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ABSTRACT

BWT introduced the idea of dense spatial beam combination(DSBC) and proved it experimentally with kW level pump source. Currently, the output power of single emitters has reached 15W~30W@BPP≈5-12mm·mrad with electro-optical efficiency>60%. This makes it possible for the high-power pump source with optical fiber output to maintain high brightness, small volume, and light weight. With commercial available chips, BWT achieved 420W output locked at 976nm from a fiber of 135μm core diameter and NA0.22, and mass of ≈500g. Also 1000W output at 976nm (or 915nm) from a 220μm core diameter 0.22NA fiber is obtained and mass of ≈400g. In the future, with increasing diode chip brightness and electro-optical efficiency, the pump source with high power and mass ratio will have an important role in small size and high power fiber lasers, which will become an active driver for defence and industrial applications.

Keywords: Diode laser, single emitter, brightness, BPP, fiber, dense spatial beam combination

1. INTRODUCTION

Fiber lasers are developing rapidly for their good beam quality and flexibility in expanding power (fiber combiner). In recent years, single fiber single mode fiber lasers are limited by transversal mode instability (TMI) and Stimulated Raman Scattering (SRS), while output power of diode pumped fiber laser oscillator stops at 5kW[1] and power of tandem pumping stops at 10kW[2]. Although output power can be increased through increasing fiber core diameter, but increased fiber core diameter lowers the output beam quality [3-4].Nevertheless, the need to improve the brightness of diode pump source is still urgent.

For industrial applications, requirement on beam quality doesn't have to be single mode, to increase power of a single fiber, a few low order modes are allowed. Until now, single fiber lasers of low order modes and combined fiber lasers of multiple modes pumped at 976nm have provided output power over 5kW and are widely applied (mainly in cutting and welding of metals), and high power pump sources are manufactured in batches to pump these fiber lasers.

2. RELATIONSHIP BETWEEN BPP OF DIODE LASER CHIP AND BRIGHTNESS OF PUMP SOURCE

Three years ago, brightness of 9xxnm diode laser chips is mostly at 3W/mm·mrad@12W for 100μm stripe width and 2W/mm·mrad@18W for 200μm stripe width. Based on such chips, BWT realized 600W and 1000W output from 200μm core diameter and NA0.22 fibers [5-6]. Currently, brightness of 9xxnm chips is up to 3.75W/mm·mrad@15W for 100μm stripe width and 3W/mm·mrad@30W for 230μm stripe width while electro-optical efficiency is maintained at around 60%. Theory of DSBC tells that with a 78% average fiber coupling efficiency (from laser emitting to fiber output, at single wavelength, with spatial beam combination and polarization beam combination, without VBG) and assuming the chips operate at maximum power (BPP of chip changes with electric current), datas are shown in the following chart:

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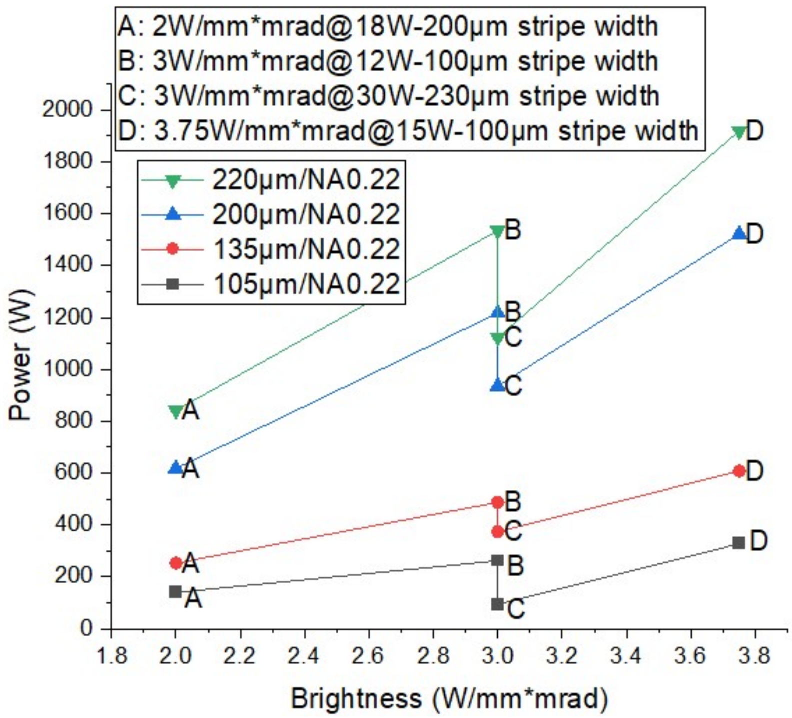

Figure 1. Chip brightness vs output power from fiber at various core diameter.

