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Thermal characteristics analysis of high power 808nm bar facial array

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Abstract

In order to optimize the output parameters of 808nm array of high-power microchannel heat sink package, the fluid thermodynamic characteristics of 50 × 10 array were simulated. The thermal distribution of the simulation results was used to guide the array assembly. The spectral characteristics of each bar in the stacked array were observed by near-field fiber scanning probe. The simulation results show that the flow rate of the stacked bar decreases gradually from bottom to top, the temperature of the bar increases gradually, and the flow rate of each stacked bar decreases slowly as it is far away from the water outlet. When the flow rate at the entrance of the stack array is 10 L/min, the temperature difference between the bottom and top bar of a single stack array is 13.1 ℃, the flow rate difference is 0.24 L/min, and the FWHM width of the stack array spectrum can reach 4.5nm. The temperature of the active region is calculated by measuring the wavelength shift of each bar in a single stacked array, and the results are consistent with the simulation results. The spectral characteristics of the array can be effectively improved by assembling the array according to the temperature distribution.

Key words: Area array fluent simulation, Temperature distribution, Spectrum width

1.INTRODUCTION

Semiconductor laser, also known as laser diode (LD), is a kind of laser which is excited by electric injection and direct pumping with semiconductor material as optical gain medium. In order to improve the output power of semiconductor laser, multiple light-emitting units can be arranged into arrays according to certain rules, including one-dimensional array and two-dimensional array.[1] One dimensional array is also called linear array or bar bar. In order to improve the luminous efficiency and power of the array, the current diffusion and photon coupling between the light-emitting cavities can be effectively limited by fabricating photoelectric isolation slots between the lightemitting cells. Generally, the bar bar has a width of 1cm, a cavity length of 1.5-4mm, a filling factor of 10%, 20%, 30% or 50%, and is composed of 10-50 light-emitting units. At present, the continuous output power of the bar bar can reach more than 300W. [2] Two dimensional array, also known as laser stack array, is composed of two or more bar bars superimposed longitudinally.

The array bars are isolated by heat dissipation materials, and the most common method is to use microchannel heat sink (MCC). Microchannel heat sink belongs to modular Microchannel Cooler (MCC). [3]MCC is a common refrigeration unit in semiconductor device packaging, especially in high-power semiconductor laser stack packaging. The MCC is composed of five layers of preformed pattern sheets, and the semiconductor laser array (bar) is welded on the front end of the upper cover. The significant advantage of this method is to increase the heat transfer area

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between solid and liquid, and reduce the thickness of the thermal boundary layer through the liquid flow channel, thus greatly improving the thermal conductivity. The heat dissipation of a single MCC package bar is very good, but the stack array composed of multiple MCC package bars, especially with the increase of stack height, will lead to uneven heat dissipation of each position caused by uneven water flow in the vertical stack array, which further affects the spectral characteristics of the stack array. This is because the heat dissipation performance of the stacked array and the area array depends on the fluid form of the cooling liquid, and is affected by the gravity and the water resistance of the microchannel inlet and outlet channels. [4] When the stacked array is increased to 30 layers, the water flow rate in the bottom microchannel of the stacked array is greatly different from that in the top microchannel of the stacked array, and the heat is uneven, which leads to the superposition broadening of the stacked array spectrum. Furthermore, the fluid distribution of each stacked array in the array is uneven, and the superposition of different light-emitting unit spectra and beams leads to the deterioration of the photoelectric characteristics of the laser and the further increase of the spectral half width.

The narrow linewidth of absorption wavelength (<5nm) of solid-state laser requires strict temperature modulation of semiconductor stack array and area array. In order to have a good thermal control and understand the thermal characteristics of stack array, it is necessary to further explore the fluid thermodynamic characteristics of stack array and area array, guide the assembly of stack array and area array with fluid and heat distribution, improve the heat dissipation ability and soaking ability, and reduce the width of stack spectrum.

