kW class monolithic high power fiber laser combined with oscillator and amplifier

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A novel fiber laser, combining with oscillator and amplifier as one monolithic configuration has been demonstrated. This monolithic fiber laser achieves 1 kW power with near diffraction limited beam quality, wavelength centered at 1069.7 nm, 3 dB bandwidth of 1.3 nm. In experiment, the novel schematic fiber laser manifests anti-reflection property, and is promising for manufacture or other applications where high average power output and antireflection property are both required.

(Received October 7, 2016; accepted April 6, 2017)

Keywords: Fiber laser, Manufacture, Antireflection

1. Introduction

Fiber lasers have experienced rapid evolution since double cladding fiber and high brightness laser diodes emerge, and have been replacing solid-state lasers progressively in industry because of its high performance and scalability. IPG has demonstrated its 10 kW fiber laser with near diffraction limited beam quality and its 100 kW fiber laser with multimode beam quality [1,2]. Moreover, extensive efforts have been made in recent decades to increase the average power of fiber laser [3-5]. Nonlinearities become the main challenge for fiber laser technology while mode instability limits the output of average power and degrades the beam quality [6-8].

High power fiber laser based on MOPA configuration has demonstrated multi-kW average power output, while fiber laser based monolithic oscillator configuration, limited by the power load capacity of fiber bragg grating, has demonstrated much lower. However, in manufacture, where reflection light from metal is unavoidable, fiber laser based on monolithic oscillator configuration is superior. For MOPA configuration, reflection light can couple into output fiber, and be amplified by Yb-doped fiber (YDF) in the amplifier stage, thus becomes backward light with very high power. Consequently, the components between the oscillator stage and amplifier stage will be damaged, and causes the failure of the all fiber system. But for monolithic oscillator, reflection light which injects into fiber oscillator, will be reflected again as high reflection grating exists. Therefore, to develop a novel schematic to obtain high power operation with anti-reflection property becomes very important for fiber laser applied in manufacture.

In this paper, we report a kW fiber laser with a novel schematic combining the advantages of oscillator and MOPA configurations mentioned above. It has an optical conversion efficiency of 81.2%, central wavelength of 1069.7 nm, 3 dB bandwidth of 1.3 nm and beam quality of 1.2 measured by 4-sigma method. This kind of fiber laser is promising for manufacture or other applications where high average power output and antireflection property are both required.

2. Experimental

The schematic of kW fiber laser is shown in Fig. 1. The monolithic fiber laser is based on a MOPA configuration. However, fiber devices between oscillator stage and amplifier stage, such as mode filed adapter or signal/pump combiner is canceled compared with traditional ones. The oscillator is made up of a pair of fiber bragg gratings (99.9% and 10% reflection rate each with center wavelength of 1070 nm), 2 m long nufern 20/400 YDF and a 7×1 multimode bump combiner which has 7 laser diodes(LD) with 115W output centered at 976nm connected to its bump fiber arms. The amplifier stage is composed of a 12 m long nufern 20/400 YDF, a counter signal/pump combiner, a cladding power stripper (CPS), and an output quart block head (QBH). The counter signal/pump combiner’s bump arms are connected to 6 laser diodes with 115W output centered at 976nm. The CPS strips residual laser power in the fiber cladding to ensure a clean signal output and a good beam quality. As YDF in the oscillator stage is very short, bump laser power provided by 7 LDs cannot be fully absorbed and the laser signal output of oscillator stage is much lower compared with traditional ones. However, without the fiber devices between the two stages, the residual unabsorbed pump laser in the first stage can transmit to the amplifier stage through the output FBG with little loss, and a real bidirectional pump monolithic fiber laser configuration is formed. In addition, the assumed reflection light will transmit backwards to the first stage without any obstacles, then would be reflected by FBGS, and eventually output by the QBH. No devices could be damaged in this process.

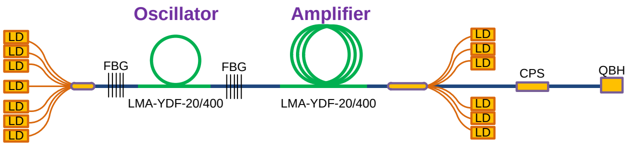

Fig. 1. Experimental setup

3. Results

In experiment, bump power output from fiber pigtails of the two combiners is firstly measured. During the experiment, it is very important that the LDs of the oscillator stage operates prior to those of the amplifier stage, which ensures the safe work of the fiber laser. The output power versus total bidirectional pump power is shown in in Fig. 2. The fiber laser has a maximum output power of 1218W while total bidirectional 1500W pump power is injected, which implies an optical efficiency of 81.2%. The output spectrum of the laser under different power levels is shown in Fig. 3. The center wavelength measured is 1069.7 nm. Due to self-phase modulation (SPM), and four wave mixing (FWM), the 3dB bandwidth of the spectrum is broadened from 0.4 nm to 1.3 nm with the increasing output power. As the fiber length of the laser is not very long (about 20 m), and the laser works at a relatively low power, no obvious stimulated Raman scattering (SRS) spectrum is observed.

