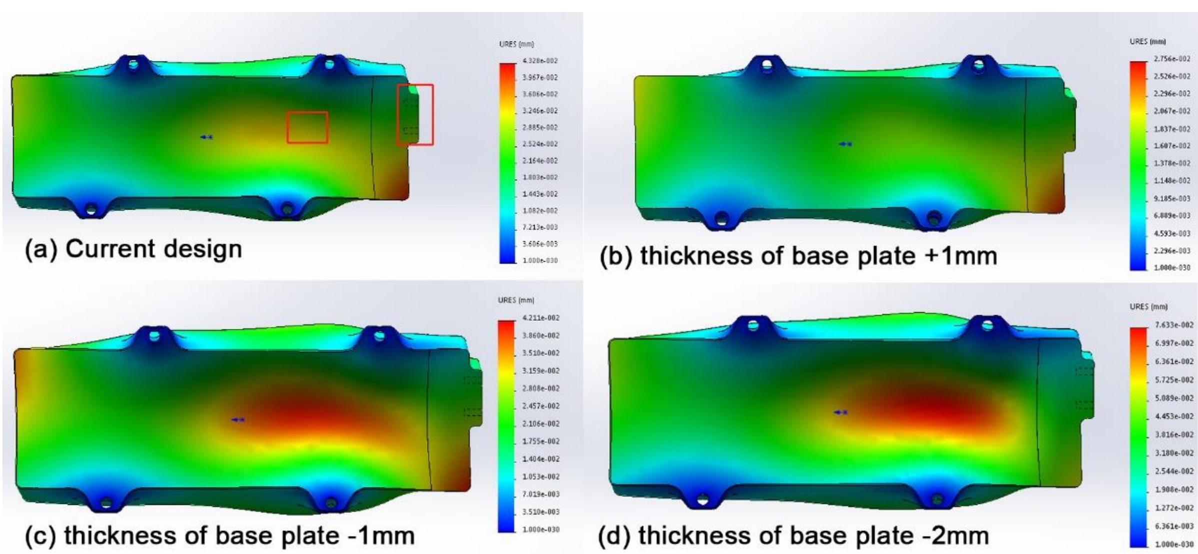

Fig. 2 Statics analysis of the module with different thicknesses of the base plate. (a) Current design. Critical spots on the light path are marked with red boxes. (b) The base plate is 1mm thicker compared to the current design. (c) The base plate is 1mm thinner compared to the current design. (d) The base plate is 2mm thinner compared to the current design.

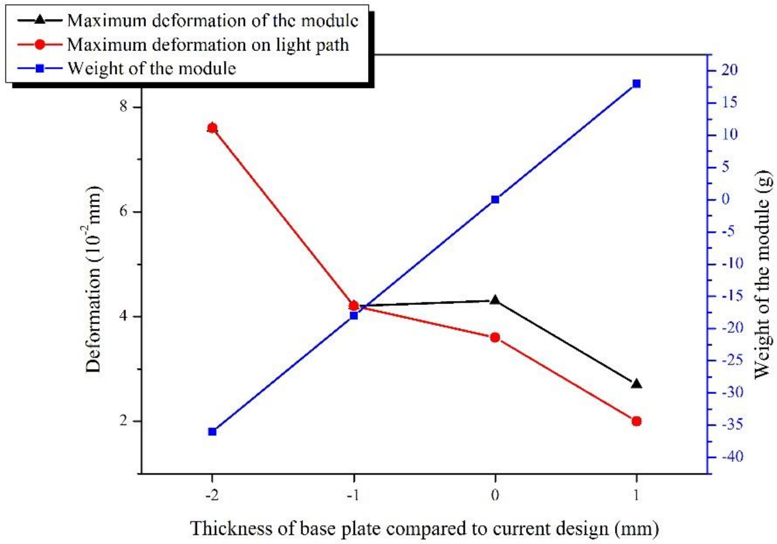

Fig. 3 Effect of adjusting the thickness of base plate on deformation and weight of the module.