It can be seen from the above figure that for a certain fiber (fixed core diameter and NA), for a certain output power, number of chips change with brightness of chips, so does size and weight of pump source. To pump fiber lasers, pump sources with chips of different brightness have different weights and sizes even at the same output power, and different water coolers are also needed. High efficiency, small size and low weight are tendency of laser source, including diode laser, solid laser and fiber laser. Brightness, efficiency and power of diode laser chips play important role in improving these aspects.

3. LOW WEIGHT, HIGH BRIGHTNESS, HIGH POWER PUMP SOURCE

To match fiber combiners, conventional fibers are selected: 135μm NA0.22 and 220μm NA0.22. DSBC and polarization beam combination are used in the optical design of the two pump sources.

For 420W LD, 3.75W/mm·mrad@15W chips and 135μm core diameter NA0.22 fiber are used. VBG wavelength locking enables this device to lock its wavelength at 30~100% output power level. The electro-optical efficiency is 41%. The LD uses aluminum alloy and sandwich structure [5]. Chips on the upside and downside share the same cooling channels, more efficiently utilizing space in the casing. Arrangement of beam spots, spectrum and power in fiber are shown in the following figure:

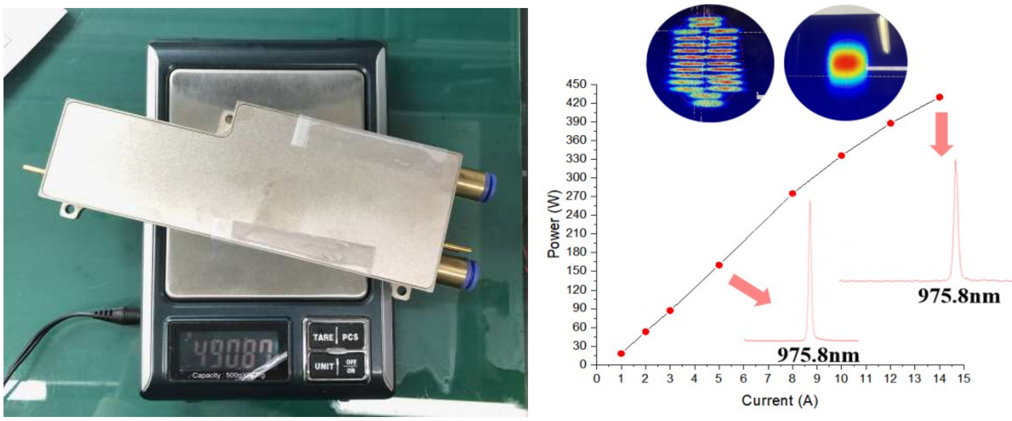

Figure 2. 420W@135μm NA0.22 LD.

Six modules went through thermal shock test and vibration test. Following are test results:

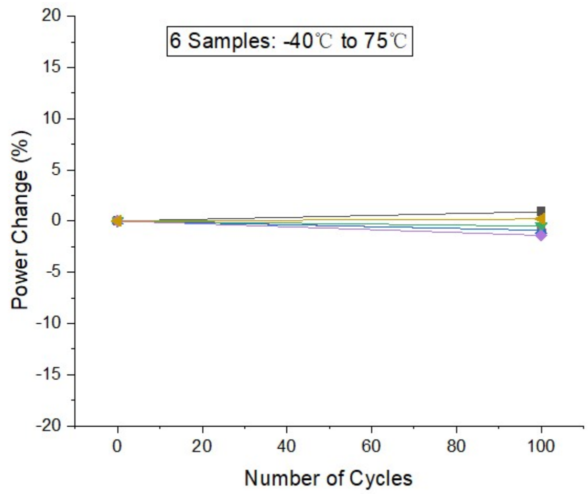

Figure 3.Thermal shock test.

