200W Gain-Switched-Diode-Seeded, Single-Polarization, Narrow-Linewidth, All-Fiber, Picosecond MOPA

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Abstract: We report a fully fiberized, single-polarization, gain-switched, diode-seeded fiber MOPA delivering 28ps pulses at a repetition frequency of 214MHz with 200W of average output power and up to 0.93µJ pulse energy.

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1. Introduction

High-power lasers operating in the picosecond regime are currently in demand for a number of applications including laser machining, material processing and frequency-doubling. Ti:sapphire lasers are commonly used for these applications, but recent demonstrations of fiberized master-oscillator-power-amplifier (MOPA) systems provide an alternative solution and are capable of operating at much higher average power levels. Up to 157W of output power was demonstrated recently using a mode-locked laser seeded MOPA [1], whilst a gain-switched laser-diode-seeded MOPA produced an output power in the region of 100W [2]. It is worth noting that such high average power sources combined offering high repetition rates and single polarization output are becoming increasingly interesting for the pumping of optical parametric oscillators (OPOs) [3].

Herein we report a fully fiberized gain-switched laser-diode-seeded MOPA system generating linearly polarized, 28ps pulses at a repetition frequency of 214MHz with a maximum average output power of 200W.

2. Experimental Setup

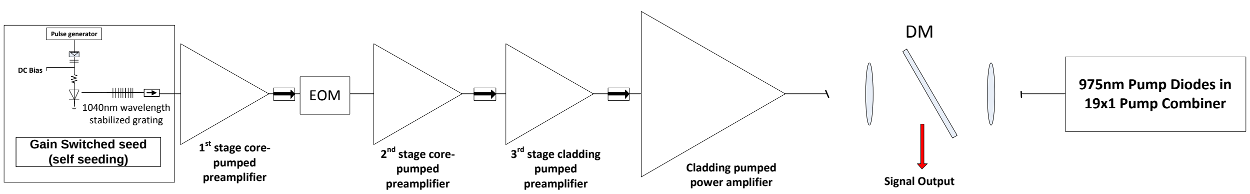

Figure 1: Fully fiberized picosecond seed laser based YDFA MOPA system incorporating 4 amplifier stages.

A schematic of our experimental setup is shown in Figure 1. A 1040nm Fabry Perot laser diode (3SPhotonics) with a polarization maintaining (PM) fiber pigtail was gain-switched using a stable train of sinusoidal electrical current pulses superimposed upon a DC bias. The pigtail of the semiconductor laser diode (SLD) was spliced to a PM fiber Bragg grating (FBG) with a 3dB bandwidth of 0.24 nm and a reflectivity of 7.2%. The repetition frequency was tuned to 858 MHz to achieve synchronization between the emitted pulses from the diode and reflected pulses from the FBG. The measured side-mode suppression ratio (SMSR) was ~40dB with a polarization extinction ratio (PER) of over 20dB. This gain switching technique, whereby a uniform FBG has been used for the self-seeding mechanism, produced near-transform-limited pulses (time-bandwidth product estimated to be 0.53 assuming Gaussian-shaped pulses) with a FWHM of ~28ps and a pulse energy of 7pJ. The pulses were then amplified in a four-stage PM ytterbium-doped fiber amplifier (YDFA) MOPA chain.

The first stage amplifier consisted of a 50cm-long core-pumped YDFA (5µm core and 130µm cladding diameter) pumped by a 180mW single-mode 976nm pigtailed laser diode. An average output power of 50mW was obtained from this stage. It was then coupled into an inline electro-optic modulator (EOM), which was operated as a pulse picker in order to reduce the pulse repetition frequency. An average power of 4mW was measured at the output of the EOM when the operating frequency was brought down to 214 MHz. Due to the excess loss of the EOM, a second core-pumped YDFA with an active fiber length of 1m was used to ensure adequate seeding of the cladding-pumped third-stage amplifier. The maximum output power from this second-stage amplifier was 20mW.