Adjusting position of the mounting lug was among the methods to minimize strain from installation stress. Fig 4 shows the simulation results of module deformation with different positions of the mounting lugs. The results indicate that position of the lugs has a significant influence on the deformation of the module. Shifting the lugs 5 mm to the right would move the spot of maximum deformation to the center of the light path. Shifting the lugs on the opposite direction would contribute to even larger maximum deformation. Fig. 5 shows that the position of lugs was set to the current design as it inflicted minimized deformation to the light path.

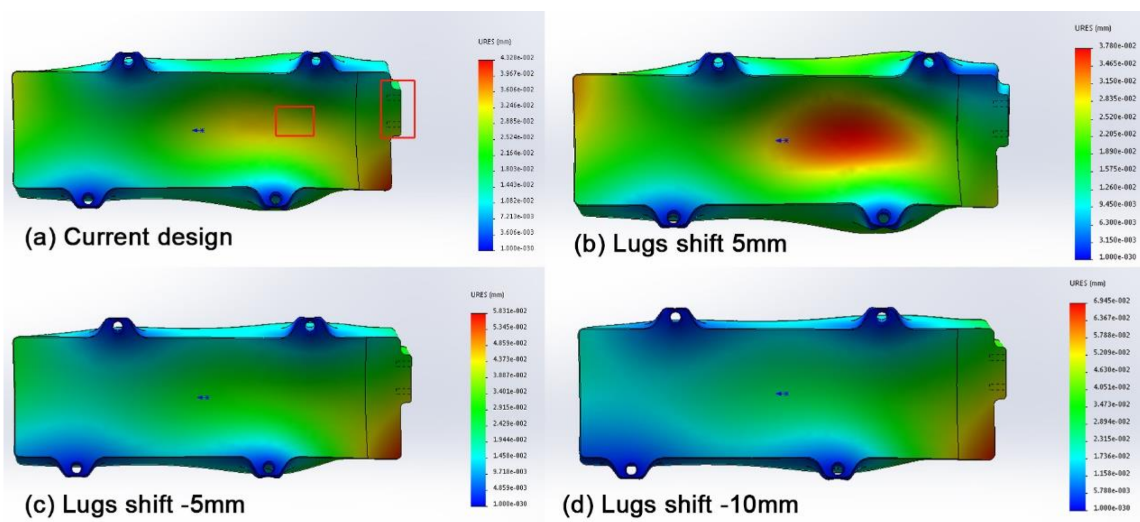

Fig. 4 Statics analysis of the module with different positions of lugs. (a) Current design. Critical spots on the light path are marked with red boxes. (b) Positions of the lugs shift 5mm to the right compared to the current design. (c) Positions of the lugs shift 5mm to the left compared to the current design. (d) Positions of the lugs shift 10mm to the left compared to the current design.

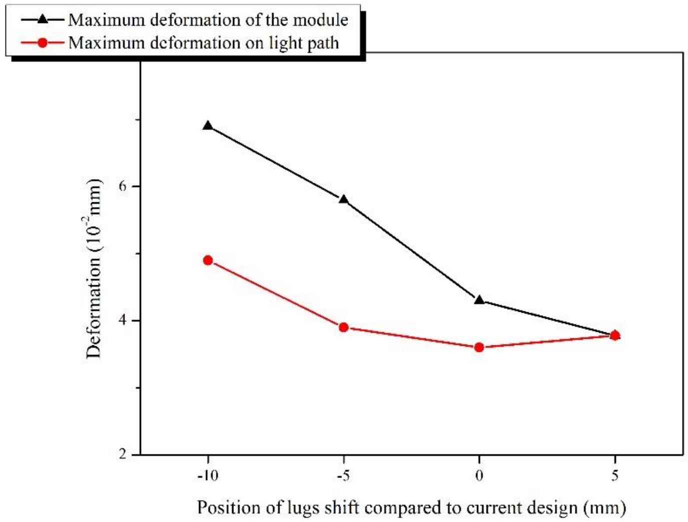

Fig. 5 Effect of adjusting the position of lugs on deformation of the module.

