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# An Yb-doped silica cladding-pumped fibre laser pumped at 974nm.

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## Abstract

An Yb-doped silica fibre has been developed for cladding pumping at 974nm. Cladding-pumped laser action has been demonstrated with slope efficiencies up to 80%

## Summary

Yb-doped silica fibre is a versatile host for laser action at wavelengths in the 1.02 to 1.15$\mu$m spectral region. Sources operating within this range are of particular interest for several applications. For example practical sources are required at 1.02$\mu$m for pumping the 1.3$\mu$m $Pr^{3+}$-doped fluoride fibre amplifier, and there is also much interest in sources operating around 1.14$\mu$m for pumping $Tm^{3+}$-doped fluoride fibre blue upconversion lasers. While Yb-doped silica has been pumped at wavelengths from 840nm to 1.06$\mu$m, 974nm is a particularly attractive pump wavelength for cladding pumping since it corresponds to the peak of the absorption band and since semiconductor MOPAs have recently become available at that wavelength.

Efficient operation of an Yb-doped silica fibre laser pumped at 870nm and emitting at 1.02$\mu$m was recently reported [1], with 260mW laser power being obtained for 550mW pump power from a Ti-sapphire laser. The overall efficiency of that device (40%) was limited by the launch efficiency of the pump beam into the doped fibre.

In this work, the operation of a cladding-pumped Yb-doped fibre laser is reported. Cladding pumping operates on the principle that the incident power is launched and guided in the outer core (inner cladding). The dopant is confined within the inner core, and the absorption per unit length of pump light travelling in the outer core is therefore reduced by a factor approximately equal to the ratio of the areas of the inner and outer cores. The reduced absorption, compared to direct core-pumping, is compensated for by using a combination of higher dopant concentration and longer fibre length. Cladding-pumping schemes have generally been employed in the past to enable more efficient launching of diode arrays into single-mode fibres [2,3,4], but in the present work the scheme is applied because it also offers an excellent opportunity for absorbing virtually all of the available pump power from a near-diffraction-limited source into the doped fibre core. This fibre core is monomoded, so that the laser output is a single-transverse mode. The fibre has been designed for pumping at 974nm, ultimately with the output from a semiconductor MOPA. The MOPA (Spectra Diode Labs SDL-5762-A6) is a 1 Watt source, which has a nearly diffraction-limited $M^2 \sim 2$, single-mode output, and for efficient laser action it is desirable to absorb all of this power in the doped fibre core.

The fibre used in the present work was fabricated by the MCVD technique and germanosilicate cores were employed to give the refractive index profile shown in figure 1. The structure has an inner core diameter of 4.25$\mu$m and an outer core (inner cladding) of 12.75$\mu$m. The NA for the inner guide is $\sim$.16 and the NA for the outer guide is $\sim$.15. Ytterbium is added by solution doping and the concentration is estimated (from analysis of starting materials and spectral loss measurements) to be $\sim$1300ppm. A germanosilicate composition was chosen for three reasons. First, very low losses can be achieved, <10dB/km in this fibre, necessary for long devices operating far from the gain peak. Second, the high $GeO_2$ content in the core allows gratings to be fabricated directly in the doped fibre. Third, the absorption and emission spectra of $Yb^{3+}$ are very host dependent [5]. For a germanosilicate host, the cross-sections are larger than for other hosts, and very broad, so that the emission spectrum extends as far as 1.2$\mu$m. These cross-sections have been measured, and are shown in figure 2.

The pump source used to date for this work is a Ti-sapphire laser operating at 974nm. Pump light was launched into the fibre using a x5 microscope objective, in order to simulate the focal spot size which would be produced by a semiconductor MOPA focussed within the acceptance angle of the fibre. The best performance to date has been obtained at 1040nm in a 5m length of fibre, with $\sim$4% optical feedback provided by the Fresnel reflections from

the cleaved fibre ends. The threshold power was 70mW (incident on the launch objective), and the slope efficiency was 80% with respect to incident power. The laser characteristic is shown in figure 3.

The wavelength of laser action can be chosen within the range 1035-1105nm, simply by varying the fibre length and the amount of optical feedback. This is largely due to the tail in the absorption spectrum (see figure 2) which extends out to beyond 1050nm, and forces laser action to occur at longer wavelengths for longer lengths of fibre. The fibre losses are sufficiently low that laser oscillation is very efficient for fibre lengths up to ~100m.

