High peak/average power picosecond pulsed MOPA system with tapered large mode area double-clad Yb-doped fiber

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Abstract. In this paper, a high peak/average power picosecond pulsed master-oscillator power-amplifier (MOPA) system utilizing tapered large mode area double-clad fiber (T-DCF) is presented. In a high average power regime, we report a pulsed MOPA laser system with average power up to 613 W at 20 MHz repetition rate with 50 ps pulse duration (613 kW of peak power and 30.6 μJ pulse energy). In high peak power regime, over 3MW of peak power pulses (at seed source bandwidth) at 1 MHz repetition rate (310 μJ pulse energy and 310 W average) was demonstrated. The outstanding properties of T-DCF for amplification of laser signals to high power/energy levels with maintaining the excellent beam quality open a new horizon for advanced laser material processing.

1. Introduction

High power/energy pulsed fiber laser systems have been a topic of intense research owing to their outstanding characteristics, demanding for various fields of laser-induced applications, ranging from science to industry. However, owing to some nonlinear effects, amplification of high power/energy pulses through the common double-clad fiber faced strong limitations.

In 2008, a new concept of double-clad fiber, called taper double-clad fiber (T-DCF) was introduced, providing a new horizon for amplification of pulsed laser to high power/energy levels [1]. In T-DCFs, both core and clad diameters vary along the fiber length. The T-DCFs provide a varying large core diameter of up to 200 μm, resulting in the minimum non-linear phase shift and the high pump absorption capability. Since the size of the core gradually increases along the fiber length, the mode content does not change through the amplification process, leading to excellent beam quality. There are some representatives, [2,3], which indicate the tremendous potential of T-DCFs as a gain medium for high power/energy amplification of pulsed laser systems. As a case in point, T-DCF can be utilized as gain mediums in coherent beam combining of ultrafast laser systems [4].

In this work, a polarization-maintained high peak/average power picosecond pulsed MOPA system utilizing a large mode area Yb-doped T-DCF is presented. Amplification of high average power and high peak power picosecond pulses are demonstrated in sections 2 and 3, respectively.

2. Experimental setup

To investigate the amplification of high power/energy pulses, a MOPA system based on Yb-doped T-DCF was fabricated. Fig.1 illustrates the schematic configuration of the experimental high-power MOPA system, consisting of a seed source, two low power optical pre-amplification stages and a high-power optical amplifier based on T-DCF. A commercially available fibre-coupled gain-switched (GS) diode is used as a seed source at 1039.5 nm, with a 50 ps pulse duration and variable repetition rate in the range of 1 to 20 MHz. The pre-amplification stages can provide up to 40 and 100 mW average power in 1 and 20 MHz, respectively. The amplified radiation of the seed source is coupled through a high-power optical isolator into the narrow end of an active polarization-maintaining tapered double-clad fiber (PM-T-DCF).

The Yb-doped PM-T-DCF has a length of approximately 7.7 m, core NA = 0.1, cladding NA = 0.26, and core/cladding ratio of 1/10 (input/output core diameter ≈10/ 98 μm). For effective thermal management, the entire T-DCF was coiled on a water-cooling Aluminium plate with custom made grooves. A 2-degree polished angle silica glass endcap (diameter of 9 mm and length of 20 mm) covered by antireflection coating at 976-1040 nm was spliced to the wide end of the T-DCF. The pump unit consists of seven commercially available wavelength-stabilized laser diodes with central emission at 976 nm, combined via a 7 ×1 combiner with an output fiber of 200/220 μm. Using a dichroic miror (to separate the pump and signal light) and a lense, up to 902 W pump light was launched into the T-DCF in free space.

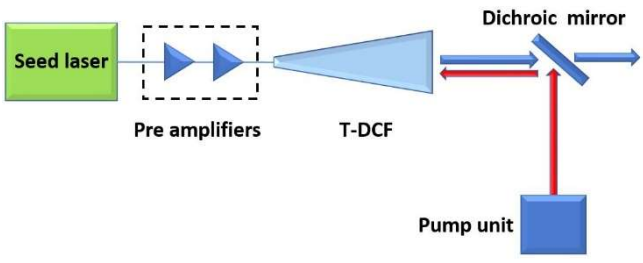

Fig.1. Scheme of the MOPA experimental setup with T-DCF.

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3. High average power picosecond pulsed MOPA system with T-DCF

To investigate the T-DCF for amplification in high average powers, a GS seed laser was operated at 20 MHz. By utilizing 7 diodes at full power, a pulsed MOPA laser system with an average power of 613 W (613 kW of peak power and 30.6 µJ pulse energy) with 68.5% slope efficiency was achieved. At this power, the signal-to-noise ratio (SNR) of the Stimulated Raman Scattering (SRS) peak was 20 dB. The spectrum of the output laser at maximum power and the output power versus the total pump power is shown in Figures 2 and 3, respectively.
The profile of the beam, coming out of the fiber facet at the far field is shown in figure 4. The beam quality measurement (M^2 factor) at 100 W output average power is depicted in Figure 4, with the profile of the beam presented in the inset.

