OWU2.pdf

33µm Core Effectively Single-Mode Chirally-Coupled-Core Fiber Laser at 1064-nm

M. Craig Swan[1], Chi-Hung Liu[1],
Doug Guertin[2], Nick Jacobsen[2], Kanishka Tankala[2], and Almantas Galvanauskas[1]
[1]Center for Ultrafast Optical Science, University of Michigan, 2200 Bonisteel Blvd., Ann Arbor, MI 48109-2099
Phone: (734)763-1233; fax: (734)763-4876; e-mail: mswan@umich.edu
[2]NUFERN, 7 Airport Park Road, East Granby, CT 06026

Abstract: The first fiber laser is demonstrated at 1064-nm using a novel index-guiding-core single-mode fiber (Chirally-Coupled-Core) with V>>2.405. Robust single-mode operation achieved at all power levels (up-to ~40W) independently of beam excitation and fiber coiling conditions.

OCIS codes: (060.2280) Fiber design and fabrication; (060.2320) Fiber optics amplifiers and oscillators

1. Introduction.

Fiber lasers with multi-kW average[1] and multi-MW peak[2,] powers in diffraction-limited output beams have been recently demonstrated using so called Large-Mode Area (LMA) fibers, in which single-mode operation is achieved in a multimode core (typically 20-µm to 30-µm diameter, with 65-µm to 80-µm state of the art demonstrations[2]) by employing careful mode-management[3, 4]. Such an approach has limited robustness and can not be monolithically integrated for LMA core sizes exceeding ~25 µm, thus offsetting many traditional technological advantages of conventional single-mode fiber technology and hindering development of power scalable all-fiber large-core fiber laser systems. Recently we had proposed and demonstrated a novel approach based on chirally-coupled core (CCC) fiber structures[5], which permits core size scaling well beyond 25-µm limit of LMA fibers while maintaining robust single-mode performance independently of mode excitation and fiber coiling conditions. Such CCC fibers permit mode-distortion-free splicing and compact coiling (below 15-cm coiling radius) thus enabling next generation all-fiber high power optical systems. However, the first CCC demonstrations have been achieved with undoped (passive) fibers.

In this paper we report the first demonstration of Yb-doped double-clad CCC fiber laser, which produces robust single-mode operation independently of beam excitation and coiling conditions (i.e. without any external mode management) from a 33µm core.

2. Yb-doped CCC fiber laser setup.

Setup for demonstrating CCC fiber based laser is shown in Fig. 1. This particular setup is not monolithic, since our primary goal here was to demonstrate robust operation of an Yb-doped CCC fiber structure. For this we chose an end-pumped configuration with a Fabry-Perot laser cavity formed by Fresnel reflection from straight-cleaved front facet (pumping side) of the fiber and by HR zero-degree mirror at the back end of the fiber. Consequently, all laser output power is exciting through the pumping end of the fiber. Note also that in this configuration back-reflecting mirror does not produce any mode-selection for a back-reflected beam. No fiber tapers or other mode selecting elements have been used. We used 5-m long Yb-doped double-clad CCC fiber, which was loosely coiled on a 14-cm radius fiber drum to ensure that bend-induced mode selection is not playing any role in the modal performance of the laser.

Basic geometry of the CCC fiber is shown in the insert of this figure. It contains a straight central core for signal propagation and one satellite core, helically wrapped around the central core. Function of the side core is to achieve mode-selective suppression of all HOM, while allowing fundamental LP_{01} mode to propagate with negligible (<<1-dB/m) losses[5]. The particular structure (different from the sample photo in the insert of Fig.1) has 33-µm Yb-doped central core with 0.06NA and undoped 16-µm side with 0.1NA. Helical pitch of the side core is 7.4mm and edge-to-edge separation between the central and the side cores is 4µm. Polymer coated inner (pumping) cladding is 250µm diameter with 0.47NA. Measured pump absorption in the cladding is 2 dB/m at 915-nm. Fiber laser was pumped at 915-nm with low-brightness fiber coupled (600µm diameter 0.22NA) pump diode. Due to the pump brightness and DC fiber inner-clad mismatch only 50% pumping coupling efficiency has been achieved in the current experiment. In the planned future experiments current double-clad CCC geometry will be more efficiently utilized using high-brightness pump diodes.