Analysis of temperature distributions of the packaging was then performed to confirm that the design could provide enough heat dissipation capacity. The module was set to be mounted on a cold plate maintaining 25 ℃. As shown in Fig. 6, the highest junction temperature of the chips was about 64.1 ℃, indicating that the thermal management of the module body meets the requirements of conduction cooling.

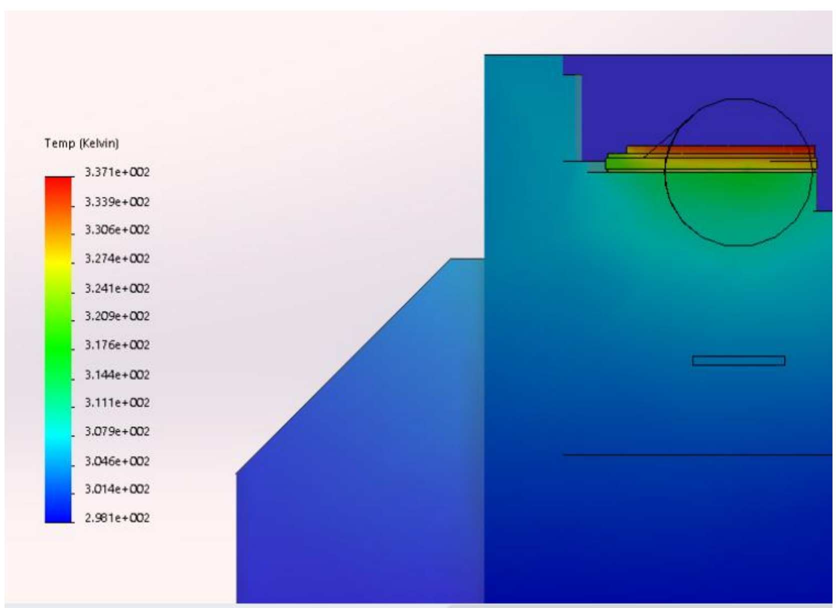

Fig. 6 Thermal analysis of the module showing the highest junction temperature.

Gas tightness was improved by a mechanical sealing structure utilizing a lid glued to the main body of the module. Sealant and a specially designed sealing structure reduce the leakage rate of the module down to below 9.9×10^{-9} Pam^{3}s^{-1}.

3. PERFORMANCE

A photo of the module is illustrated in Fig. 7, showing the weight of the module is 189.8 g. As shown in Fig. 8, the power vs current curve indicates the module output power reaches 200 W at 11 A with E-O efficiency at 50.38%. The locking range of the laser diode is from 5A to 11A. The spectrum at 5A and 11A with cooling water temperature at 25 °C is in Fig. 9, showing the wavelength at 975.8 nm. Over 90% of output power is in band of 974.5 nm to 977.5 nm. In Fig. 10, it showed the output power showed no sign of decline after over 250 h of burn-in at 12 A.

Fig. 7 Photo of the module.

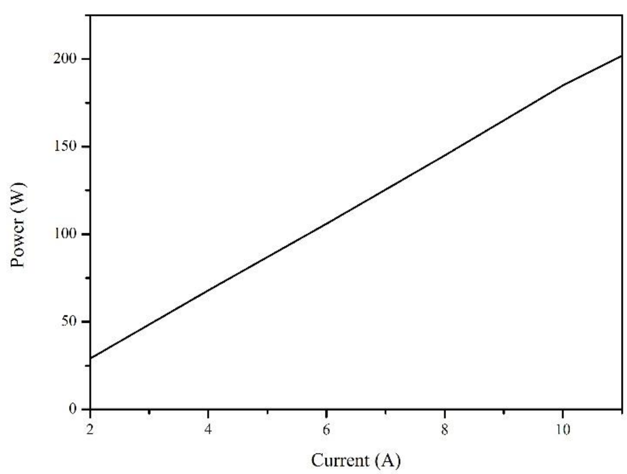

Fig. 8 Output power of the module in the current range of 2~11A.

