Designs for efficient high-energy high brightness Q-switched cladding-pumped ytterbium-doped fibre lasers

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We compare different high-energy, Q-switched cladding-pumped Yb-doped fibre laser designs. Large mode areas reduce amplified spontaneous emission and increase energy storage and damage threshold. Mode-selecting tapers or low-NA cores with mode-selecting gain improve the brightness.

Double-clad rare-earth doped fibre lasers pumped by high brightness laser diodes are very efficient and compact sources of cw and pulsed radiation [1-3]. In contrast to conventional bulk crystal lasers, the low pump absorption rate and waveguiding nature of double-clad fibre lasers result in relatively long cavity lengths, small effective core areas, and high round trip gain. Consequently, amplified spontaneous emission (ASE), various nonlinear effects, and optical damage are important factors for Q-switched fibre lasers. Here, we theoretically and experimentally study different fibre designs for Q-switched cladding-pumped ytterbium doped fibre lasers.

To demonstrate impact of ASE on performance of Q-switched fibre laser we first calculated [4] the maximum extractable energy as a function of pump power for 10 m long fibre with different core diameters (6 and 40 μm). The results are shown in figure 1.

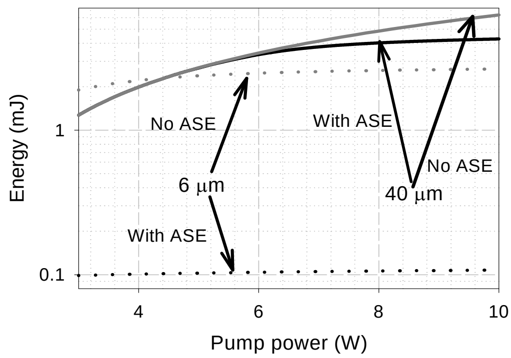

Fig. 1. Maximum extractable energy versus pump power for different core sizes.

The results (fig 1) clearly demonstrate that: (i) in the presence of ASE, pulse energy scales almost proportionally with the core area, (ii) ASE plays significant role in small core fibre.

Experimentally, we have tested two type of fibre lasers based on (i) large mode area fibres and (ii) multi-mode fibres. One of the fibre had a tapered section to suppress higher order modes [5]. Parameters of the fibres tested are shown in Table 1.

Table 1

	LMA SM	LMA MM	MM	MM-Taper
Core	20 μm	40 μm	33 μm	33 μm
Cladding Ø	150 μm	100x400μm	200μm	200 μm
NA	0.06	0.06	0.13	0.13
M^2	1.3	3	7	1.8

In the experimental setup shown figure 2, Q-switching was obtained by an acousto-optic modulator (AOM) from which the first order was reflected back to the cavity by a high reflectivity mirror. The fibres were 10 m long. The cw output power was fixed at 3 W, so that the pump rate was approximately the same for all lasers.

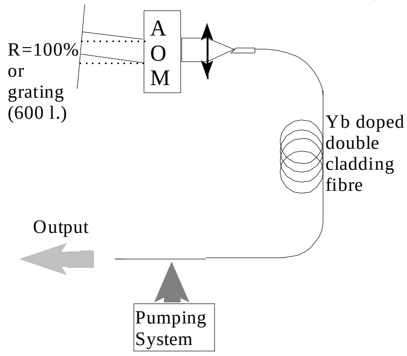

Fig. 2 Experimental setup

Pulse energy was measured as a function of the repetition rate (Fig. 2). As it is clearly seen pulse energy extracted from different fibres is the same at high repetition rate (20 kHz). At a lower repetition rate (4 kHz) a small difference start to occur depending on the core area.

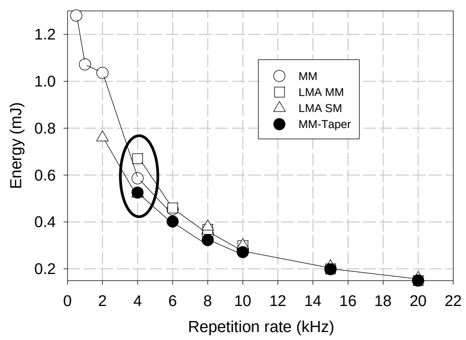

Fig. 3 Pulse energy versus repetition rate.

Note also low energy penalty in MM fibre with tapered section.

Either the damage threshold of the facet or the onset of lasing between pulses limited the pulse energy. We have observed the fibre facet damage at peak powers of 10-14 kW (~ 2GW/cm^2). Rayleigh back-scattering originated the lasing between pulses. This effect is proportional to the NA^2 and fibre length and was most clearly seen in high NA fibres.

In conclusion we investigated two types of fibre lasers in millijoules level Q-switched regime: large mode area fibres and multimode fibres. Extracted energy from both types of fibres was comparable. Good spatial beam quality was obtained by applying a tapered section. Finally, on one hand, LMA fibre are giving highe energy with higher brightness with the expense of complicate design and high bend losses, on the other hand multimode fibres are much simplier to design and can be tapered down to improve the beam quality with a comparable output pulse energy but the Rayleigh backscattereing is a limitation at low repetition rate regime.

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