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SPIE.

Event: SPIE LASE, 2023, San Francisco, California, United States

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ABSTRACT

On last year's SPIE conference, BWT has launched a pump source in weight around 500g, which was locked at 976nm, output 420W from a 135μm diameter and NA 0.22 fiber. In order to meet the need of higher output power pumping of fiber lasers, BWT has achieved 650W output from a 135μm diameter and NA0.22 fiber with a diode laser locked at 969nm and 982nm based on dense spatial beam combination (DSBC) and wavelength beam combination. In the absorption spectrum of Yb^{3+} ions, 969nm and 982nm have lower absorption coefficients than 976nm,. The active fiber with the same doping concentration will produce less heat accumulation per unit length, which has an obvious effect on improving the TMI threshold (transverse mode instability) and increasing the single-mode fiber laser power. With the enhancement of pump source brightness and the improvement of active fiber doping process and wave-guide structure, the power of single mode fiber laser directly pumped by diode laser is expected to exceed 10kW in the future.

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

1. INTRODUCTION

The brightness of diode laser pump source is one of the key factors in fiber laser power expansion [1], and the brightness of the chip directly determines the brightness of the pump source, but the brightness improvement of the chip is a slow process [2]. The brightness of the pump source can also be improved through polarization beam combining and wavelength beam combining technologies. In the category of incoherent beam combining, with the help of the dependence between spectrum and polarization with the half wave plate made of birefringent crystal, polarization beam combining can be used twice at most [3]. But the beam combining efficiency is lower than 90%. Thermal management related to the losses will become very troublesome in the design of higher power pump sources. Such technical solution will not be adopted in efficient and compact photoelectric systems.

For a long time, the dense wavelength division multiplexing (DWDM) technology in wavelength combining has been mature and simple in structure. Multi spectral efficient beam combining [4] can be achieved through filters or gratings, and it is easier to integrate into the pump source. Therefore, according to the absorption spectrum of Yb^{3+} ions in the fiber laser, selecting the appropriate target wavelength, and using VBG wavelength locking and narrowband filtering technology can effectively improve the brightness of the pump source.

2. THEORETICAL RESEARCH

2.1 Narrowband filter design

Narrow band filter is the key device for wavelength beam combining. The design of film structure and coating process play a decisive role in beam combining efficiency. According to the absorption spectral line of Yb^{3+} ions in the fiber laser, the beam combining wavelength is determined as 969nm and 982nm. In order to simplify the optical path and facilitate the installation and adjustment, the beam combining angle is 45°, and the target beam combining efficiency is>95%. Utilizing high refractive index coating layer and low refractive index film with an optical thickness of $\lambda 0/4$, which called $\lambda 0/4$ film system, based on the optical film theory [5]. The advantages of this type of film system are simple

Components and Packaging for Laser Systems IX, edited by Alexei L. Glebov, Paul O. Leisher,
Proc. of SPIE Vol. 12402, 124020C · © 2023 SPIE · 0277-786X
doi: 10.1117/12.2648594

calculation and preparation process. It is easy to use extreme value method for monitoring during plating, as shown in the figure below.

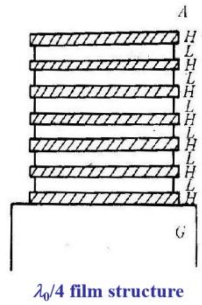

Figure 1. Structure of of coatings of the narrow band filter.

SiO_2 and Ta_2O_5 are used as film materials, with 0°incident wavelength of 1045nm and transmission efficiency of 100%. Theoretical calculation shows that under the 45°incidence condition, the beam combining efficiency of the p-polarization of 969 ± 0.5nm and 982 ± 0.5nm is greater than 98%. Even when the incident light is s-polarization, the average beam combining efficiency of 969 ± 0.5nm and 982 ± 0.5nm is greater than 94%, as shown in the figure below. In order to achieve the highest beam combining efficiency, VBG is used to control the spectral energy bandwidth containing more than 98% within 1nm, and p-polarization beam combining is selected.

