2.1 kW single mode continuous wave monolithic fiber laser

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Abstract: A monolithic 2.1 kW single-mode continuous wave fiber laser, operating at 1083 nm is demonstrated. The laser is pumped with commercial fiber pigtailed multimode diodes through all-fiber pump-signal power combiners in a bi-directional MOPA architecture. The 800 W signal from an 11 µm MFD oscillator is amplified to 2.1 kW in a 14 µm MFD stage, pumped with 2kW power at 915nm, for an overall fiber laser slope efficiency of 69%. Raman power is more than 30 dB below the 1083 nm signal power.

1. Introduction

During the last two decades, the output power of diffraction limited continuous wave (CW) Ytterbium-doped fiber lasers has dramatically increased to the multi-kilowatt level. Coupled with high wall-plug efficiency, good and stable beam quality, and high reliability, fiber lasers have penetrated into the commercial laser market. To date, a record 10 kW output power from an all-fiber tandem configuration single-mode Yb fiber laser has been demonstrated [1]. In that work, several lower-power short-wavelength fiber lasers were used to pump a 1070 nm signal laser. This approach overcomes pump brightness limitations, but lowered the laser's efficiency due to the lower Yb absorption at the 1018 nm pump wavelength. Lower power 1 to 3 kW fiber lasers [2-4] using direct diode pumping have been demonstrated in a single oscillator in a laboratory setup, where coupling of the 975nm pump power is attained by stacks of diodes and bulk optics. An all-fiber, alignment-free approach is preferred as being more flexible, robust and reliable. A 2kW monolithic fiber laser was demonstrated in [5] in a multiple-stage MOPA using 975 nm diodes in a side pumping technique. However parameters such as the amount of Raman light generated and device efficiency were not reported. The Raman light is an important parameter in determining delivery fiber length, power scalability, and in operation it is an indicative of how susceptible the fiber laser is to backward traveling Stokes light. Attempts to decrease SRS by increasing the mode field diameter (MFD) of the fiber have led to multimode lasing or modal instability. Finally, in [5] the diode laser wavelength was 975 nm. This is favorable to raising the Raman threshold since Yb has its highest absorption value at this wavelength, resulting in a shorter gain fiber length. However, the absorption peak at 975 nm is very narrow and thus, the pump diodes must be held at a specific temperature in order to maintain maximum efficiency. Although Yb absorption is lower, resulting in longer fiber lengths and increased nonlinearities, it is preferable to operate at 915nm where the amplifier's power level is less susceptible to fluctuations in diode parameters. In addition, the output power of 915nm fiber pigtailed laser diodes is continuously increasing and one can take advantage of these developments to realize compact all-fiber lasers with high output power and lower noise. We present an all-fiber, maintenance-free 2.1 kW system that uses end pumping with 915 nm diodes with a Raman level more than 30 dB below the signal level after 3 m of singlemode delivery fiber.

2. Experiments and Results

The all-fiber bi-directional MOPA architecture is shown in figure 1. The oscillator was formed with a high reflector (HR) and an output coupler (OC) fiber Bragg gratings written in

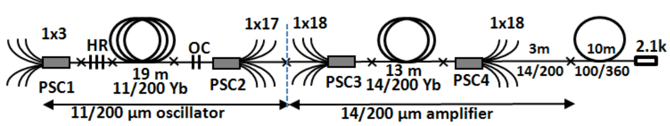

Figure 1. 2.1 kW MOPA configuration: 11/200µm oscillator and 14/200µm amplifier

11/200 μm (mode field/cladding diameter) single-mode (SM) fiber. The gain medium was a 19m OFS commercial 11/200 μm double clad Yb-doped fiber (DCY). Pump light was coupled to the oscillator using two OFS 11/200 μm pump-signal power combiners (PSC). A total of 20 commercially available 58W pump diodes at 915 nm were used to generate 800W of signal output with 72% conversion efficiency, as measured before the amplifier. The Raman power after the oscillator was more than 60 dB below the signal power. The amplifier was built using 13 m of 14/200 μm DCY and two (18+1)x1 PSC combiners with more than 95% pump and signal light transmission. A total of 2 kW of power from 36 diodes was used to bi-directionally pump the amplifier. The output was measured after 3 m 14/200 μm fiber, and 10 m 100/360 μm delivery cable. Total MOPA signal output power was 2.1 kW, corresponding to an amplifier slope efficiency of 77%, as shown in figure 2. The optical spectrum at full power was recorded (figure 3), showing that the Stokes power is more than 30 dB below the signal power. In figure 4, the signal to Stokes power ratio (OSNR) was plotted to determine power scalability. At maximum power, no modal instabilities, thermal effects, nor power rollover were observed. With higher power pumps, it is predicted that a power level of 2.6 kW can be achieved with the Raman level below 20 dB.

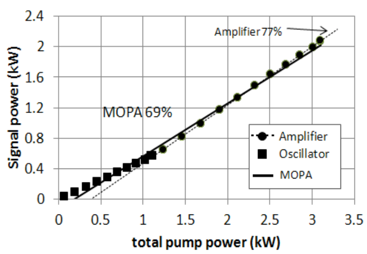

Figure 2. Fiber laser efficiency. Power measured at MOPA's output.

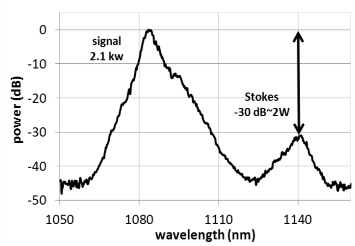

Figure 3. Optical spectrum at 2.1 kW. Signal λ=1084nm, Stokes λ=1140 nm

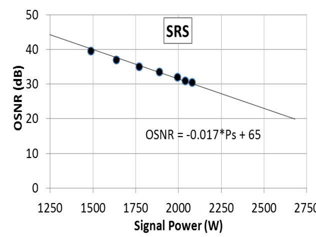

Figure 4. Optical spectrum at 2.1 kW. Signal λ=1084nm, Stokes λ=1140 nm

4. Conclusions

We have demonstrated a robust, alignment-free all-fiber 2.1 kW in single-mode CW monolithic end pumped fiber laser. Pump power coupling is achieved by bi-directional end pumping through >95% transmission pump-signal power combiners, and using commercial fiber-pigtailed pump diodes. Nonlinearities are minimized by employing LMA 11 μm and 14 μm MFD Yb gain fibers in a MOPA architecture, where Stokes power is more than 30 dB below signal power after 3 m of single mode delivery fiber.

5. References

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