700-W single transverse mode Yb-doped fiber laser

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Abstract: We demonstrate 700-W fundamental mode beam from Yb-doped fiber laser operating at 1092 nm. Coiling 20-μm diameter and 0.06 NA core fiber into 15-cm diameter spool eliminates higher-order modes through distributed mode filtering.

OCIS codes: (060.2320) Fiber optics amplifiers and oscillators; (140.3070) Infrared and far-infrared lasers

Recent development of techniques for achieving diffraction-limited beams from multimode core fibers and advances in high power and high brightness diode lasers have made it possible to dramatically increase output powers from Yb-doped fiber lasers [1, 2]. Use of large size core reduces detrimental nonlinear effects and prevents optical damage as well as facilitates high power pump coupling and efficient pump absorption in a double clad structure. As a result, fiber lasers currently represent the solid-state laser technology with the highest available powers and the best beam quality.

In this paper we report further improvement in the generated output powers from a single-transverse mode Yb-doped cw fiber laser. 700-W output constitutes the record power level in a single transverse mode achieved to date, indicating potential for generating significantly higher output powers.

The experimental fiber laser set-up is shown in Fig. 1. For this cw fiber laser implementation we chose to use 0.06 NA and 20-μm core Yb-doped fiber. Use of low NA and this particular core size enables efficient distributed mode filtering at the relatively large coiling radius of 15 cm. Numerical modeling predicts differential loss between LP_{01} and LP_{11} modes in this fiber to be better than 20 dB/m, providing a robust single-mode output from 30-m long fiber. The large coiling radius produces no observable pump power scattering loss in 400-μm diameter, 0.45 NA pump cladding. This double-clad fiber structure was end pumped using four diode-bar laser pumps operating at three different wavelengths of 915-nm, 936-nm and 976-nm. Each diode pump was separately coupled into 800-μm diameter, 0.22 NA delivery fibers. The fiber laser was pumped from both ends. One end was pumped with three wavelength-combined diodes at 915-nm, 936-nm and 976-nm with estimated coupled power into 400-μm pump clad of ~233 W at each wavelength. The other end was pumped with ~270 W of coupled pump power at 976 nm. Coupled pump powers were estimated comparing with the coupling into un-doped fibers with cladding dimensions and NA identical to those of the active fiber. The CW fiber laser cavity was formed by Fresnel reflections from straight-cleaved Yb-doped fiber ends, producing two equal-power output beams. The measured output power from this simple cw fiber laser is shown in Fig. 2 for each beam and for the total output power. Laser threshold was ~3 W and efficiency 75%. Laser emission wavelength was 1092 nm. At the total coupled pump power of 970 W, the fiber laser produced 700 W of total output in both beams.

Beam profile observations and M^2 measurements confirmed that the laser was robustly operating in a single transverse mode at all power levels. Measured M^2 of 1.42 represents only a preliminary result, still affected by the phase aberrations accumulated in our initial beam sampling setup. No signature of LP_{11} mode has been detected.

In conclusion, we have demonstrated to our knowledge the highest power so far achieved in a single transverse mode beam from cw fiber laser. Such advancement constitutes an important technological step in developing other types of fiber based laser systems. Extremely high output powers from such lasers enable a variety of practically significant applications which were not possible previously. It is likely that the demonstrated powers do not represent the limit for the fiber technology and possibly could be scalable further towards multi-kW power levels from a single emitter.

References

[1] J. Limpert, A. Liem, H. Zellmer, and A. Tunnermann, "500-W continuous-wave fiber laser with excellent beam quality ", Electronics Letters, **39**, 645 (2003)

