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Yb:Al-doped depressed clad hollow optical fiber laser operating at 980nm

J. Kim, D. B. S. Soh, C. Codemard, S. Yoo, Y. Jeong, J. Nilsson, and J. K. Sahu
Optoelectronics Research Center, University of Southampton, Southampton SO17 1BJ, UK.
jsk@orc.soton.ac.uk

Abstract

We demonstrate an Yb-doped cladding-pumped depressed-clad hollow optical fiber laser emitting a single-mode beam at 980 nm with a slope efficiency of 34% and up to 3.1W of output power.

High-power 980 nm sources are required in many applications such as pump source for erbium-doped fiber amplifier, fiber DFB laser or for blue generation by frequency doubling. Cladding-pumped Yb-doped fiber sources operating at 980 nm have been demonstrated using a jacketed air clad structure [1]. However, the three-level 980nm transition lasing requires small inner-cladding (~30 μm) and short length fiber (e.g., ~40 cm in [1]) to avoid the 1030 nm quasi-three-level laser emission. Power-scaling of such fibers require the use of expensive high-power, high-brightness multimode pump source.

In order to obtain Yb lasing at 980 nm, 1030 nm emission should be suppressed along the fiber while a very high level of Yb-excitation must be achieved. As previously demonstrated in the case of 930 nm emission in Nd-doped fiber laser [2], we propose a double-clad depressed clad hollow optical fiber (DCHOF), which has a sharp cut-off for the fundamental LP_{01} mode and does not guide light beyond the cut-off wavelength.

An Yb-doped DCHOF fiber was fabricated using the MCVD and solution doping technique. At the final collapsing stage, a hole of 0.5 mm diameter was left in the preform which was then milled to a double D-shape to improve the pump absorption by breaking the symmetry. The preform was drawn to a fiber with a 120 μm diameter pure-silica inner cladding, coated with a low-index polymer outer cladding. This provided a nominal inner-cladding NA of 0.48. The core consisted of a 5.7 μm Yb-doped aluminosilicate ring (NA 0.07) around an air hole of 16 μm diameter, and a depressed ring in the inner cladding of thickness 11 μm.

Our numerical analysis predicts that the fundamental LP_{01} mode cut-off was ~1025 nm, while the fiber is single-moded at 980 nm. Figure 1 shows the distributed loss of 16dB/m at ~1030nm by the fundamental mode cut-off. Here, the transmitted power was measured using white light source with 30cm fiber length. Both ends of the DCHOF were spliced to single mode fibers (SMFs) in order to remove the guided cladding modes. In addition, Figure 1 shows that the absorption at 980nm was less than that at 915nm. The reason seems to be due to the relatively low modal overlap at 980nm with the doped ring core compared to 915nm, because 980nm is close to the fundamental mode cutoff wavelength.

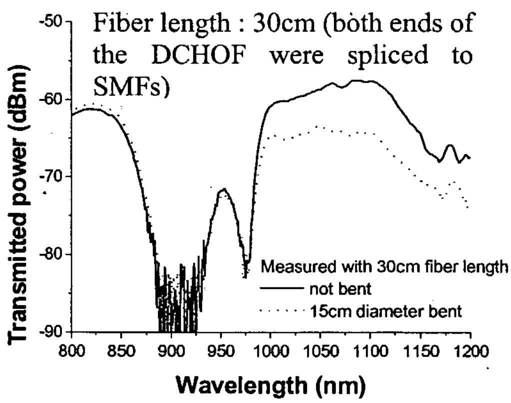

Figure 1. Transmission spectrum of Yb:Al-doped DCHOF depending on different bending diameters.

The laser configuration is shown in figure 2 with an end facet image of the DCHOF. The fiber was pumped by two low brightness 915 nm multimode laser diodes, which specify the maximum power with 200μm and 0.2 NA fiber coupling, one at each end, through a combination of lenses and dichroic mirrors. A maximum pump power of 19 W could be launched into the fiber. A laser cavity was formed between a perpendicularly cleaved end facet (4% Fresnel reflection) and a 100% reflective dichroic mirror (DM) highly reflective (HR) at 980 nm and highly transmissible (HT) at 1030 nm. The reflected

intra-cavity beam was lens-coupled to the angle-cleaved fiber end. The fiber was 6 m long and the operational single-pass pump absorption was almost 10 dB.

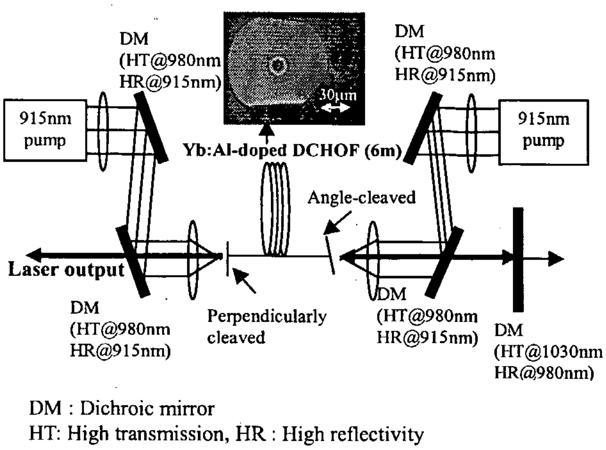

Figure 2: Laser configuration for 980nm Yb:Al-doped DCHOF.

The laser output characteristics are shown in figure 3. Here, the maximum output power was 3.1 W with 34% slope efficiency (η) with respect to the launched pump power. The threshold was obtained 9.2 W of launched pump power. The laser output was ring-shaped. We then collapsed the fiber ends and measured the beam quality. An M^2-value of 1.09 was obtained, demonstrating single-mode operation in agreement with our calculation.

Compared to our earlier results [1], this fiber has an order of magnitude larger inner-cladding area. This results in a higher threshold, but it allows for higher-power pump sources that will enable power-scaling well beyond the 10 W level. Improvements in the slope efficiency will also help to increase the output power.

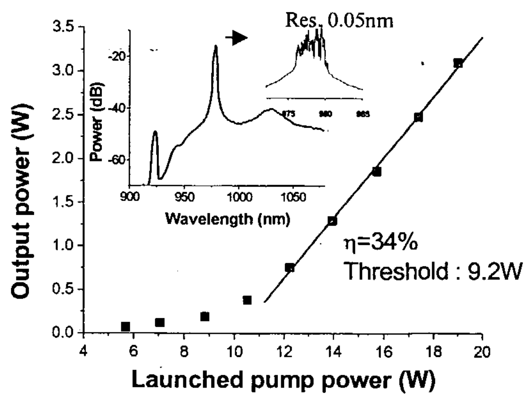

Figure 3: DCHOF laser 980 nm output power *vs.* launched pump power. Inset: optical spectrum (res. 1 nm).

References

1) K. H. Ylä-Jarkko et al., "A 3.5 W 977 nm cladding-pumped jacketed-air clad ytterbium-doped fiber laser", *OSA Trends in Optics and Photonics v. 83, Advanced Solid State Photonics 2003, John J. Zayhowski, ed.*, pp. 103 – 107.

2) J. Kim et al., "Nd:Al-doped depressed clad hollow fiber laser at 930nm", *Advanced Solid State Photonics 2005 Vienna, Austria MC5*.