2. Experiment and design

The 808nm array is assembled horizontally by 10 groups of bar arrays, which is a vertical stack composed of 50 bar arrays encapsulated by microchannel heat sink. There are 500 MCC package bars in the whole array, and the package height is 1.7mm. The diameter of the water inlet and outlet holes of the designed array is 25.4mm, and the water flux is 100L / min. the water enters through the two water inlet holes of the array, and is evenly distributed to 10 groups of bar arrays, and then flows out from the two water outlet holes of the array, with the diameter of 25.4mm.

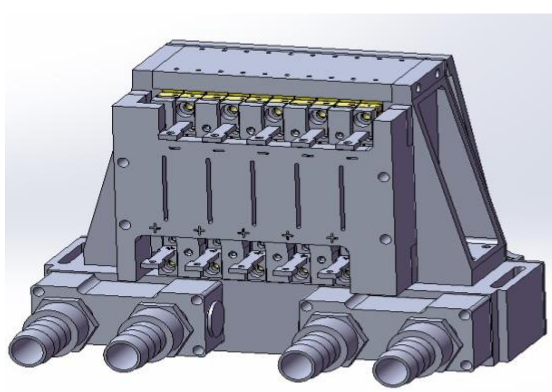

Fig 1. Array structure

In order to get accurate results, the 808nm bar of a single MCC package is modeled and analyzed, and the simulation results are checked by testing the flow and temperature drift of the single bar. The shape of the microchannel heat sink is shown in Fig2, with the size of 28mm(L)X11.3mm(W) , and the cross-sectional area of the inlet and outlet is $28.27mm^2$. The number of internal microchannels is 10, and the minimum cross-sectional area of microchannels is $2.5mm^2$. The size of UMB is 2x10mm and the average heat generated is 45W.

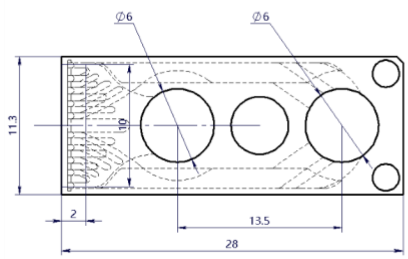

Fig 2. Single MCC structure

A 50 layer vertical stacked array is formed by the bar of the microchannel heat sink package, and the total height of the stacked water channel is 95mm. The cross-sectional area of the corresponding water inlet and outlet and vertical channel is $28.27mm^2$, and the cross-sectional area of the microchannel in the stacked array is $125mm^2$. At this time, the cross-sectional area of the microchannel and the cross-sectional area of the water inlet and outlet channel, the water resistance of the water inlet and outlet channel and the gravity have an important impact on the heat sink of each MCC in the stacked array.

Through the analysis of the flow pattern of water in the array, the design of the array water channel is guided, so as to reduce the water resistance of the array channel, uniform the water flow of each array, and reduce the width of the superposition spectrum.

3 Results and discussion

The results show that the temperature of active region decreases with the increase of flow rate, and the pressure difference between inlet and outlet increases with the increase of flow rate. When the flow rate is from 0.09L/min to 0.35L/min, the temperature of active region decreases from 65.3 ℃ to 50.7 ℃, the temperature decreases by 14.6 ℃, and the pressure drop of inlet and outlet increases from 0.005MPa to 0.04MPa.

Table 1. Temperature of active region of microchannel heat sink under different flow rates

Group	Flow(L/min)	Temperature(℃)	Pressure drop(Pa)
A-1	0.0454	74.2	2004
A-2	0.0572	70.3	2735
A-3	0.0885	65.3	5010
A-4	0.1169	63.4	7469
A-5	0.1751	58.8	13629
A-6	0.2370	55.8	21836
A-7	0.2621	54.8	25654
A-8	0.3569	50.7	43408
A-9	0.4783	48.5	73573

The simulation results and the actual test results are shown in Figure 3, in which (b) 9 bars are selected for test. According to the working wavelength of batons at 0.2L/min, three batons at 808nm, three at 805nm and three at 810nm were selected respectively. The test results show that the center wavelength of 9 bars is reduced by 4.3nm on average from 0.1L/min to 0.35L/min, the temperature drift coefficient of 808nm band is 0.3nm /℃, and the corresponding temperature is increased by 14.3℃. The variation of temperature with flow rate shows that the simulation results are in good agreement with the measured results.