[2] http://www.spioptics.com/cleo.htm

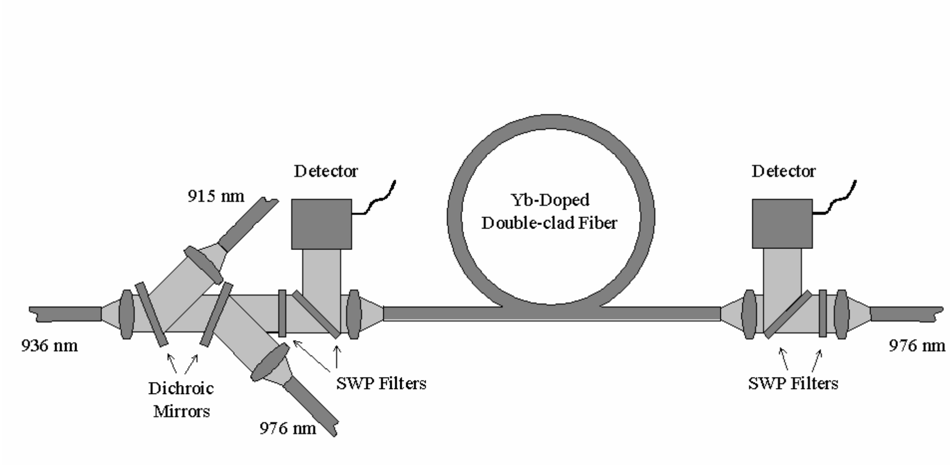

Figure 1– CW Yb-doped fiber laser setup.

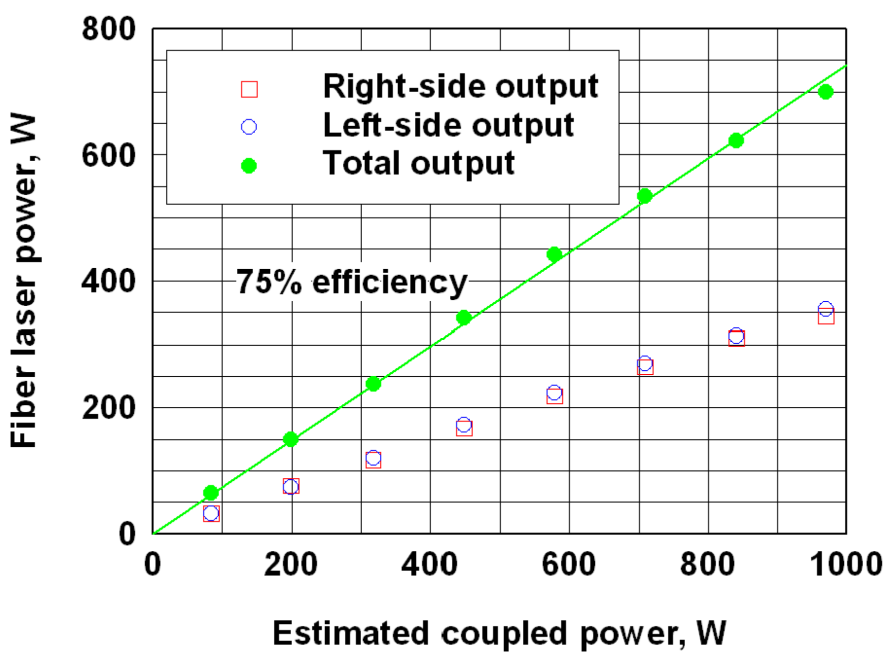

Figure 2 – Measured output power from a cw Yb-doped fiber laser. Right-side and left-side in the legend of the figure refers to the setup configuration in Fig. 1 above.

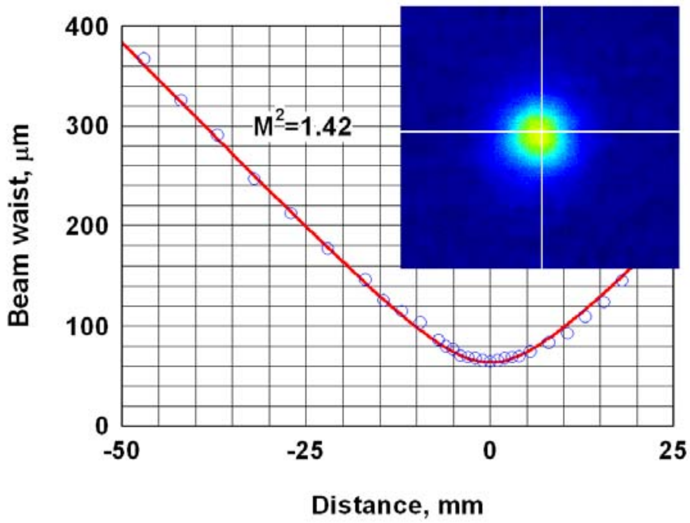

Figure 3 – Beam profile and M^2 measurement.