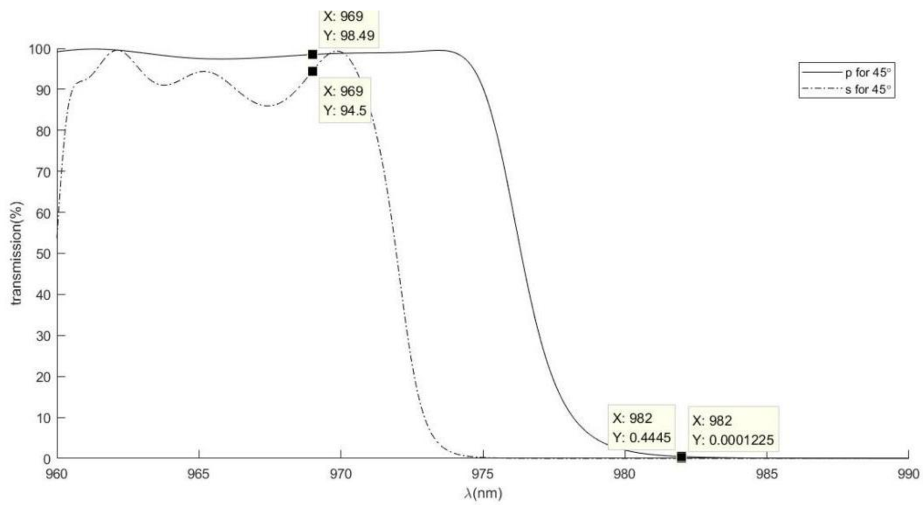

Figure 2. Transmission efficiency of the coating for p polarization and s polarization.

2.2 Pump source optical design

Optical design still follows DSBC [6], fiber combination is the easiest way to expand power of fiber laser pump. Based on principle of conservation of brightness, the higher the proportion of energy in 0.18/0.22NA, the lower loss of combiner's taper welding. The proportion of energy in NA0.18 reaches 96.621% in the design, such as the pic below.

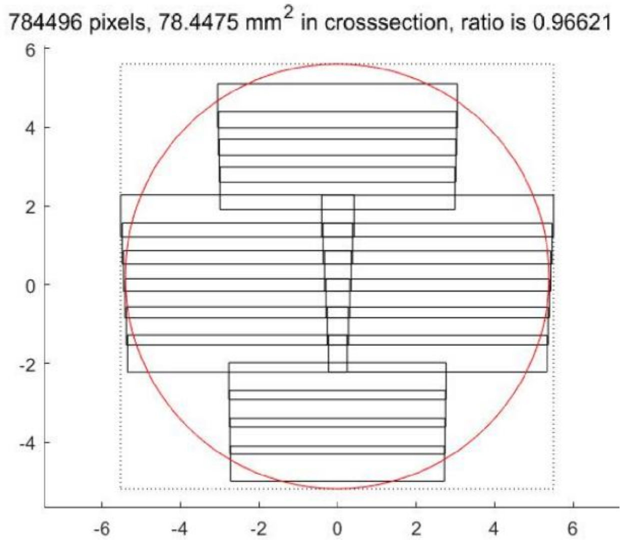

Figure 3. Simulated cross sections of beams on coupling lens. The circle represents an area that light power gets inside of it can be contained in the NA of the fiber.

Here's the whole optical design:

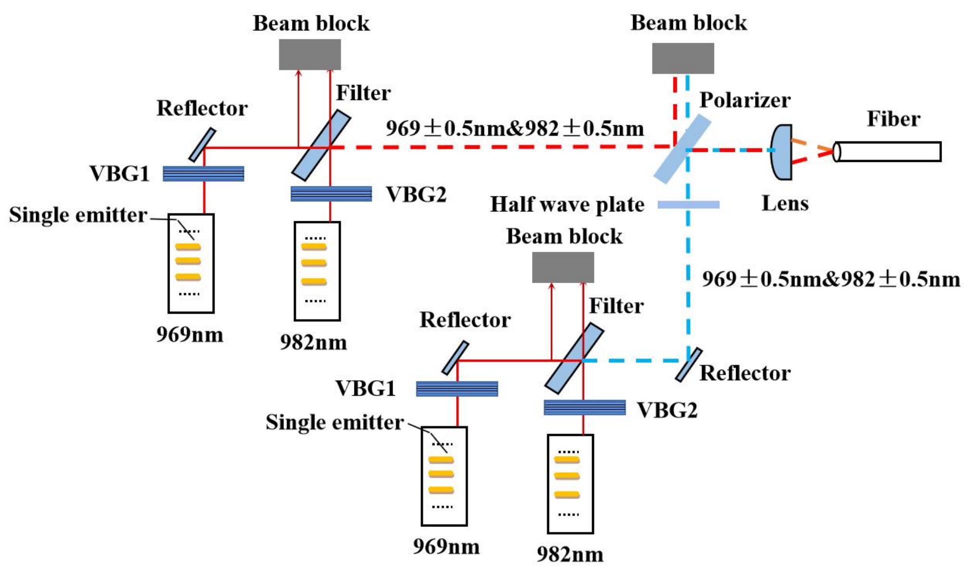

Figure 4. Schematics of the optical design.