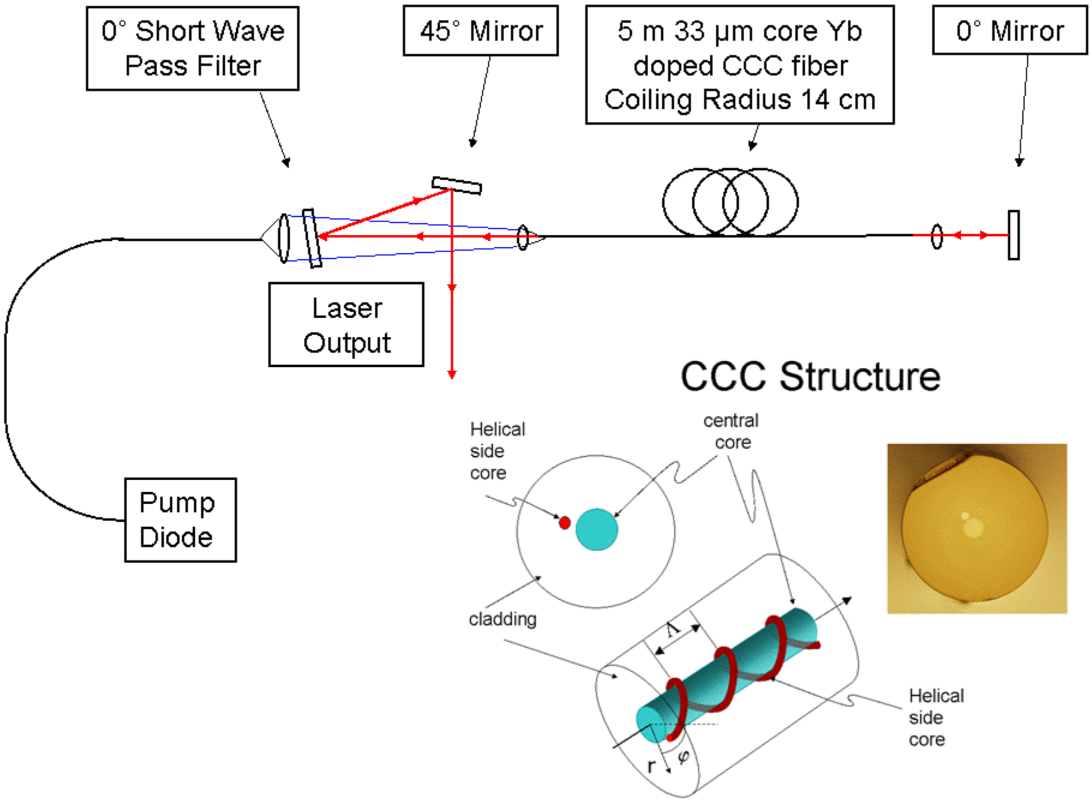

Figure 1: Yb-doped CCC fiber laser demonstration setup. Chirally-Coupled Core fiber structure and cross section of a fabricated CCC fiber is shown in the insert.

3. Experimental results.

A measured fiber laser output power is shown in Fig. 2. Up to 37W of output power has been achieved at 1066nm wavelength with 75% slope efficiency and ~6W lasing threshold. Achieved power was only limited by the available pump power. Achieved good slope efficiency and low threshold indicate low loss for LP_{01} mode. Measured beam profile is shown in the insert of Fig. 2. We verified that laser output was single-mode and stable at all measured power levels, irrespective to the alignment of the back-reflecting zero-degree mirror at the back end of the cavity. Measured spectrum of the laser is shown in Fig. 3. It has a narrow linewidth (measured linewidth was limited to ~0.1nm by the resolution of the used spectrum analyzer) centered at 1066-nm wavelength. Observed spectrum did not change with the power level and was stable in time.

In conclusion, this is the first demonstration of Yb-doped CCC fiber laser operation with robust single-mode performance at powers significantly exceeding lasing threshold and without employing any external mode-management (such as single-mode excitation or bending-assisted mode selection). This enables significant extension (to >>3kW) of achievable single-mode power with all-fiber laser systems. This work is in progress towards demonstrating higher average powers with the existing fabricated 33-µm core Yb-doped CCC fibers, towards demonstrating monolithic all-fiber CCC systems, and towards the development of 50-µm core CCC fibers.

The authors acknowledge support by US Army Research Office grant W911NF0510572.

