Polarization-maintaining Ytterbium-doped Fibre With an Aluminosilicate Inner-cladding Fabricated Using In-situ Doping Technique

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The ytterbium-doped fibre laser (YDFL) has become the forerunner for high-power fibre lasers and amplifiers largely owing to the broad emission of Yb^{3+} ions (λ = 975 to 1200 nm) and their ability to be incorporated in a silica host in relatively high concentrations. Achieving multi-kilowatts of output power from a fibre has been made possible through improved fibre design and fabrication. In this paper we report on a robust polarization-maintaining (PM) YDFL with a unique aluminosilicate pedestal structure.

A Yb-doped aluminosilicate pedestal fibre was fabricated using modified chemical vapour deposition (MCVD) and a novel in-situ solution doping technique [1]. The preform was then drilled and assembled with borosilicate stress rods to form a PANDA structure. A double clad fibre with 120 μm outer diameter was pulled from the preform. The refractive index profiles along the slow and fast axis of the PM fibre are shown in Fig. 1. The refractive index contrast in the pedestal layer and in the core was achieved by Al and Al-Yb doping, respectively. The pedestal layer has 0.12 NA with respect to silica which is comparable to fibre where the pedestal layer is raised by P or Ge. [2] The core NA is 0.13 with respect to the pedestal layer. We note that the inner-cladding NA can be adjusted to obtain an effective core NA of <0.06. The diameter of the core and pedestal is 8 and 31 μm, respectively. The Yb concentration in the fibre is ~ 2 wt% according to Yb small signal absorption at 976 nm.

Thermal expansion mismatch between the pedestal layer and silica cladding was estimated by linear function of weight factor of glass constituent, i.e. $\Delta p = \sum_i f_i w_i$ where Δp is change in the thermal expansion coefficient, f_i is thermal expansion of constituent, i, and w_i is molar weight of constituent, i. [3] The f_i of P_2O_5, GeO_2, and Al_2O_3 were obtained as 1.33 $\times 10^{-7}$, 0.71 $\times 10^{-7}$, and 0.5 $\times 10^{-7}$ $^oC^{-1}$ mol%$^{-1}$, respectively, from [3]. In order to achieve a 0.12 NA, 5.68 mol% of P_2O_5 is required in the pedestal layer which will induce 7.58 $\times 10^{-7}$ $^oC^{-1}$ of thermal expansion mismatch against the silica cladding. A GeO_2-SiO_2 pedestal layer would produce 2.41×10^{-7} $^oC^{-1}$ of thermal expansion mismatch for the corresponding NA with 3.42 mol% of GeO_2. The same NA can be raised by 2 mol% of Al_2O_3 which causes only 1×10^{-7} $^oC^{-1}$. Thus, the respective thermal expansion mismatch caused by P_2O_5-SiO_2 and GeO_2-SiO_2 is ~ 7.6 and ~ 2.4 times higher than that by Al_2O_3-SiO_2. Note that the stress rods overlap the pedestal layer as shown in Fig. 1, which clearly indicates low stress build-up in the preform with aluminosilicate inner-cladding. The birefringence of the fibre was measured as 2.4×10^{-4}.

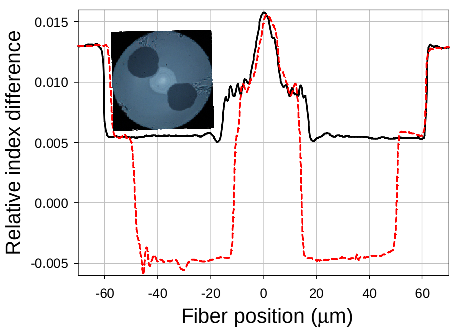

Fig. 1 Refractive index profile of aluminosilicate PM pedestal fibre in slow (dot line) and fast axis (solid line)

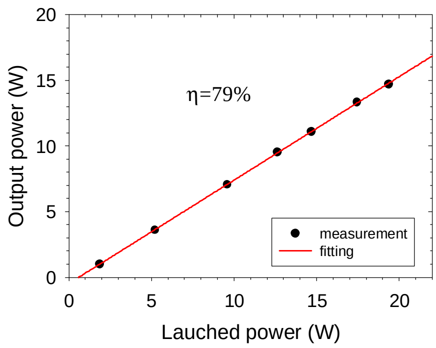

Fig. 2 Laser performance of aluminosilicate PM pedestal fibre

Laser performance of the PM Yb-doped pedestal fibre was tested in a linear cavity pumped at 975 nm. We utilized a half-wave plate and a polarization beam splitter to align polarization direction of laser oscillation along with a birefringence axis of the fibre. The laser output power vs launched pump power is presented in Fig. 2. The output power linearly increases with the pump power and exhibits 79% of slope efficiency. The maximum output power is 14.7 W which is limited by available pump power. The fibre length used was 2.5 m permitting ~98% of pump absorption. The polarization extinction ratio was higher than 12 dB at maximum power.

In conclusion, we report the first demonstration, to our knowledge, on PM aluminosilicate pedestal fibre which is readily scalable to large mode area design.

References

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