**CTuQ5** **3:30 pm**

## 7.7 mJ pulses from a large core Yb-doped cladding pumped Q-switched fibre laser

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Double-clad rare-earth doped fibre lasers pumped by high brightness laser diodes are very efficient and compact sources of cw and pulsed radiation.[1,2] For Q-switching, fibre lasers are limited by the build-up of amplified spontaneous emission (ASE) between pulses. Rayleigh backscattering and fibre facet damage are other important issues that need to be considered. The ASE limit is relaxed if large-core fibres are used, however, at some point the fibre becomes multimoded. This is often undesirable. We have previously studied Q-switching of large-core Yb-doped fibre lasers, including those with special core designs for enhancement of the beam quality (so-called large mode area fibres).[3]

Also in this paper, we investigate Q-switching of a large-core cladding-pumped Yb-doped fibre laser, but here, we focus on maximizing the pulse energy and pay less attention to beam quality. We used a fibre with a 60 µm core (NA 0.05, simple step index design) and a 300 µm inner cladding diameter. The inner cladding was non-circular to improve the pump absorption. The fibre was silicone-coated, giving a nominal NA of 0.4 for the inner cladding. As a rule of thumb, the maximum extractable energy (as limited by ASE or spurious lasing) is around ten times the saturation energy,[4] which in this case gives:

$$E_{ext} \approx 10 \cdot \frac{h\nu_s A}{(\sigma_{es} + \sigma_{as}) \cdot \Gamma_s} = 20 \text{ mJ}$$

Our experimental set-up is shown in Fig. 1. We could launch up to 30 W of pump power into the fibre from two beam shaped 915 nm diode bars. With a free-running fibre laser with feedback from perpendicularly cleaved ends, the double-ended output power reached 17 W. When we inserted the AOM the power dropped to 10.2 W (single-ended) with the AOM always on (with feedback for the first-order beam).

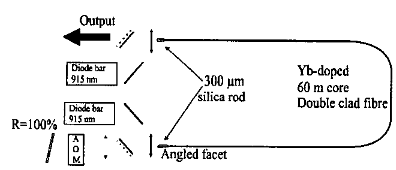
The low core NA and a short fibre length (3.5 m) helped to reduce Rayleigh backscattering.[4] To avoid facet damage, we spliced at both fibre ends a 3 mm piece of 300 µm core-less fibre (silica rod). The signal beam expanded inside these fibres to a larger diameter. This eliminated the damage problem and also reduced the feedback from the fibre ends. The beam expander sections were supposed to increase the spot size up to 300 µm, but they were slightly too long to preserve the beam quality.

We then Q-switched the laser by on-off modulating the AOM. The pulse energy and average output powers (without ASE) are shown in Fig. 2. The average power curve includes ASE, which accounted for as much as 30% of the average power at 500 Hz. At that repetition rate, the pulse energy was 7.7 mJ. We did not observe any fibre facet damage, nor any spurious lasing between pulsing.

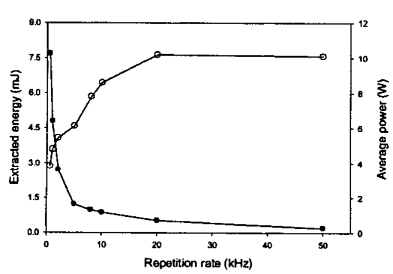
Even though we are below the ASE-limit, the presence of ASE indicates that even higher pulse energy could be obtained if the ASE could be avoided. However, we could not use ASE seeding/recirculation as in[1] to increase the pulse energy since the laser wavelength coincided with the ASE peak at 1037 nm. However, we believe that with a longer fibre, the laser would shift to longer wavelengths. This would allow us to recirculate the ASE and reach even higher pulse energies.

The pulse shape is shown in Fig. 3. Because of the short fibre length we had clean single pulses of a relatively short duration (250 ns). Thus, we reached a peak power as high as 30 kW.

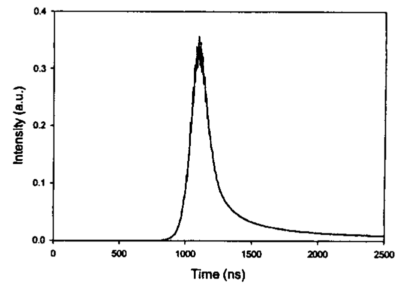
We measured the beam propagation parameter ($M^2$) to be 31. This was much higher than the value measured without the 3 mm core-less fibre termination ($M^2 = 7$). We expect to be able to improve the beam-quality with a shorter termination, (which, however, is difficult to manufacture.) and/or by incorporation of a mode-selective mechanism within the cavity.




CTuQ5 **Fig. 1.** Experimental set-up.




CTuQ5 **Fig. 2.** Extracted energy (black) and average power (white) against the repetition rate.




CTuQ5 **Fig. 3.** Q-switched pulse shape at 500 Hz.

### References

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