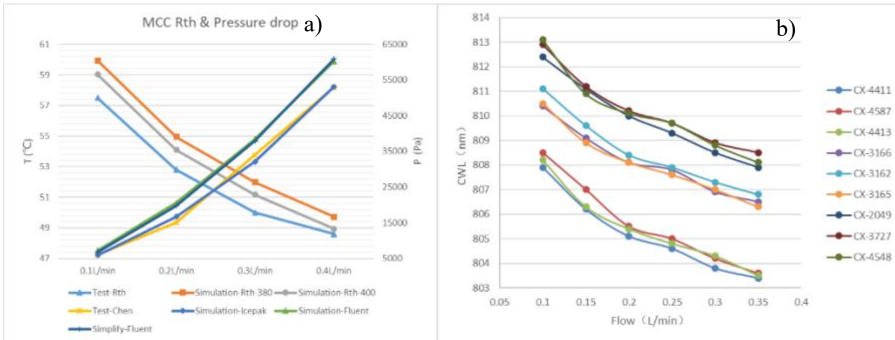

Figure 3. Single bar at different flow rates. (A. simulation results B. actual measurement results)

The simulation results and test results of the stacked array are shown in Fig. 4. The bottom layer of the vertical square of the 50 bar stacked array is set to be 1 #, and the top layer is set to be 50 #. The flow distribution from bottom to top is shown in Fig4(A), and the change trend is shown in Fig4(B). The top flow is 0.12l/min, and the top flow is 0.36l/min. According to the simulation and test results of single bar, 50# bar corresponds to 1# bar, the temperature difference is 14.6 ℃, and the wavelength shift is 4.38nm. The results show that the wavelength of 1# bar decreases by 1.3nm, and the wavelength of 50# bar increases by 3 nm. The simulation results are in good agreement with the actual test results. According to the simulation results, the bar array is selected to form a stack array. The actual 73 sets of 50 bar stack array test results are as follows: Fig4(D), the half width of the test spectrum is 3.9-4.5nm, and the average is 4.2nm, which achieves the purpose of narrow linewidth stack array.

