High power radially-polarized Yb-doped fiber laser

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Radially-polarized light is characterized by a donut-shaped intensity profile and exhibits axially symmetry both in field-amplitude and polarization direction. Radially-poalrized beams can produce a strong longitudinal electric field component along the beam axis under the condition of tight focusing. This unique property leads to a range of applications in material processing, high-resolution microscopy, particle acceleration and trapping.

Here, we present an alternative approach for efficiently generating radially-polarized output directly in an Yb-doped fiber laser by employing an S-waveplate in an external feedback cavity arrangement. The S-waveplate consists of spatially-variant sub-wavelength gratings which are produced by femtosecond laser pulse direct writing in a fused-silica window. These grating structures induce form birefringence with slow and fast axes aligned parallel and perpendicular to the grating direction respectively, which is aligned at an angle $\varphi/2$ from the azimuthal angle φ [1].

The experiment set-up, illustrated in Fig. 1, consisted of ~ 1m length of non-polarization maintaining Yb-doped with an external feedback cavity. The fiber had a core diameter and numerical aperture of 20μm and 0.08 respectively. The calculated V-number of this fiber was 4.79 and hence the fiber could support a few lower order modes. The end of fiber adjacent to the external cavity was cleaved at 8° to suppress the broadband feedback and hence parasitic lasing between the fiber end facets. The opposite end was perpendicularly-cleaved to serve as the output coupler. The Yb fiber was cladding-pumped by a 60W laser diode. An S-waveplate and a polarizing beam splitter (PBS) were placed in the external cavity between rear mirror and fiber collimating lens. The PBS allowed only p-polarized light to pass through it, which was sunsequently incident on the S-waveplate. When the orientation of the S-waveplate, shown by the arrow in Fig.1(a), is aligned parallel to the p-polarization, it converts the p-polarized beam into a radially-polarized beam, which is then coupled into the fiber to excite the radially-polarized TM_{01} mode.

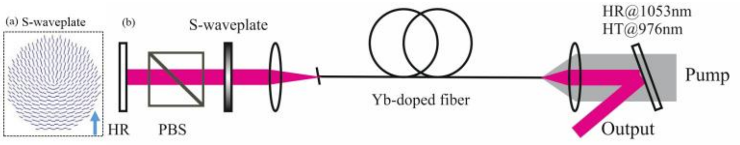

Fig. 1 (a) Schematic of nanogratings ; (b) experimental laser set-up.

Fig.2(a) shows the output power as a function of the launched pump power. The output power increased linearly with pump power with a slope efficiency of 65.8% with respect to launched pumpe power. The laser yielded a maximum output power of 32W at 1050nm for the maximum available pump power of 50W. The typical output beam intensity distribution is shown in Fig.2(b) confirms that the output beam has a donut-shaped

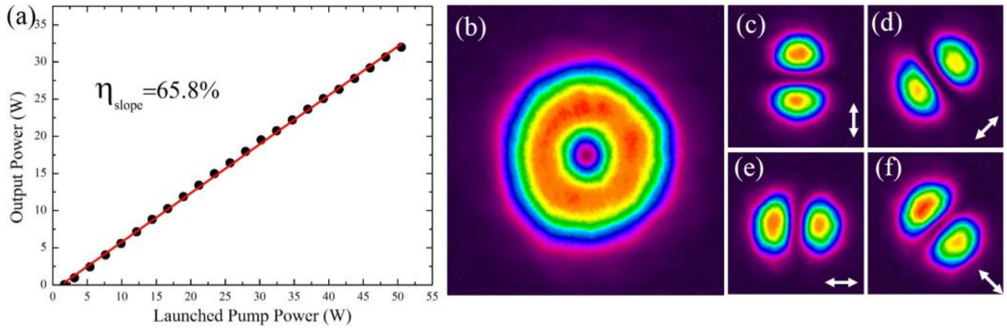

Fig. 2 (a) Laser output power measurement ; (b) beam intensity distribution in far-field ; (c)-(d) beam profile after passage through a rotated linear polarizer.

intensity profile with a null in intensity at the centre of the beam. Figs.2(c)-(e) show the two-lobe structures of output beam beam after passing through a polarizer oriented at different angles thus verifying that the polarization is indeed radial. The polarization purity was measured to be > 95% over the full range of output power. The beam propagation factor (M^2) was measured to be 2.1 and hence in close agreement with the theory confirming the high quality and purity of radially-polarized TM_{01} mode that was generated. To the best of our knowledge, this is the highest power and highest slope efficiency for radially-polarized fiber laser to date. The prospects for further improvement in efficiency and higher output power will be discussed.

References

[1] M. Beresna, M. Gecevicius, and P. G. Kazansky, "Polarization sensitive elements fabricated by femtosecond laser nanostructuring of glass [Invited]," Opt Mater Express **1**, 783-795 (2011).