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80 W green laser based on a frequency-doubled picosecond, single-mode, linearly-polarized fiber laser

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A picosecond single-mode, linearly polarized fiber source producing 176 W of average power was employed to generate up to 80 W average power at 530 nm by frequency doubling through a single LBO crystal.

1. Introduction

High average power green sources are of great interest for industrial and scientific applications. Although intracavity-frequency-doubled solid-state laser have produced output powers greater than 100 W, thermo-optic effects have degraded their output beam quality factor to values greater than 10 imposing a severe restriction for potential applications [1]. Thanks to their good thermal properties, laser sources based on rare-earth (RE) doped fibers are excellent for the generation of high beam quality, high average power beams, in the kilowatt range in continuous wave regime [2] and several hundred watts in pulsed operation [3]. Consequently high-power ytterbium doped fiber lasers are now competing with their bulk counterpart for frequency doubling to the green. Recently up to 60 W output power has been achieved by second-harmonic generation (SHG) from a fiber source pulsed at 10 MHz with 5 ns pulse duration [4]. For laser micromachining high repetition rate and picosecond pulsed sources are preferred, because of the reduced thermal effects. To date fiber based picosecond sources with several hundred watts of average output power have been demonstrated in Master Oscillator – Power Amplifier (MOPA) configurations. However, at high power nonlinear effects such as self-phase modulation (SPM) and stimulated Raman scattering (SRS) in the fiber may affect the laser output characteristics (e.g., linewidth) and subsequently the SHG efficiency. At the same time, efficient SHG in a crystal requires a high peak power, in the multi-kW regime in case of LBO. Pulsed sources with variable repetition rates allow the average power to be scaled to high powers, or reduced to low powers, while maintaining a fixed peak power that maximizes the SHG efficiency. Here we present the frequency-doubling of a picosecond 1060 nm fiber source with electrically controllable repetition rate in an LBO crystal.

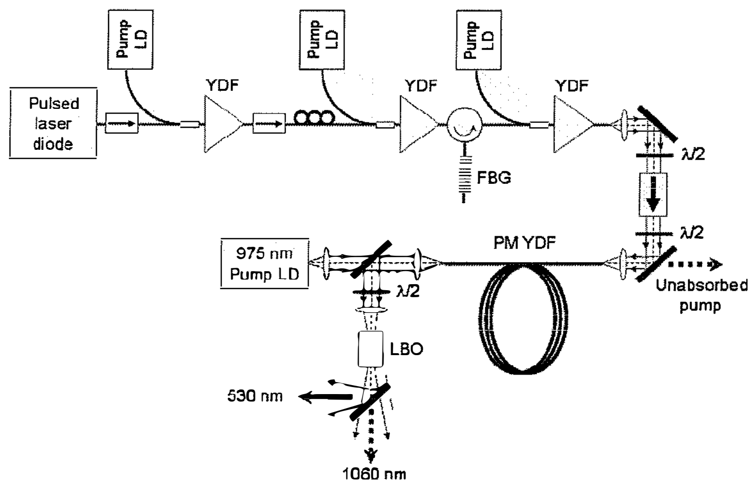

Fig. 1. Experimental set-up. FBG: fiber Bragg grating; YDF: ytterbium-doped fiber; PM: polarization maintained.

2. Experiment and results

The high-power green laser consists of a frequency doubled fiber MOPA system as shown in Fig. 1. It is composed of four cascaded ytterbium doped fiber amplifiers where the final stage includes a birefringent YDF cladding pumped by a high-power laser diode stack emitting at 975 nm. The high-power double-clad YDF was designed with diameters of 19 µm and 400 µm and numerical apertures (NA) of 0.08 and 0.48 for the core and D-shaped inner cladding, respectively. The fiber was 8 m long. The pump absorption was about 9 dB. The amplifier chain was seeded by a gain-switched laser diode system producing 80 ps pulses at 1060 nm as previously described in reference [3]. Although easily variable, the repetition rate was fixed at 120 MHz. The fiber laser could generate up to 176 W of average output power with a slope efficiency of 68% with respect to launched pump power (Fig. 2). SRS precluded higher peak powers and hence average powers at this repetition rate. At higher repetition rates, it was possible to reach output powers up to 210 W, however frequency conversion revealed instabilities above 180 W of fundamental power. The instabilities may be thermally induced, either in the fiber MOPA or the LBO crystal. The laser output beam at 1060 nm was linearly polarized with a polarization extinction ratio of 19 dB and was diffraction limited (M^2~1.05). The output spectrum obtained at maximum power shows an extinction ratio between the ASE and signal powers in excess of 30 dB at 0.2 nm optical resolution (presented in Fig. 3). The signal power within 1 nm was estimated to be higher than 96% of the total power. The laser linewidth was 0.5 nm.

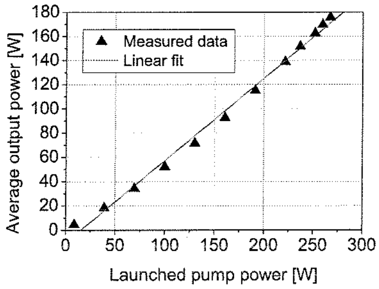

Fig. 2. Output power characteristics.

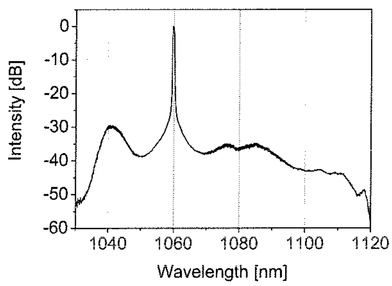

Fig. 3. Optical spectrum at maximum power (resolution = 0.2 nm).

The output laser beam at 1060 nm was focused into a 15 mm long LBO crystal for frequency doubling to 530 nm. The maximum power reached 80 W for a fundamental power of 176 W corresponding to a conversion efficiency of 46% (Fig. 4). The attainable peak power of 18 kW was still short of optimum for SHG. Higher conversion efficiency could be reached with higher peak powers or a longer nonlinear crystal. The frequency-doubled beam was nearly diffraction limited (M^2<1.15). We emphasize that while the repetition rate was fixed in Fig. 2, it had been optimized to achieve maximum power in the green.

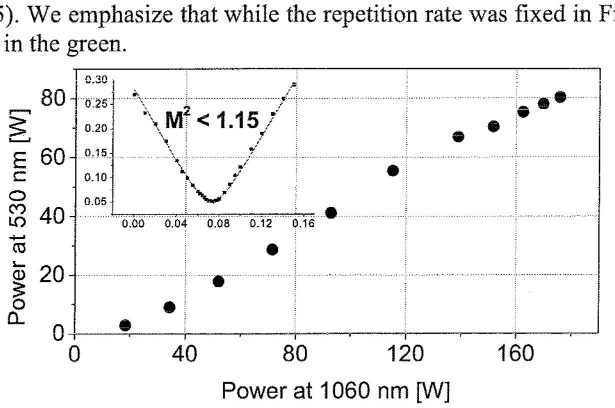

Fig. 4. Green power versus fundamental power. Inset: Beam quality measurement of the frequency-doubled 530 nm beam.

3. Conclusions

A diffraction-limited 80 W green laser was realized through frequency doubling a picosecond pulsed fiber source. The presented fiber MOPA has proved to be very suitable for nonlinear frequency conversion. Further power scaling beyond hundred watts with diffraction limited output beam appears feasible with modest modifications of the current fiber MOPA or frequency doubling configuration.

4. References

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