In order to achieve efficient laser action at 1020nm, and at wavelengths longer than 1105nm, it is necessary to introduce some wavelength discrimination into the laser cavity. An attractive means of doing this is to incorporate fibre gratings into the laser cavity [1]. Gratings have now been successfully fabricated directly into the doped fibre using two interfering beams from a line-narrowed KrF: the technique has been described previously [6]. The optimisation of these gratings is expected to lead to high conversion efficiencies for both 1020 and 1140nm laser operation. Results of laser action in fibres incorporating gratings will be presented.

## References

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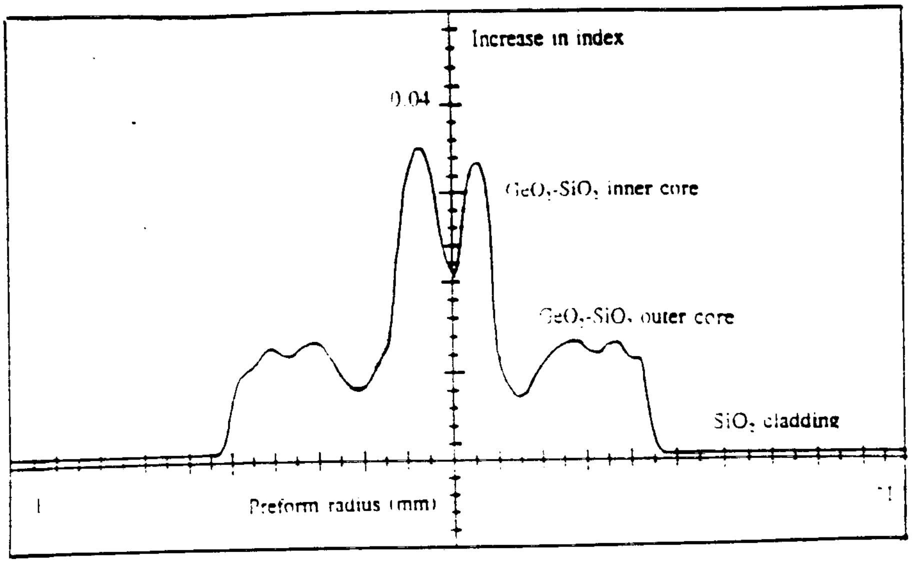

**Figure 1** Refractive index profile of the preform core region, showing the regions of increased index. Regions of reduced index seen at the interface of the inner and outer cores and at the centre are a function of the manufacturing process. These partially diffuse in the fibre and do not significantly affect the waveguiding structure.

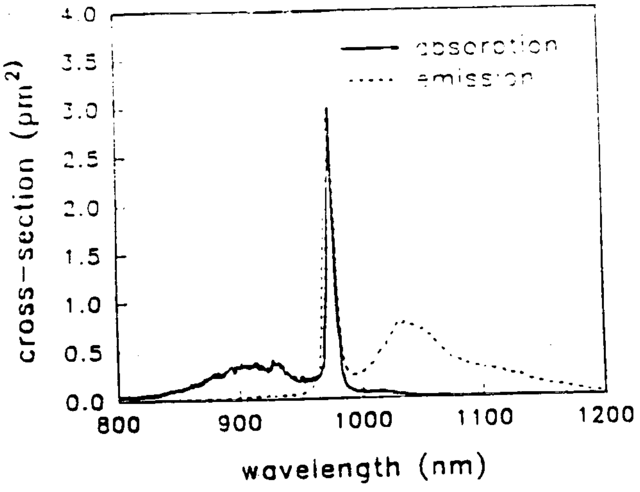

**Figure 2**
Absorption and emission spectra for Yb$^{3+}$ in a Germanosilicate host.

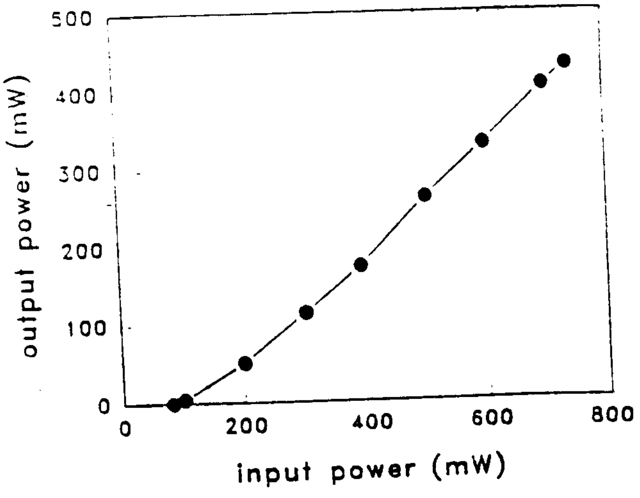

**Figure 3**
Performance of the Yb$^{3+}$-doped silica cladding-pumped laser.