Structure design use sandwich structure [7]:

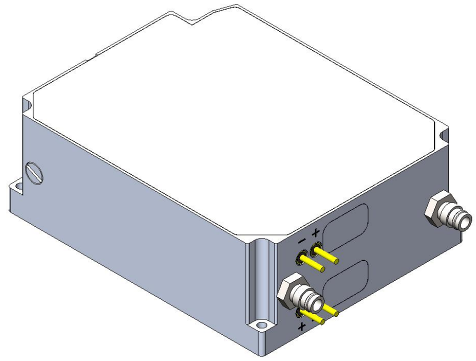

Figure 5. Housing of the laser.

3. EXPERIMENT RESEARCH

The spectral bandwidth containing 98% energy output through VBG locking can be effectively controlled within 1nm, and the signal-to-noise ratio can be kept above 20dB in the full current range, which can ensure a high wavelength beam combining efficiency in the full current range. However, due to insufficient process optimization, the average beam combining efficiency of the filter is only 90%, and the 969nm beam has a large loss.

The spectrum, spot, and power data are shown below.

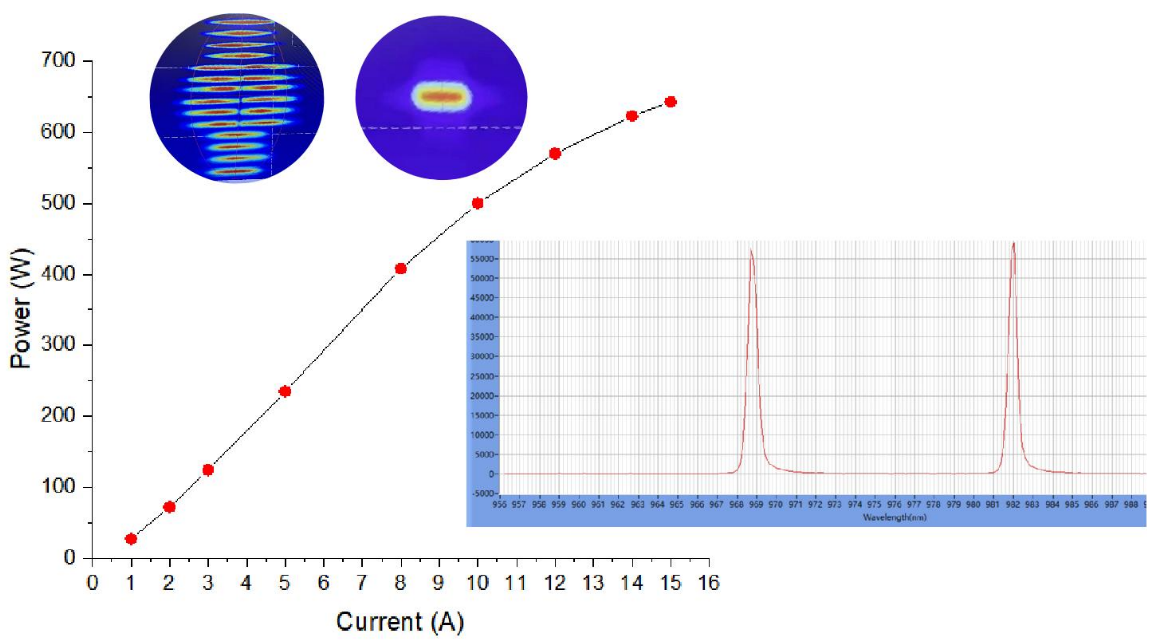

Figure 6. Measured beam spots and change of power vs current.

In order to improve the reliability of the pump source, the coupling end optical fiber adopts the quartz end cap fusion and cladding optical filtering technology, which makes the temperature of the optical fiber outside the pump source near the room temperature.

4. CONCLUSION

The experiment proves that before the chip brightness gets a breakthrough improvement, VBG and narrowband filter can effectively improve the brightness of the pump source, and the signal to noise ratio of VBG locked in the full current range and the reflection (transmission) rate of narrowband filter are the key factors to achieve high efficiency beam combining. Later, we will optimize the film system design and coating process, and try to increase the number of wavelengths of beam combining to improve the brightness of the pump source to a higher level.

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