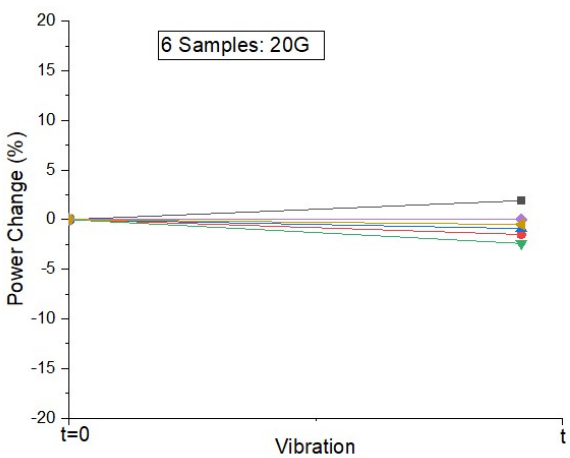

Figure 4. Vibration test.

1000W LD uses 3W/mm·mrad@30W chips and 220μm core diameter NA0.22 fiber. 1000W 915nm LD and 1000W 976nm LD can be realized respectively with electro-optical efficiency>44%. The LD also uses aluminum alloy. To achieve even higher ratio between power and weight, the casing is reduced while retaining necessary structural strength. Arrangement of beam spots and power in fiber are shown in the following figure:

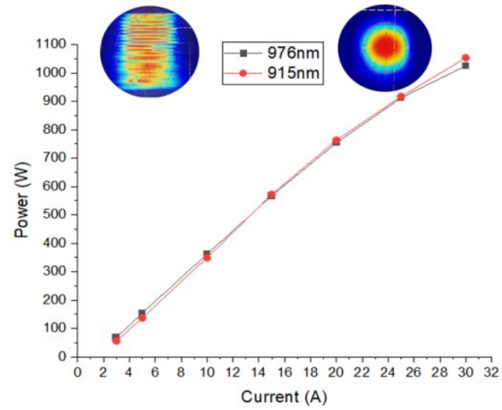

Figure 5. 1000W@220μm NA0.22 LD.

To improve reliability of the pump source, the coupling structure adopts quartz end cap fusion and cladding light filtering technology. Because of these technologies, temperature of fiber out of the pump source is near to room temperature when the output power is 1000W. Six modules went through thermal shock test and vibration test. Following are test results:

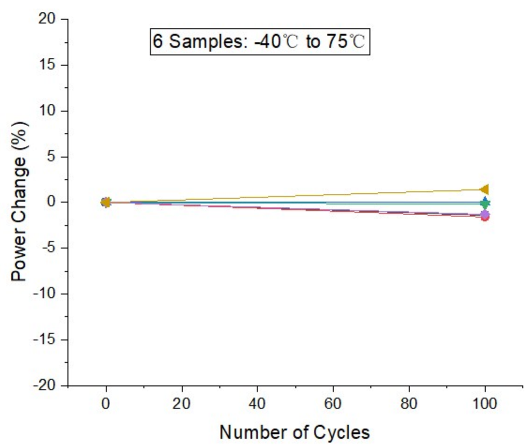

Figure 6. Thermal shock test.

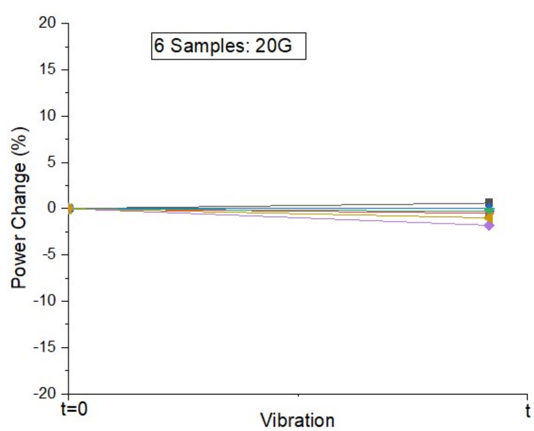

Figure 7. Vibration test.

4. CONCLUSION

High brightness output is achieved at the expense of electro-optical efficiency. That means, maximum output power and maximum electro-optical efficiency can not be obtained at same time. That is decided by brightness of chips and normalized frequency of fiber. In spatial beam combination of multiple single emitters, there is a balance between brightness and electro-optical efficiency. The prefered selection depends on specific application. For example, industrial applications and defence applications focus on different aspects and will have different selections.

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