71 W average power sub-MW peak power diffraction-limited monolithic tapered fiber amplifier

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Ultrashort pulse fiber laser systems with both high average and peak power are promising tools for a wide range of applications. Usually pulsed fiber laser systems exhibit either high average power [1] or high peak power [2]. Only utilization of rod-photonics-crystal-fiber technology [3] allows one to achieve both high average (130 W) and peak (870 kW) power with a price of non-monolithic design (mainly bulk elements are used in [3], which lead to the laser's high cost and lose of reliability). Moreover not perfectly single-mode output (M^2 = 1.30) results in limitation of maximum average power caused by mode instability. Recently sub-MW peak power in monolithic all-fiber laser scheme was demonstrated in [4] using tapered fiber approach. Scalability of average power in tapered fiber to 28 W at peak power of 292 kW was demonstrated in [5]. In the current communication we demonstrated further progress in average and peak power scaling using this approach.

The tapered fiber developed in the current work was similar to one from [4] and had photodarkening-free P_2O_5-Al_2O_3-SiO_2 core doped with 2 wt.% of Yb_2O_3. The fiber had second fluorine-doped silica cladding (NA=0.28) and boron-doped stress rods inserted to the first cladding to create anisotropy (see inset on Fig. 1a). The tapered fiber was realized using non-stationary fiber drawing process. The main difference to [4] was increased to ~3 m fiber length and more "flat" thick fiber part. Output core, first and second cladding diameters were 43 µm, 344 µm and 389 µm correspondingly (see Fig. 1a). The seed 1064 nm 8 ps 10 MHz pulses with 50 mW average power was coupled to the thin tapered fiber end. The fiber was counter-pumped with 976 nm 0.15 NA 107 W wavelength-stabilized multi-mode pump through the thick tapered fiber end (dichroic mirror was used). With this configuration we succeeded to achieve 71 W average power with 69% slope efficiency (Fig. 1b), corresponding to 820 kW peak power. At the maximum obtained power the SRS only starts to evolve (<0.5% of output power) (Fig. 1c). The autocorrelation function for output pulses exhibit some distortions (Fig. 1c inset red), caused by a high level of self-phase modulation, but pulse duration only slightly widened to 8.6 ps. The M^2 factor at the maximum output power was measured by Thorlabs M2MS-BP209IR beam profiling system to be 1.16/1.17. Thus, we demonstrate monolithic diffraction-limited pulsed laser with sub-MW peak power (820 kW) and average power of 71 W, which is the record one for monolithic fiber lasers. Possibility of further average power scaling, while keeping sub-MW peak power will be discussed at the conference.

The work was supported by grant 18-19-00687 from the Russian Science Foundation.

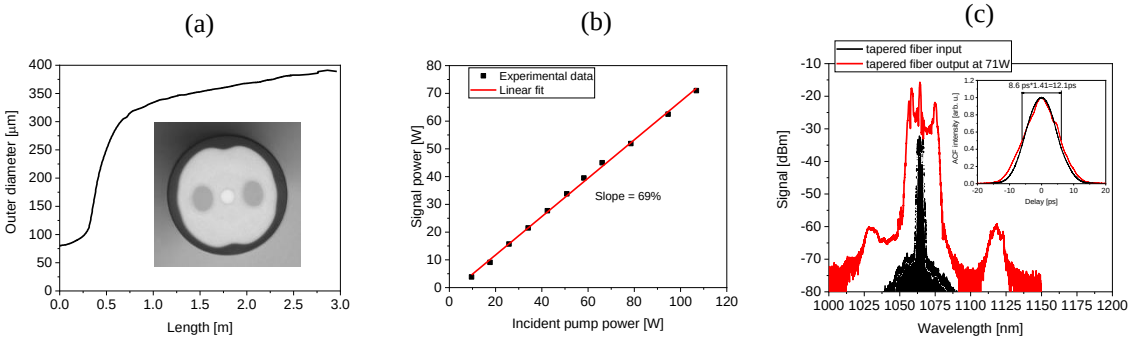

Fig. 1 (a): dependence of outer diameter on the tapered fiber length (inset: fiber cross section photo); (b): output signal power on incident pump power dependence; (c) signal spectra at the tapered fiber input (black) and tapered fiber output at 71 W average power (red) (inset: autocorrelation functions before and after tapered fiber at 71 W average power).

References

[1] R. Song, J. Hou, S. Chen, W. Yang, and Q. Lu, "157 W all-fiber high-power picosecond laser," Appl. Opt. **51**(13), 2497 (2012).

[2] G. Shi, S. Fu, Q. Sheng, J. Li, Q. Fang, H. Liu, A. Chavez-Pirson, N. Peyghambarian, W. Shi, and J. Yao, "Megawatt-peak-power picosecond all-fiber-based laser in MOPA using highly Yb^{3+}-doped LMA phosphate fiber," Opt. Comm. **411**, 133 (2018).

[3] Z. Zhao, B.M. Dunham, and F.W. Wise, "Generation of 150 W average and 1 MW peak power picosecond pulses from a rod-type fiber master oscillator power amplifier," J. Opt. Soc. Am. B **31**(1), 33 (2014).

[4] K. Bobkov, A. Andrianov, M. Koptev, S. Muravyev, A. Levchenko, V. Velmiskin, S. Aleshkina, S. Semjonov, D. Lipatov, A. Guryanov, A. Kim, and M. Likhachev, "Sub-MW peak power diffraction-limited chirped-pulse monolithic Yb-doped tapered fiber amplifier," Opt. Express **25**, 26958 (2017).

[5] A. Fedotov, T. Noronen, R. Gumenyuk, V. Ustimchik, Y. Chamorovskii, K. Golant, M. Odnoblyudov, J. Rissanen, T. Niemi, and V. Filippov, "Ultra-large core birefringent Yb-doped tapered double clad fiber for high power amplifiers," Opt. Express **26**, 6581 (2018).

978-1-7281-0469-0/19/$31.00 ©2019 IEEE