Single-Mode Chirally Coupled Core Yb-doped Fiber Lasers and Amplifiers for High Power Scaling

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ABSTRACT

Current monolithic single-mode kW fiber laser systems predominantly rely on ~20µm-25µm core conventional LMA fibers. Further power scaling requires increase in fiber core size. However, conventional LMA approach can not provide with a robust monolithic performance of fiber systems with core sizes larger than ~25µm. We are currently developing a new class of index-guiding fiber structures which offer a radical solution to this long standing problem. Chirally Coupled Core (CCC) fibers permit very large effectively single-mode core sizes well beyond conventional V = 2.405 limit, and, consequently, enable to preserve all principal technological advantages of conventional single-mode fibers: undistorted single-mode propagation through fiber splices, possibility of fiber-pigtailed fiber-optic components, compatibility with fiber coiling for compact laser system packaging, etc. Previously we had demonstrated robust single-mode performance of passive (undoped) CCC fibers with ~35µm core sizes. Here we report demonstration of robust single-mode performance of Yb-doped double-clad CCC fiber lasers and amplifiers operating within 1030nm to 1064nm spectral region.

CW fiber lasers were demonstrated in 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. Such configuration enables to demonstrate robust single-mode operation independently of beam excitation and coiling conditions (i.e. without any external mode management). No fiber tapers or other mode selecting elements were present. 3m to 5m long ~35µm diameter and 0.06NA core Yb-doped double-clad CCC fibers were used, 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. Fiber has 250µm diameter and 0.47NA polymer coated inner (pumping) cladding. 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.

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 low-brightness pump sources. Achieved good slope efficiency and low threshold indicate low loss for LP_{01} mode. 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 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. We also characterized these Yb-doped double-clad CCC fibers in amplifier configuration and demonstrated up to ~30dB small signal gain, only limited by the onset of spurious lasing in an unsaturated end-pumped double-clad amplifier.

In conclusion, we demonstrated Yb-doped CCC fiber lasers and amplifiers 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, towards demonstrating monolithic all-fiber CCC systems, and towards further CCC fiber core size scaling.

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