2581

A high efficiency, low threshold, erbium-doped holey optical fiber laser

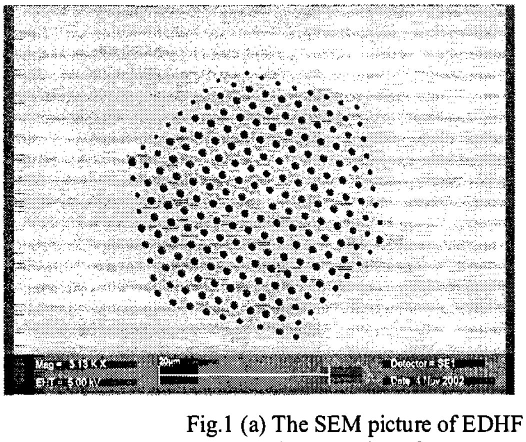
K.Furusawa, J.K.Sahu, T.M.Monro, and D.J.Richardson
Optoelectronics Research Centre, University of Southampton, Highfield, Southampton, SO17 1BJ, United Kingdom
Tel:+44-23-8059-7673, Fax:+44-23-8059-3149, email:djr@orc.soton.ac.uk

Abstract: We report the first continuous wave operation of an erbium doped holey fiber laser with a slope efficiency as high as 57.3%, and with an absorbed pump power threshold as low as 0.5mW.

OCIS codes: 060.2280 Fiber design and fabrication, 140.3510 Lasers, fiber

Holey optical fibers have attracted a lot of interest in recent years due to their unique and useful optical properties. To date most work has focused on using these properties in passive fiber devices however many of these useful properties, for example the possibility of both small and large modes areas, are also of great relevance for active rare earth doped devices. Until now the only reports of lasers and amplifiers based on HFs have used Yb doped fibers. This is mainly because of the problems associated with incorporation of OH^- ions into such fibers during the fabrication process. The effects of water absorption on Yb doped fibers are much less significant compared to other rare earth ions, such as Er, where a high water content can massively reduce fiber efficiency and device performance. In this paper we report the fabrication of a low OH^- content, small-core Er doped holey fiber (EDHF) and demonstrate the first continuous laser operation of an EDHF. The laser has a very high efficiency (~57.3%) and a very low pump power threshold (~0.55mW).

We fabricated an erbium-doped aluminosilicate fiber preform (NA~0.14, dopant concentration~1000ppm) by the MCVD method using the solution doping technique. The core of this perform was extracted and polished down to obtain surfaces of optical quality and then inserted into a capillary bundle. This extracted core ultimately defined the core of the final fiber. The resulting holey fiber preform was drawn down to fiber dimensions using a two-step drawing approach incorporating appropriate preform dehydration steps, which allowed us to greatly reduce the incorporation of hydroxyl ions. As a result, both background and OH losses in the EDHF are almost the same as the conventional solid fiber that was pulled from the original preform as a reference (EDF: $\lambda_{cut\text{-}off}$~1.2μm). The absorption spectrum and the SEM picture of the fiber cross section are shown in Fig.1. The hole spacing Λ and the diameter d are 2 μm and 1μm, respectively. The Er ions are confined to a region of ~1μm dimension at the centre of the core, which is partly formed by the pure silica capillaries surrounding the doped core. For this reason, the absorption in EDHF is weaker than the conventional fiber. However, the 980nm absorption (~10dB/m) in the EDHF is relatively stronger than that at 1550nm owing to the tighter modal confinement achievable in HFs at shorter wavelengths.



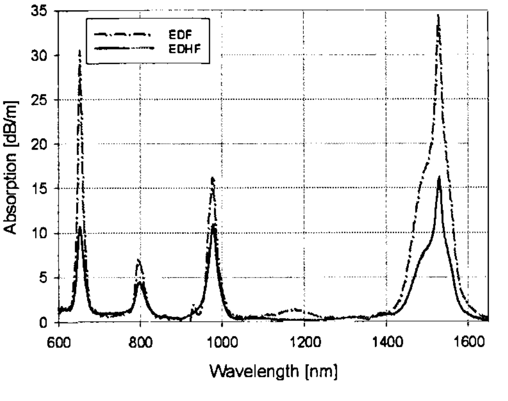


Fig.1 (a) The SEM picture of EDHF and (b) the comparison of the absorption spectrum between the reference EDF (dashed line) and the EDHF (solid line).

We constructed a Fabry-Perot laser cavity by using the combination of a high reflector and a normal cleaved end facet of a 3.4m long EDHF. A pump laser diode (980nm) was free space coupled through an isolator into the cleaved end of the EDHF with a coupling efficiency of ~50%. The output was extracted from the cleaved end of the cavity using a dichroic mirror. The output characteristic of the laser is shown in Fig.2. We obtained the slope efficiency of 57.3% and a laser threshold of 0.55mW at 1535nm with respect to absorbed pump. This value is even higher than that of the reference EDF (~51%), owing to improved modal overlap of pump and signal beams within the HF. Note that the quantum efficiency limit is ~64%.

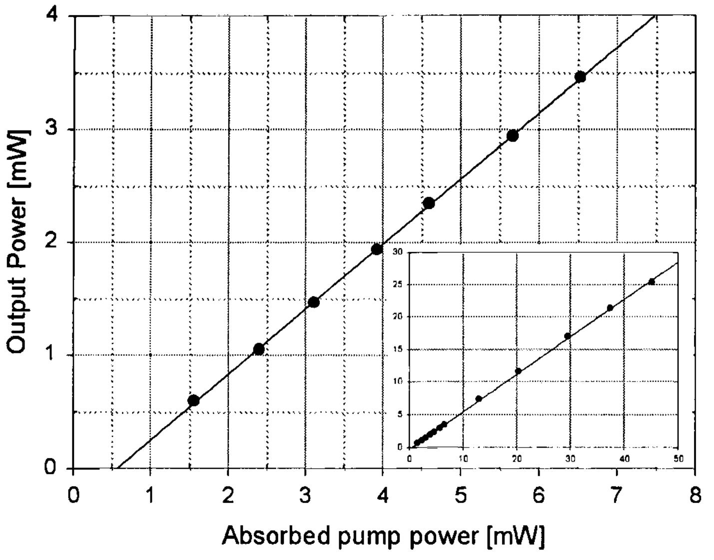


Fig.2 Output characteristics of the EDHF laser near the threshold, and at high output powers (inset).

In summary, we have demonstrated the first laser operation using an erbium doped holey fiber. Owing to the geometry of the doped area, the slope efficiency as high as 57.3% and the absorbed pump power threshold as low as 0.55mW has been obtained.

[1] W.J.Wadsworth et al. "Yb^{3+} doped photonic crystal fibre laser," *Electron.Lett.* **36** pp.1452-1454 (2001)
[2] K.Furusawa, et al. "A mode-locked laser based on ytterbium doped holey fibre," *Electron.Lett.* **37** pp.560-561 (2001)
[3] K.Furusawa , et al "Cladding pumped Ytterbium-doped fiber laser with holey inner and outer cladding," *Opt.Exp.* **9**, pp.714-720 (2001)