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Hybrid Q-switching in double clad fiber lasers

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Abstract: A novel cladding pumped Nd^{3+} fiber laser operating in an enhanced Q-switched regime with stable repetition rate is described. By exploiting fiber nonlinearities in the laser cavity, we demonstrated a pulse train with peak power of 3.7kW and pulse duration of 2ns.

In order to obtain high peak power for conventional Q-switched fiber lasers, one can either use highly doped fibers to reduce the pulse width which is proportional to the cavity length[1], or utilize a large mode area fiber as the gain medium to increase the extractable energy stored in the fiber[2]. But these fiber lasers have to be pumped by single mode laser diodes whose powers are normally low, resulting in low average output power. On the other hand, due to the very high intensities achievable in single mode fibers, nonlinearities can play an important role in generating short pulses whose width does not depend on the cavity lifetime but rather on the dynamics of stimulate Brillouin scattering (SBS)[345]. However due to the nature of the nonlinear process in the silica fibers, the repetition rate of this process is unstable unless special measures are taken[3,4].

In this paper, we report a novel hybrid configuration which takes advantages of both fiber nonlinearity and conventional Q-switching technique and generates a stable pulse train with high peak power and short pulse width. We used two 3W laser diodes to pump a double clad Nd^{3+} fiber. The setup is much like a conventional Q-switched fiber laser except that in the front end the double clad Nd^{3+} fiber was spliced with a short piece of a multimode fiber which has a matched core with the inner cladding. The purpose is to have a low reflection ($\sim 2.85*10^{-6}$) for the signal at the input end, and at the same time not to lose any launching efficiency for the pump. Note that without this special splice, experiments showed that high peak pulses did not occur every time due to the presence of the 4% reflection at the input end which decreases the population inversion achievable.

With this configuration, a repetition rate stabilized pulse train with peak power of ~3.7kW and pulse width of 2ns has been obtained as shown in inset of Fig. 1. Compared with 330W peak power in conventional Q-switching regime, the peak power is an order higher. The pulse width is determined by the interaction period between the transverse acoustic wave and the core, and is about 1ns for a 6μm diameter core. The repetition rate was controlled by the AOM. The average power was ~500mW. The giant pulse train occurred at a range of repetition rate from 6.6kHz to 16.4kHz.

Fig. 1 and 2 show the pulse peak powers from front and rear end dependence on the fiber length. The pulse peak power from rear end was lower than that from front. Peak powers of 3.7kW from

front end and 1kW from rear end have been obtained at a 7.2m optimum fiber length. When we spliced the double clad Nd^{3+} fiber with a 10m single mode (SM) fiber, the peak powers from front did not change when we cut back the SM fiber, and we did not find any changes in the pulse shapes. For pulses from rear end, however, the peak powers decreased rapidly after the splicing of the SM fiber, and gradually clamped to a power level of ~300W at 10m of the SM fiber. The pulse shapes were depleted as shown in the insets of Fig. 2 due to stimulated Raman scattering and three Stokes components have been observed in the spectrum.

In conclusion, we have demonstrated an enhanced Q-switching in a double clad Nd^{3+} fiber laser which increases the peak power by an order of magnitude compared with the normal Q-switching regime. This hybrid Q-switching can be treated as a special Q-switching technique used to generate high peak pulses by amplifying narrow seed pulses induced by SBS.

Captions

Fig. 1 Peak power from front end against fiber length. (Inset) A typical output pulse train at repetition rate of 14 kHz.

Fig. 2 Peak power from rear end against fiber length. (Insets) Pulse shapes at the beginning and the end of the SM fiber.

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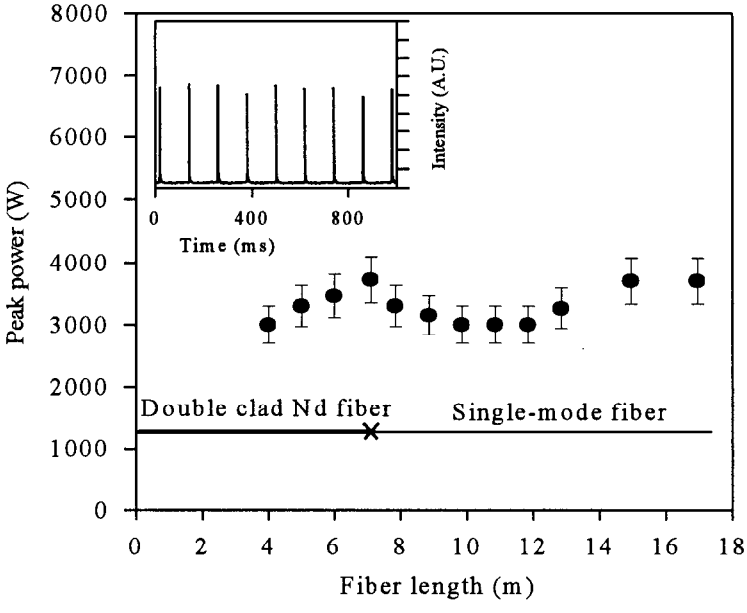
Peak power (W)
8000
7000
6000
5000
4000
3000
2000
1000
0
Intensity (A.U.)
0
400
800
Time (ms)
Double clad Nd fiber
Single-mode fiber
0
2
4
6
8
10
12
14
16
18
Fiber length (m)

Fig. 1

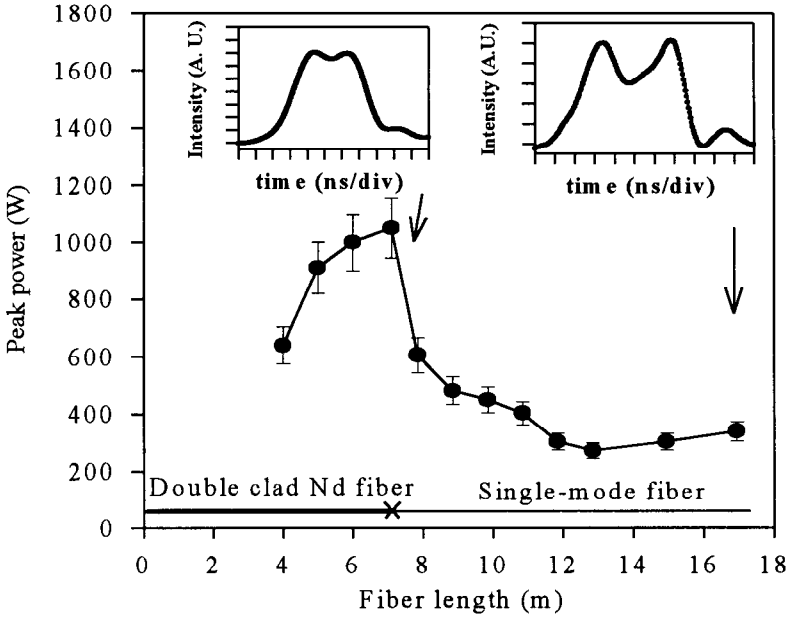
Peak power (W)
1800
1600
1400
1200
1000
800
600
400
200
0
Intensity (A. U.)
time (ns/div)
Intensity (A.U.)
time (ns/div)
Double clad Nd fiber
Single-mode fiber
0
2
4
6
8
10
12
14
16
18
Fiber length (m)

Fig. 2.