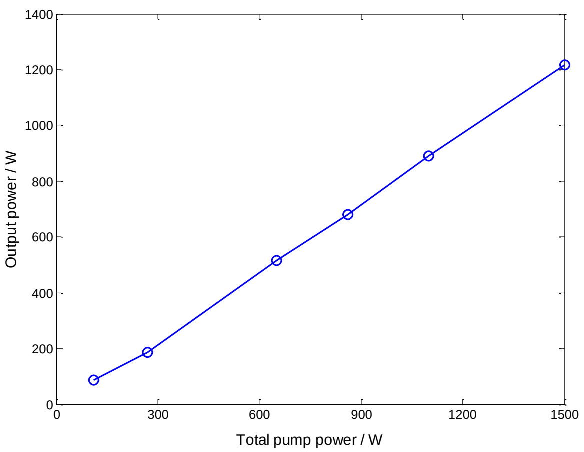

Fig. 2. Output power of the fiber laser vs. the total pump power

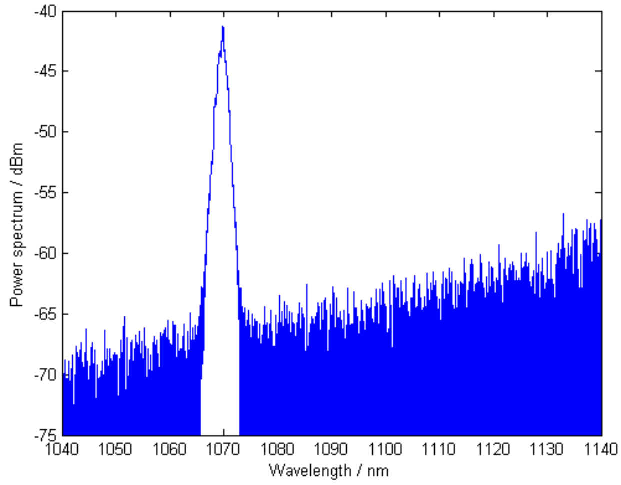

Fig. 3. Spectrum of the fiber laser at different output power

As the beam quality is concerned as an import factor to evaluate a fiber laser, we use 4-sigma method to measure the M2 factor of the laser at the maximum output power point. Fig. 4 shows the M2 factor measured by the M2 analyzer. The measured M2x and M2y is 1.247 and 1.288 respectively, which implies a good beam quality.

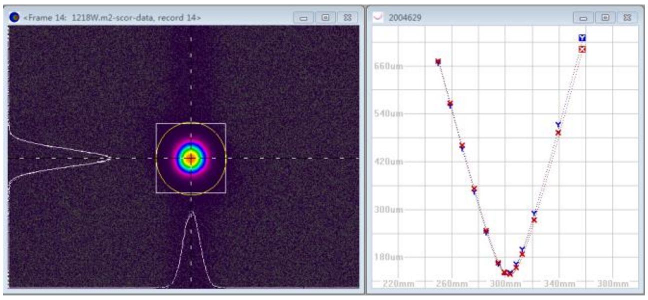

Fig. 4. Measured M2 factor of the fiber laser at the maximum output

To verify the anti-reflection property of the novel schematic fiber laser, we place a water cooled aluminum plate in front of the end of fiber laser with a distance of 20 cm and let it operates at its maximum output. The anti-reflection power from one fiber port of co-pumping combiner is measured as 0.03W, which is stable and safe for the system. 60 minutes later, the plate is removed and output power of the fiber laser is measured again. The fiber laser functions well and no power degradation is observed.

4. Discussion and conclusion

In this paper, we demonstrate a novel configuration, combining the advantages of oscillator and MOPA configurations. By canceling fibers devices between oscillator stage and amplifier stage in a traditional MOPA laser, a bidirectional pumped oscillator- amplifier monolithic configuration is realized. The laser attains 1.2kW power output while preserves a nearly diffractive-limited beam quality and its anti-reflection property is confirmed through the aluminum plate machining experimental test. Limited by the LDs, the laser only manifests a kilowatts operation. By increasing the LD numbers or single LD pump power, such laser is potential to attain much higher power output. We believe this fiber laser is promising for manufacture or other applications where high average power output and antireflection property are both required.

Acknowledgements

The research is funded by the program for the National Science Foundation of China (NSFC) (11404305, 11474257).

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