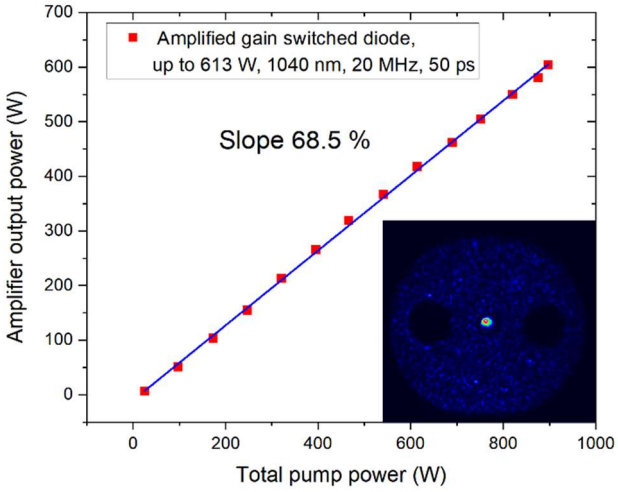

Fig.2. Output spectra of high power MOPA system at the maximum achieved power.Inset: the far-field beam profile and the fiber facet image.

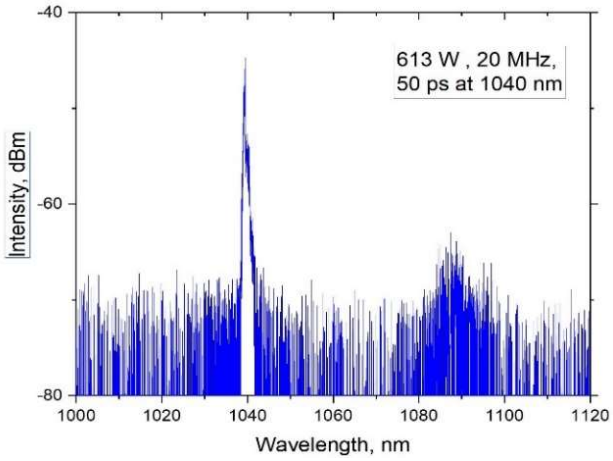

Fig.3. Output power of MOPA system vs total pump power.

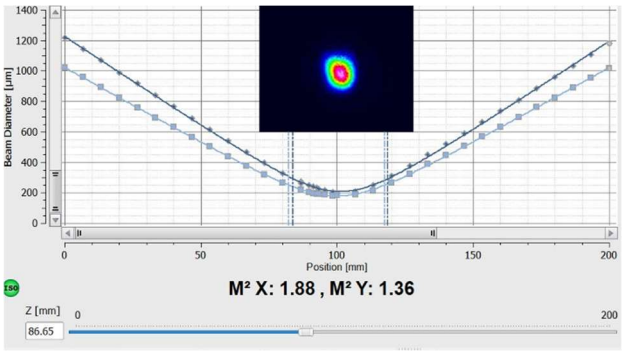

Fig.4. The result of the beam quality measurement at 100 W output average power at 20 MHz 1, with the beam profile inset

4. High average power picosecond pulsed MOPA system with T-DCF

To investigate the T-DCF in amplification to high peak powers /energy levels, we utilized a GS seed laser operating at 1 MHz. By injecting the seed laser and increasing the pump, a pulsed MOPA laser system delivered 310 W of average power and 6.2 MW peak power (310 µJ pulse energy), with an optical efficiency of 56 %. The spectrum of the output laser at the maximum power is depicted in Figure 5. As can be seen, from the perspective of inline amplification, around 13 dBm was the SNR of the SRS.

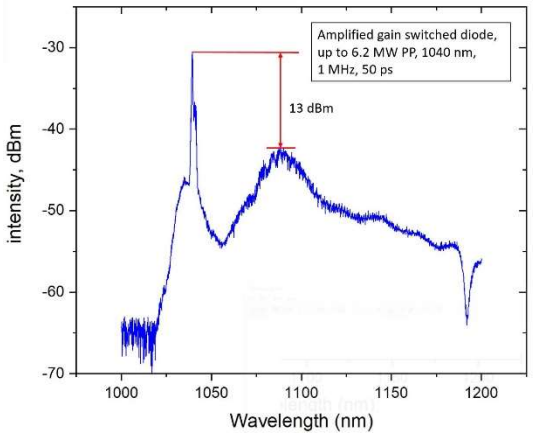

Fig.5. Output spectra of high power MOPA system at 1 MHz repetition at the maximum achieved output power.

5. References

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