The third-stage YDFA comprised a 2.5m-long cladding-pumped large-mode-area (LMA) fiber with a core diameter of 10μm, 0.08 NA and an inner-cladding diameter of 125μm, 0.46 NA. The fiber was co-directionally pumped by a 10W, 975nm multi-mode (MM) pump diode through the use of a fiberized (2+1) x 1 MM pump combiner. A maximum average output power of 2.6W was obtained from this stage. The output was then taper-spliced to the final-stage amplifier, comprised of a 2.6m-long LMA fiber with core and cladding diameters/NA of 30μm/0.06 and 250μm/0.46 respectively (NUFERN PLMA-YDF-30/250-VIII). The tapered splice ensured single-mode operation whilst the use of a fast-axis blocking PM isolator ensured single-polarization seeding to the final-stage amplifier. The fiber was counter-pumped via free-space coupling. A dichroic mirror (DM) was used (as shown in Fig. 1) to separate pump and signal beams. An end cap was spliced to the output of the LMA fiber to avoid damage to the end facet.

3. Results

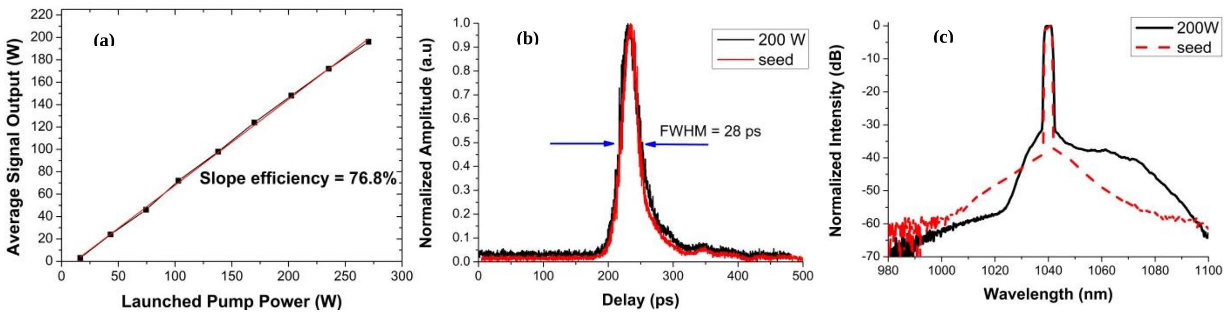

Figure 2(a) Overall slope efficiency at 214 MHz, (b) Pulse shapes measured with 32GHz photo-detector, (c) Spectra measured with 2nm resolution with center wavelength at 1040nm.

A maximum output power of 200W was obtained with a total launched pump power of 270W as shown in Figure 2(a), corresponding to a slope efficiency of 76.8% (around 90% of the launched pump power was effectively coupled into the active fiber). A pulse energy of 0.93μJ and a peak power of 33kW were obtained at a pulse repetition frequency (PRF) of 214MHz. The total end-to-end gain achieved in this system was ~51dB. The measured PER was more than 13dB while the M^2 value was measured to be ~1.1. As shown in Figure 2(b), no significant temporal distortion was observed even at the maximum output power. The full width at half maximum of ~28ps at 200W was directly measured with a wideband photo-detector and oscilloscope. Figure 2(c) compares the spectra before and after the fiber MOPA chain. The amplified spontaneous emission (ASE) is suppressed by more than 30dB below the signal peak at the maximum operating output power of 200W. With such a high optical signal-to-noise ratio (OSNR), further power scaling is possible; the only limitation on maximum peak power being the introduction of nonlinear effects, especially stimulated Raman scattering (SRS). Further details on signal amplification at lower PRF will be presented at the meeting.

4. Conclusion

We have demonstrated a 200W, single polarization, 28 ps pulse source, based on a gain-switched, diode-seeded, all-fiber MOPA. A pulse energy of 0.93μJ and a peak power of 33kW were obtained. The experimental results show that further power scaling and pulse-energy extraction will be possible in due course from this system.

5. References

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