Simple Scheme for Single-Ended Operation of a Cladding-Pumped Fiber Laser

L. Pearson, J. S. P. Chan, P. Wang, W. A. Clarkson
Optoelectronics Research Center, University of Southampton, Highfield, Southampton, SO17 1BJ, UK
lep@orc.soton.ac.uk

Abstract: A novel, all-fiber geometry for achieving predominantly single-ended laser operation without the use of high reflectivity dielectric coatings or in-fiber Bragg gratings is described. Preliminary results for a cladding-pumped Yb-doped fiber laser are reported.

Summary: Over the last few years there has been very rapid progress in the scaling the output power from cladding-pumped fiber lasers and amplifiers. The main attractions of fiber lasers are derived from their geometry, which allows a high degree of immunity from the detrimental effects of heat generation and good output beam quality owing to the waveguiding properties of the active ion doped core. The laser output signal is normally retrieved from one end of the fiber by use of an external feedback cavity or in-fiber Bragg grating, although both methods inevitably increase the complexity and cost of the device. Here, we report a novel, all-fiber approach for achieving single-ended laser operation, which is compatible with high-power cladding-pumping and which is extremely simple to implement as it needs no additional optical components. Our approach is based on a novel fiber-end-termination scheme that allows the effective feedback reflectivity from a fiber end-facet to be reduced to a very low level and hence dominate as the output coupling loss. In a simple proof-of-principle experiment, 3.9 W of single-ended output was obtained from a cladding-pumped ytterbium-doped fiber laser with a slope efficiency with respect to absorbed pump power of 67%.

The double-clad ytterbium-doped offset-core fiber and fiber-end termination scheme used in our experiments are shown schematically in Figure 1. The fiber core diameter, core numerical aperture, core-offset and inner-cladding diameter were 28µm, 0.1, 20µm and 380µm respectively. Feedback for lasing is provided by the ~3.6% Fresnel reflection from a perpendicularly-cleaved end-facet at the pump input end of the fiber, and, at the opposite (out-coupling) end, by a much lower reflectivity fiber-end-termination. The latter was prepared by heating the end section of the fiber and twisting the fiber so that the core has a helical path in this region. The fiber was then perpendicularly-cleaved in the twisted region to produce a high quality end-facet (i.e. with low scattering loss) perpendicular to the fiber's longitudinal axis. As a result of the helical trajectory, the core's path is at an angle with respect to the facet normal, and hence light fed back by Fresnel reflection suffers a further loss, which depends on the angle. The core angle is determined by the core offset and number of turns per unit length, and hence can be selected to reduce the level of optical feedback from the end-facet to the required level without the penalty of a high 'bend loss' due to the helical trajectory. In the limit of very low feedback reflectivity, the ratio of the powers from opposite fiber ends is approximately given by $P_1/P_2 \approx (R_2/R_1)^{1/2}$, where R_1 and R_2 are the effective feedback reflectivities at the output coupling and pump in-coupling ends of the fiber respectively [1]. Thus by making $R_1 << R_2$, it is possible to achieve a predominantly single-ended laser output. The use of very low feedback reflectivities does lead to an increase in threshold, but this is not a problem in a high-gain cladding-pumped fiber configuration with the appropriate fiber-end-termination design.

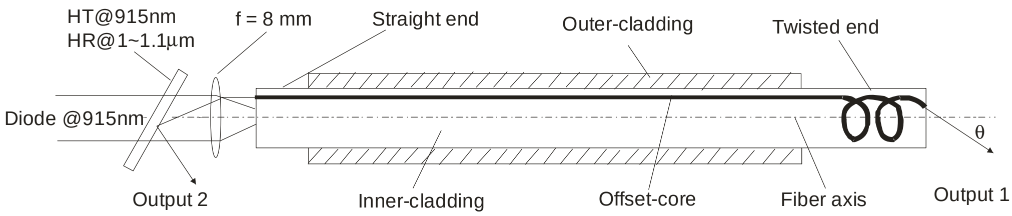

Figure 1. Schematic drawing of ytterbium-doped offset-core fiber for single-ended output operation

In preliminary experiments, the core angle with respect to the fiber's longitudinal axis at the output end-facet was ~2.2º. The 16 meter fibre was end-pumped by a diode source at 915nm. This resulted in a maximum output power from end 1 of 3.9W and only 0.4W from end 2. The central laser wavelength was around 1070nm. At the maximum available pump power, the slope efficiency was ~67%. The beam quality factor (M^2) for the laser signal was measured to be ~2.1.

In summary, single-ended laser operation of an ytterbium-doped fiber using a novel all-fiber design has been demonstrated. Further studies aimed at improving the fiber design to increase the power ratio (P_1/P_2) and to scale to higher powers levels are ongoing and will be reported at the conference.

[1] W.W. Rigrod, J.Appl. Phys. **36** 2487-2490 (1965)