CMP 1:30 pm–3:30 pm

Room 103

Pulsed Fiber Lasers

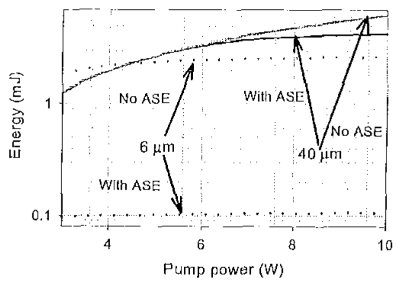
Yan Sun, *Lucent Tech., Bell Labs., USA, Presider*

CMP1 1:30 pm

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

C.C. Renaud, H.L. Offerhaus, J.A. Alvarez-Chavez, J. Nilsson, P.W. Turner, W.A. Clarkson, A.B. Grudinin, *Optoelectronics Res. Centre, Univ. of Southampton, Southampton SO17 1BJ, United Kingdom; E-mail: ccr@orc.soton.ac.uk*

Double-clad rare-earth-doped fiber lasers pumped by high brightness laser diodes are very efficient and compact sources of cw and



CMP1 Fig. 1. Maximum extractable energy versus pump power for different core sizes.

pulsed radiation.[1-3] In contrast to conventional bulk crystal lasers, the low pump absorption rate and waveguiding nature of double-clad fiber 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 fiber lasers. Here, we theoretically and experimentally study different fiber designs for Q-switched cladding-pumped ytterbium-doped fiber lasers.

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

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 fiber.

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

In the experimental setup shown, Fig. 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 fibers 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.

Pulse energy was measured as a function of the repetition rate (Fig. 2). As it is clearly seen pulse energy extracted from different fibers 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.

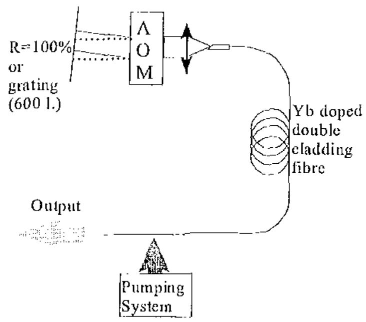
Note also low energy penalty in MM fiber with tapered section.

Either the damage threshold of the facet or the onset of lasing between pulses limited the pulse energy. We have observed the fiber 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 fiber length and was most clearly seen in high NA fibers.

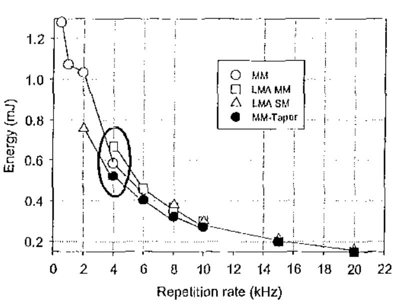
In conclusion we investigated two types of fiber lasers in millijoules level Q-switched regime: large-mode-area fibers and multimode fibers. Extracted energy from both types of fibers was comparable. Good spatial beam quality was obtained by applying a tapered section. Finally, on one hand, LMA fiber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

CMP1 Table 1.

	LMA SM	LMA MM	MM	MM-Taper
Core	20 m	40 m	33 m	33 m
Cladding Ø	150 m	100 × 400 m	200 m	200 m
NA	0.06	0.06	0.13	0.13
M^2	1.3	3	7	1.8



CMP1 Fig. 2. Experimental setup.



CMP1 Fig. 3. Pulse energy vs. repetition rate.

1. H.L. Offerhaus, J.A. Alvarez-Chavez, J. Nilsson, P.W. Turner, W.A. Clarkson, D.J. Richardson, "Multi-mJ, multi-Watt Q-switched fiber laser," Postdeadline paper, CPD 10, CLEO'99, Baltimore (1999).
2. V. Dominic, S. MacCormack, R. Waarts, S. Sanders, S. Bicknese, R. Dohle, E. Wolak, P.S. Yeh, E. Zucker, "110 W fiber laser," Postdeadline paper, CPD 11, CLEO'99, Baltimore (1999).
3. A. Al-muhanna, L.J. Mawst, D. Botez, D.Z. Garbuzov, R.U. Martinelli, J.C. Connolly, "14.3 W quasicontinuous wave front-facet power from broad-waveguide Al-free 970 nm diode lasers," Appl. Phys. Lett. **71**, 1142–1144 (1997).
4. I. Kelson and A. Hardy, "Strongly pumped fiber laser," IEEE J. Quantum Electron **34**, 1570–1577 (1998).
5. J.A. Alvarez-Chavez, A.B. Grudinin, J. Nilsson, P.W. Turner, W.A. Clarkson, "Mode selection in high power cladding pumped fiber lasers with tapered section," Technical digest, CWE 7, CLEO'99, Baltimore, (1999).