16-µJ Pulse Energy, Picosecond, Narrow-linewidth Master Oscillator Power Amplifier Using Direct Amplification

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Abstract: We present a gain-switched-diode-seeded 1034.5-nm master oscillator power amplifier, employing direct amplification through standard commercial Yb^{3+}-doped fibres to generate 15.6µJ-pulse-energy, 126kW-peak-power, picosecond pulses with 3dB spectral bandwidth of 0.87nm.

OCIS codes: (060.2320) Fiber optics amplifiers and oscillators; (060.4370) Nonlinear optics, fibers; (140.3280) Laser amplifiers; (140.3538) Lasers, pulsed; (250.4480) Optical amplifiers; (250.5960) Semiconductor lasers; (320.5390) Picosecond phenomena

1. Introduction

High-power and high-energy pulsed fibre laser sources in the picosecond regime are of great interest for applications such as material processing and nonlinear frequency conversion. Power scaling through a mode-locked-fiber-laser-seeded master oscillator power amplifier (MOPA) has previously been demonstrated to deliver an average output power of 125W but the pulse energy was limited at 0.12µJ, with a corresponding peak power of 9.6kW [1]. On the other hand, energy scaling through a gain-switched-laser-diode-seeded MOPA was able to output 100ps pulses with pulse energy of 8.6µJ and a peak power of 86kW, while the average power was limited at 62W [2].

Here we present an all-fiberized polarization-maintaining MOPA system, which is seeded by a gain-switched laser diode, capable of generating high-energy and high-power picosecond pulses. The system employs direct amplification through standard commercial Yb^{3+}-doped fibres to generate 124ps pulses with energy of 15.6µJ at 5.47MHz, corresponding to a peak power of 126kW. The pulses have a 3dB spectral bandwidth of 0.87nm centered at 1034.5nm and an average power of 102W has been obtained at the output of the system.

2. System Configuration

As depicted in Fig. 1, the all-fiberized picosecond MOPA consists of a gain-switched laser diode as the seed, followed by a 4-stage Yb^{3+}-doped fibre-amplifier chain. A 1030-nm Faby-Perot laser diode (Oclaro), gain-switched by a train of RF pulses running at a repetition rate of 87.5MHz, is self-seeded by a uniform fibre Bragg grating (QPS Photronics) to generate 120-ps 3.77-pJ pulses at 1034.5nm with a 3dB spectral bandwidth of 0.026nm. A fibre pigtailed electro-optic modulator (Photline) is used as a pulse picker in the chain to reduce the repetition frequency to 5.47MHz. Three pre-amplifiers are used to realize enough signal power to seed the final-stage power amplifier. The pulses are fed into the power amplifier through an in-house-made tapered section to maintain a single-mode operation. Fiberized isolators are used to prevent backward amplified spontaneous emission (ASE) leakage between stages.

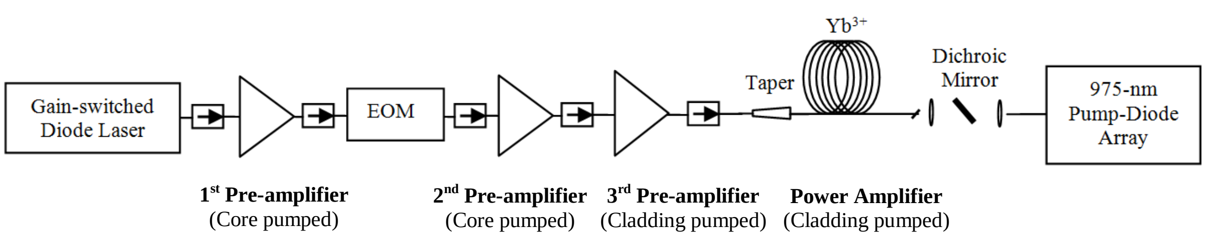

Fig. 1. All-fiberized polarization-maintaining Picosecond Yb^{3+}-MOPA system seeded by a gain-switched laser diode

The power amplifier consists of a 2.5m- long standard commercial large-mode-area (LMA) Yb^{3+}-doped fibre (Nufern PLMA-YDF-25/250-VIII), which has a core diameter of 25µm with an NA of 0.06 and a cladding diameter of 250µm with an NA of 0.46. A silica end-cap is spliced to the output end of the fibre to reduce the risk of facet damage. An array of 975-nm multi-mode pump diodes are then combined to free-space backward-pump this LMA fibre. A launching efficiency of 95.5% has been achieved.

