Ytterbium Doped Nanostructured Optical Fibers For High Power Fiber Lasers

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With the breakthrough in ytterbium (Yb) doped fiber laser power scaling to kilowatt levels [1], the search for improved host glass properties has received much attention. A silica host, which is commonly used in high power fiber devices, has the advantage of being low-cost, reliable and able to sustain extremely high optical densities, as compared to other alternative glasses. However, silica is considered to be a poor host in terms of the level of Rare-earth(RE) that can be incorporated into it without the clustering effect of RE ions. This makes it difficult to achieve the high level of RE concentration in silica fibers, that is needed to shorten the device length of high power fiber lasers, which helps to suppress the non-linear effects (such as stimulated Raman and Brillouin scattering) in fibers. In this paper, we investigate Yb doped Y_2O_3 (or $Y_3Al_6O_{12}$) nanoparticles in a silica rich matrix, as an alternative to the Yb in a 'standard', such as aluminium or phosphorous co-doped, silica host for use in high power fiber lasers. Y_2O_3 is a good host for RE incorporation, and efficient Yb:Y_2O_3 ceramic lasers have been reported in [2]. It is expected that Y_2O_3 nanoparticles within a silica host will improve the RE solubility in fibers.

Doping of Yb into thermally induced Y_2O_3 (or $Y_3Al_6O_{12}$) nanoparticles within the SiO_2-Al_2O_3-P_2O_5-Li_2O-BaO core glass of an optical fiber preform was achieved by a standard MCVD-solution doping technique. During the preform collapsing stage, which is performed at high temperature, the Yb:Y_2O_3 (or Yb:$Y_3Al_6O_{12}$) nanoparticles are phase-separated into the silica-rich core. After preform fabrication and under suitable heat treatment, the phase-separated region becomes crystalline. Fig.1 shows the transmission electron microscope (TEM) image of a phase separated preform core that was post-processed at 1300^{0}C for 3h at the heating rate of 20^{0}C/min followed by cooling at the same rate. The nanoparticles can be observed in the core, with a diameter of less than 20nm with uniform size distribution, and the electron diffraction pattern (inset Fig.1) reveals the crystalline nature of the nanoparticles.

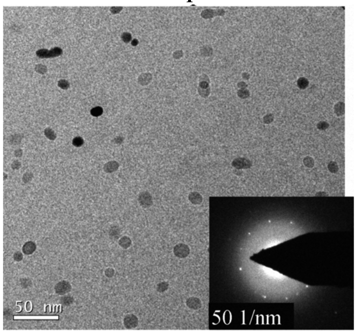

Fig. 1 TEM image of the Yb doped Y_2O_3 nanoparticles preform core annealed at 1300^{0}C (Inset: Electron diffraction pattern of the nanoparticles).

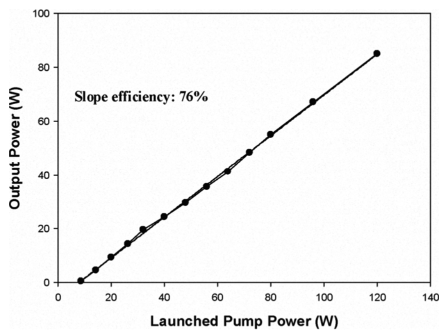

Fig. 2 Fiber laser output power vs. launched pump power.

Double-clad fibers were drawn from nanostructured preforms to 400 μm inner cladding diameter (D-shaped) with a 49 μm core (NA ~ 0.14), and coated with a low index polymer outer cladding. The inner cladding diameter was chosen to enable an efficient pump launch from the high-power pump diodes. The small signal cladding absorption at the pump wavelength of 975 nm was ~ 11dB/m. The background loss, measured with a high resolution OTDR at 1285 nm, in 125 μm OD fibers, was found to vary between 40 – 450 dB/km depending on the core composition. For laser experiment, an end-pumped 5 m long fiber was perpendicularly cleaved at the pump launch end to provide 4% Fresnel feedback for the laser cavity. At the other end a higph reflector (100% @ 1000 – 1100nm) was used to close the laser cavity. Fig.2 shows the laser output characteristics. The output reached 85W when 120W of pump power was launched. The slope efficiency was 76%. The laser spectrum at 12W of output power in a 125 μm nanostructured fibers was centered at ~ 1045 nm.

Our initial result is what we believe to be the first demonstration of a high-power laser in a RE-doped nanostructured fiber. This new generation of fibers will keep the advantage of the mechanical properties of silica glass, whereas the spectroscopic properties of RE ions can be engineered by varying the nanoparticle compositions.

References

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