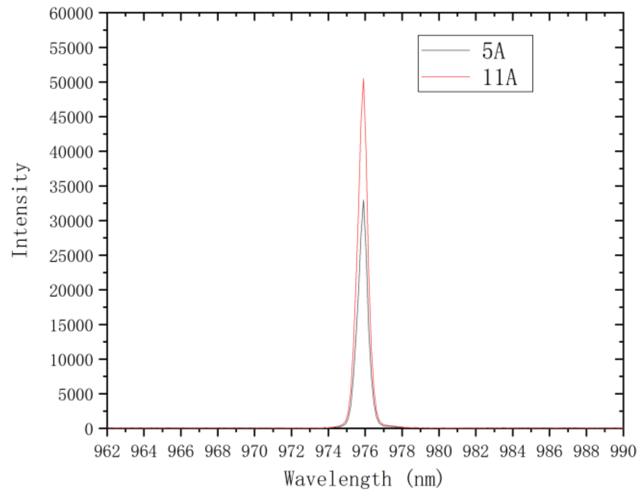

Fig. 9 Spectrum of the module at 5A and 11A.

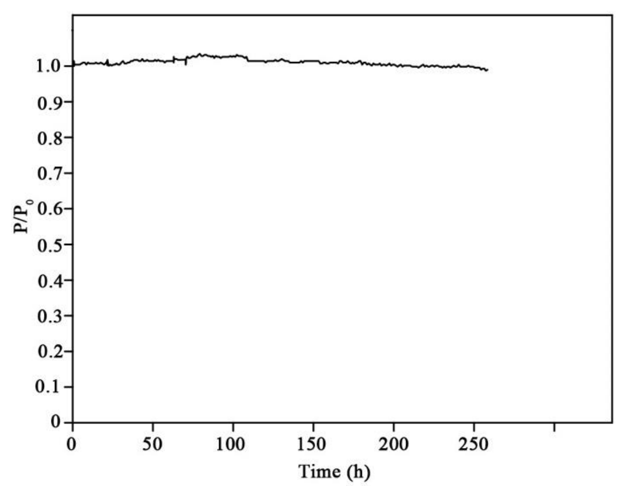

Fig. 10 Output power of the module during burning-in at 12A.

4. SUMMARY

In this paper, our development on low SWaP diode lasers at BWT is reported. We present an optimized aluminum compact structure design to achieve a wavelength-locking laser output within weight less than 190 g. Through the statics analysis of the package, the module structure is designed to reduce strain and keep the maximal deformation spot away from the optical system and fiber ferrule assembly. Thermal simulation confirms that the waste heat dissipation capacity of the module body meets the requirement. 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} Pam^3s^{-1} by a compact sealing structure with sealant. This product achieved a specific mass of 0.95 g/W and a specific volume of 0.64 cm^3/W without complex structure design, showing a cost-friendly approach for SWaP laser applications.

REFERENCES

[1] Dan Xu, Di Ma, Zhenkun Yu, Lei Xu, Xiaohua Chen, "Kilowatt wavelength-stabilized CW and QCW diode laser," Proc. SPIE 11262, 112620C (2020).

[2] M. Kanskar, C. Bai, L. Bao, Z. Chen, C. Chiong, M. DeFranza, K. Fortier, M. Hemenway, S. Li, E. Martin, J. Small, B. Tomakian, W. Urbanek, B. Wilkins, J. Zhang, "High brightness diodes and 600W 62% efficient low SWaP fiber-coupled package," Proc. SPIE 11262, 112620A (2020).

[3] Thomas Ebert, Hans-Georg Treusch, Peter Loosen, and Reinhart Poprawe "Optimization of microchannel heatsinks for high-power diode lasers in copper technology", Proc. SPIE 3285, (1998).

[4] Liu. X.S., et al., [Packaging of high power semiconductor lasers], Springer, New York, Chapter 6 (2015).