Ultra-short pulse Yb^{3+} fiber based laser and amplifier system producing >25W average power

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We have demonstrated an ultra-short-pulse Yb^{3+}-fiber laser and amplifier system that produces >25 W average power. The output pulses were recompressed to a duration of 110 fs using a standard bulk grating-based compressor.

For the increasing number of applications demanding ultra-short pulses at high average powers, diode-pumped Yb^{3+} -fiber technology represents an attractive solution. It has been shown that high power pulses in a fiber amplifier with normal dispersion evolve towards parabolic pulses with a linear chirp, which enables recompression to short durations despite significant self-phase modulation in the fiber [1]. Parabolic pulses from Yb^{3+} -fiber amplifiers have been demonstrated with average powers up to 17 W (pulse energy 230 nJ) using a bulk glass seed laser [2], and up to 13 W (pulse energy 260 nJ) using a fiber based seed laser [3]. Here we report both a higher average power of >25W, and higher pulse energies of 410 nJ from an all Yb^{3+} -fiber system. A conventional bulk-grating compressor was used to remove the linear chirp, resulting in 110 fs pulses. We note that by using the CPA technique to avoid nonlinear effects, fiber-based systems producing 75 W average power have been demonstrated, albeit with substantially longer output pulses (400 fs), and requiring a more complex and less compact setup [4].

Fig. 1. shows a schematic of our system. We used a diode pumped mode-locked Yb^{3+} -fiber seed laser [5] followed by two Yb^{3+} -fiber amplifiers. The oscillator produced ~30pJ pulses at 62 MHz repetition rate centred at 1055 nm. The pulses have a positive linear chirp with a spectral FWHM of 20 nm and FWHM duration of 1.8 ps. The fiber amplifiers have low NA, large mode area core design doped with 8000 ppm by weight Yb^{3+} ions, and they were optically isolated to suppress cascaded ASE. The first amplifier fiber was pumped at 975 nm, has a length of 1.6 m and core and inner cladding diameters of 20 μm and 200 μm respectively. The second amplifier fiber was pumped at 972 nm, had a length of 4.0 m and core and inner cladding diameters of 40 μm and 400 μm. Amplifier efficiency with respect to absorbed pump power was 79%. By carefully launching the seed pulses to excite just the fundamental fiber mode, we obtained close to single mode output from the system.

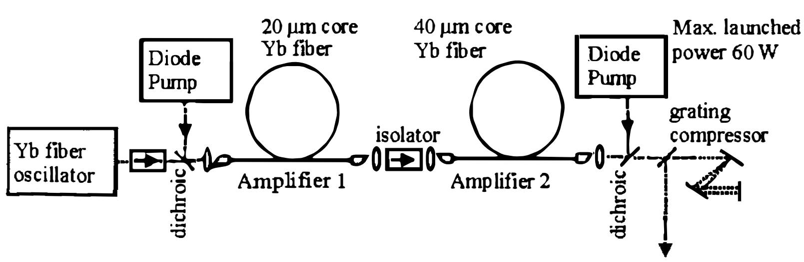

Fig. 1. Schematic of parabolic amplification system

The output pulses were compressed using conventional bulk gratings with 830 grooves/mm. The grating separation was optimised experimentally by minimising the width of the recompressed pulse autocorrelation. Due to power handling constraints imposed by our gratings, we passed only a fraction of the uncompressed pulse output power through the compressor. However, this power handling capacity would be substantially increased using suitably optimised gratings. Fig. 2. shows that the optimum grating separation reduced significantly as the pulse energy was increased, which demonstrates the strong nonlinear evolution from linear propagation (lowest powers) towards the parabolic pulse form at high powers.

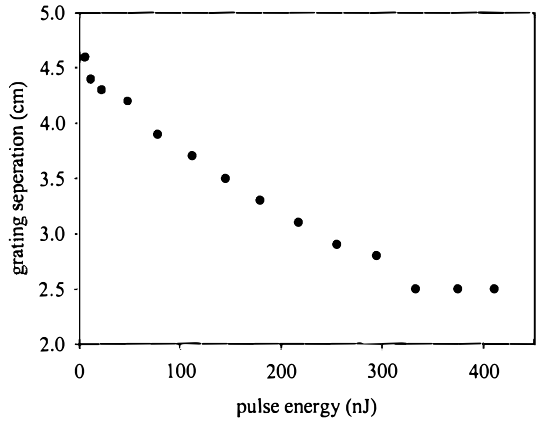

Fig. 2. Grating separation required to compress pulses

The spectrum and autocorrelation of the pulses are shown in Fig. 3. (a) and (b) respectively. The spectral bandwidth of the high energy pulses was ~20 nm. The measured autocorrelations correspond to pulse durations of ~160 fs at low energy and ~110 fs at 410 nJ. The autocorrelations demonstrate that the pulses did not have large pedestals and that the pulse quality was good ($\Delta\nu\Delta\tau$ ~0.6) for pulses with energies up to 410 nJ. We note that the system also produced pulses at higher average powers of up to 40 W without the onset of significant Raman scattering. However for these higher energy pulses the nonlinear spectral broadening was excessive, and the quality of the recompressed pulses was reduced.

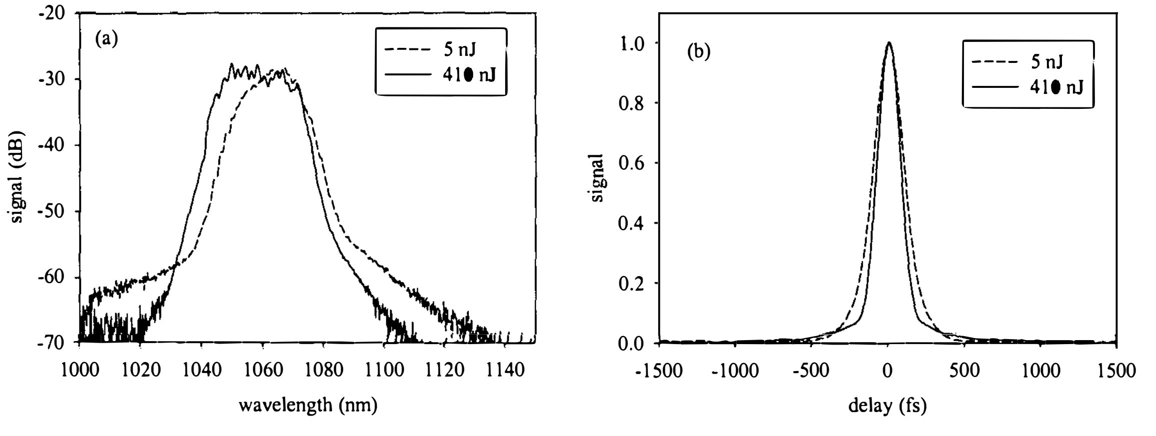

Fig. 3. (a) spectra and (b) autocorrelations of low (5 nJ) and high (410 nJ) energy pulses

In conclusion, we have demonstrated an all Yb^{3+} -fiber oscillator and amplifier system which produced >25 W average power, with pulses recompressible to a duration of 110 fs.

References

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