References

[1] V. Gapontsev, D. Gapontsev, N. Platonov,O. Shkurikhin, V. Fomin, A. Mashkin, M. Abramov, S. Ferin, “2 kW CW ytterbium fiber laser with record diffraction-limited brightness,” Proc. Conference on Lasers and Electro-Optics/Europe, Munich, Germany, June 12-17, 2005, Page(s) 508

[2] Kai-Chung Hou, Ming-Yuan Cheng, and Almantas Galvanauskas, Doruk Engin, Rupak Changkakoti, and Pri Mamidipudi, “Multi-MW Peak Power Scaling of Single-Transverse Mode Pulses using 80-µm Core Yb-doped LMA Fibers,” Advanced Solid State Photonics, Tahoe, USA, January 29 – February 1, 2006, postdeadline paper MF5

[3] M.E.Fermann, “Single-mode excitation of multimode fibers with ultrashort pulses”, Optics Letters, **23**, pp.52-54, 1998.

OWU2.pdf

[4] J.P.Koplow, D.A.V.Kliner, and L.Goldberg, “Single-mode operation of a coiled multimode fiber amplifier”, Optics Letters, **25**, pp.442, 2000.

[5] Chi-Hung Liu, Guoqing Chang, Natasha Litchinister, Doug Guertin, Nick Jacobson, Kanishka Tankala, Almantas Galvanauskas, “Chirally Coupled Core Fibers at 1550-nm and 1064-nm for Effectively Single-Mode Core Size Scaling”, paper CTuBB3 at CLEO/QELS 2007, Baltimore, MD

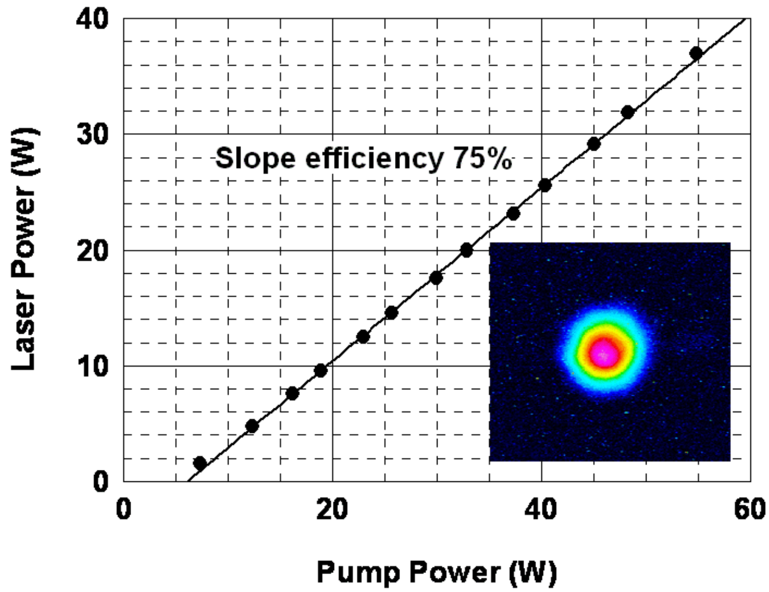

Figure 2: Measured output power vs absorbed pump power and the measured beam profile (insert).

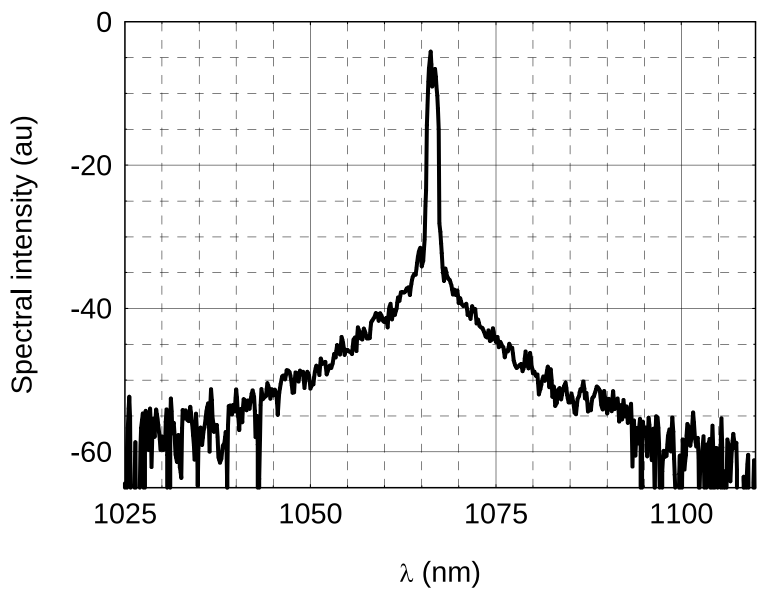

Figure 3: Measured spectrum of the CCC fiber laser. Spectral Intensity is plotted in logarithmic scale.