3. Experimental Results

The energy and power of the 120ps pulses are boosted through the power amplifier. At the output of the MOPA system, pulse energy of 15.6μJ and peak power of 126kW have been achieved. This is estimated by excluding the contributions from the ASE and stimulated Raman scattering (SRS) to the 102W average power that is obtained at the output of the MOPA. The pulse energy is scaled up by 66.2dB through the MOPA system and an output polarization extinction ratio (PER) of 12.3dB is obtained.

The 3dB spectral bandwidth is broadened to 0.87nm due to self-phase modulation (SPM) in the power amplifier stage. The graph in Fig. 2 shows the evolution of the spectral bandwidth at different average output power of the MOPA system, while the inset shows the output spectrum measured at 0.5nm resolution when the pulse energy reaches 15.6μJ. The peak around 1080nm is due to SRS. In the temporal domain, the pulse is only slightly broadened to 124ps, as shown in Fig. 3. The average output power of the MOPA system is plotted against the launched pump power in Fig. 4, with a corresponding slope efficiency of 79%. Further energy scaling with the current system is limited by the SRS level.

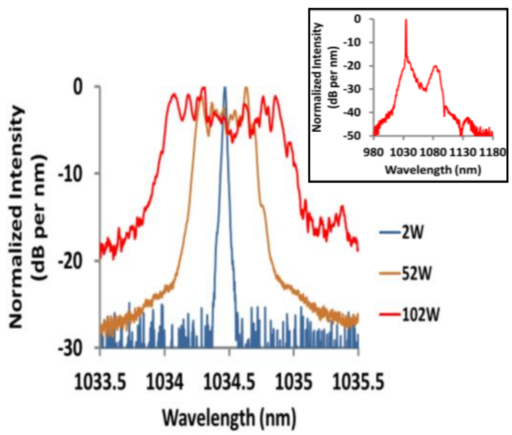

Fig. 2. Spectrum at different average output power of the MOPA system (resolution=0.01nm)
Inset: Spectrum at 102-W output power of MOPA, with an estimated pulse energy of 15.6μJ (resolution=0.5nm)

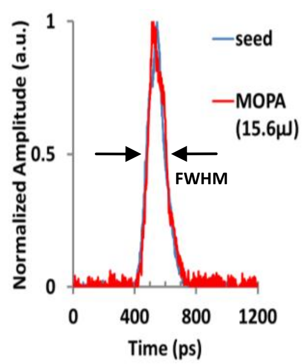

Fig. 3. Temporal pulse before and after the MOPA
Pulse duration measured at the full width at half-maximum (FWHM)

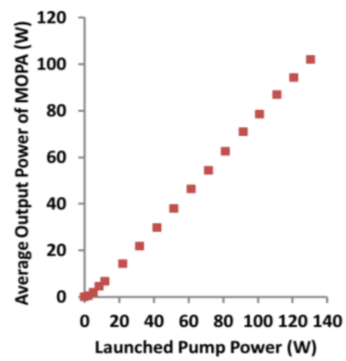

Fig. 4. Average output power versus launched pump power in the final amplifier

4. Summary

We have presented an all-fiberized polarization-maintaining gain-switched-laser-diode-seeded MOPA system that is capable of producing high-energy and high-peak-power picosecond pulses. It employs direct amplification through standard commercial Yb^{3+}-doped fibres to generate 124ps pulses with an energy gain of 66.2dB, reaching 15.6μJ at 5.47MHz and a peak power of 126kW. The pulses have a 3dB spectral bandwidth of 0.87nm centered at 1034.5nm. The PER is measured to be more than 12dB at the maximum average output power of 102W. Such a high-pulse-energy high-power picosecond fiberized MOPA is of great interest in many technological applications including material processing and nonlinear frequency conversion.

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5. References

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