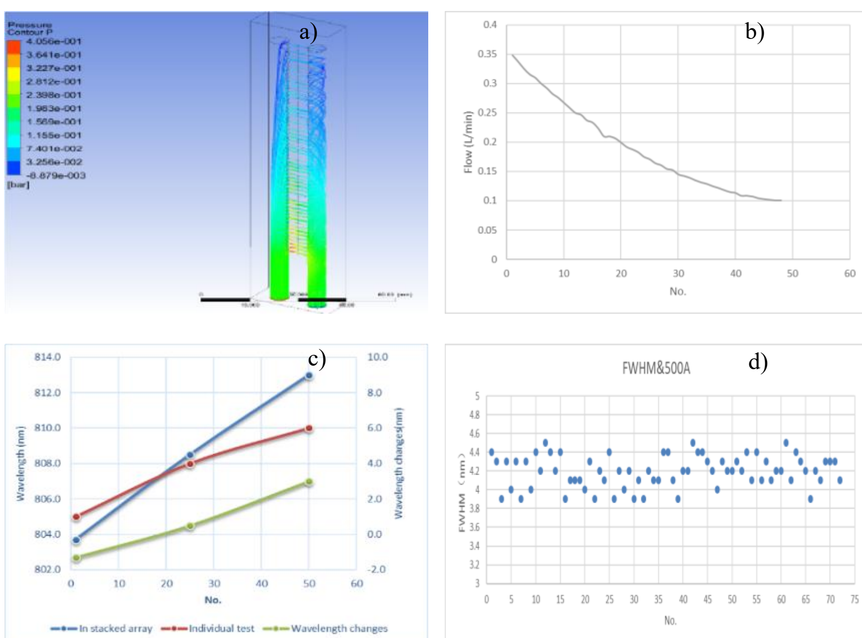

Figure 4. Under the condition of flow rate of 10L / min (A. pressure distribution in the stack B. flow distribution in the stack C. wavelength change at different positions of the stack D. actual measured half width of the stack)

The plane array is designed to be centrosymmetric, and the left and right water channels do not interfere with each other, so it is enough to simulate and analyze 5 stacked arrays on one side. The simulation results are shown in Fig. 5. By optimizing the water inlet and outlet angle, the flow rate is basically evenly distributed in five stacked arrays, but the flow rate of stacked array 5 # is slightly less than that of stacked array 1 #. Therefore, when the array is assembled, the wave length near the water inlet and outlet and the wave length of the middle stacked array are determined according to the central wavelength distribution of the stacked array. In this way, the wavelength is the same. After assembling the stacked array, the spectral superposition can minimize the spectral broadening of the stack array.

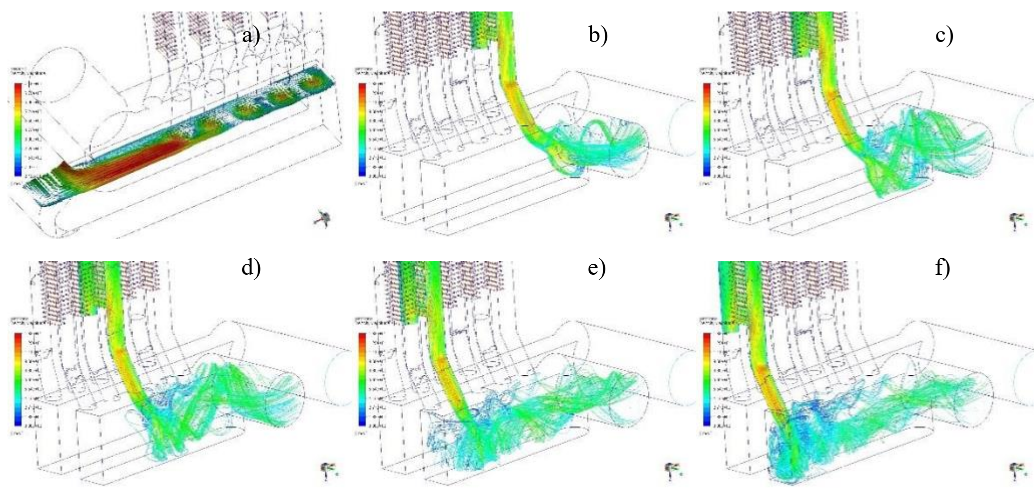

Fig 5. Water flow distribution of array

4 Conclusion

To sum up, according to the fluid distribution, the assembly of stacked array and planar array is an effective method to reduce the spectral broadening. The results show that the average central wavelength of single bar is reduced by 4.3nm and the temperature is increased by 14.3 ℃ from 0.1L/min to 0.35L/min. The flow rate of the bottom bar is 0.12 L / min, and the flow rate of the top bar is about 0.36 L / min. the flow rate of the bottom bar decreases and the temperature of the top bar increases. According to the results of temperature distribution in the stacked array, the half width of the stacked array spectrum can be limited to 4.2 nm. As the array is far away from the outlet, the flow rate of each stacked array decreases slowly, and the main source of water resistance is not the array water channel. When the array is assembled, the central wavelength of the array should be from large to small from both sides to the middle.

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