

UV-induced Refractive Index Change in Ce³⁺-Doped Fibres

L. Dong, P.J. Wells, D.P. Hand and D.N. Payne

Optoelectronics Research Centre,
The University of Southampton,
Southampton, S09 5NH, England.

Telephone: (0703) 592878

Abstract

An optically-induced index change of 1.4×10^{-4} has been observed when Ce³⁺-doped fibres were subjected to UV light at 266nm. The effect is comparable with that observed in Ge-doped fibres with the potential of being improved with higher dopant-level.

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Summary

UV-induced index changes approaching 10^{-4} in germanosilicate fibres have been reported by Hand¹. Fibre gratings can be written into these fibres by interfering UV light into the core^{2,3}. Narrow-band gratings of this type have many applications, e.g. mode-selection in fibre lasers, WDM telecommunications and sensors. They are compact, easy to align, tunable, and less likely to be damaged in high-power applications.

We report here a new type of photosensitive fibre composed of SiO₂, P₂O₅, Al₂O₃, and Ce₂O₃, which has potential for improved devices. The photosensitivity is

believed to be result from the photoionisation of electrons from Ce^{3+} ions and subsequent trapping at defect-centres in the glass. The Ce^{3+} absorption band is located around 290nm, well away from the preferred transmission wavelength. Moreover, the index change was found to be comparable with that in Ge-doped fibres with the potential for further enhanced effect with increased cerium doping levels.

Three fibres were fabricated by MCVD, using a solution-doping technique⁴. P_2O_5 and Al_2O_3 co-dopants were used to favour the formation of Ce^{3+} rather than Ce^{4+} state⁵. A porous layer of SiO_2/P_2O_5 was first deposited at a relatively low temperature (about 1300°C), after which it was solution-doped with $AlCl_3$ and $CeCl_3$. Nitrogen instead of the usual oxygen was employed in the collapse process to further encourage the formation of the Ce^{3+} ions. Doping levels were controlled by varying the concentration of $CeCl_3$ in the aqueous solution. In all the three fibres, a single absorption peak at 290nm was found and was attributed to Ce^{3+} ions. The Ce^{3+} concentrations were determined using the absorption data given by Laczka⁶ to be 1,900ppm, 5,800ppm and 11,700ppm. A linear dependence on the solution strength was found with no sign of insolubility or devitrification, indicating the possibility of higher Ce^{3+} concentration in the future. A fibre doped only with Al_2O_3 was also made. The fibres have NA's between 0.13 and 0.19 and estimated P_2O_5 concentrations between 12mol% and 23mol%. They also have a loss of about 150dB/km at 1.55 μ m.

The effect of UV irradiation on spectral loss was measured with a slice of the preform containing 5,800ppm Ce^{3+} ions. The Ce^{3+} peak was reduced and a broad

band absorption extending from UV to IR was created on UV exposure. The induced loss at $1.55\mu\text{m}$ was negligible. After UV exposure, A reversal of these changes was observed, with the loss induced in IR recovering by over 90% in 10hrs. The Ce^{3+} peak, however, took 4.5 days to recover by only 65%. Three different recovery time constants were found while monitoring the loss at 633nm. These are 34s, 8mins and 13hrs, indicating that three different defect-centres are involved.

A novel dual-core fibre interferometer technique was employed to measure the photosensitivity to UV irradiation(266nm) generated from a frequency-quadrupled, pulsed YAG laser. The composite fibre comprised one photo-insensitive phospho-silicate core and one Ce^{3+} -doped core. A probe signal was launched into both cores of the coating-stripped dual-core fibre and a fringe pattern was formed in the output far field. Changes in the position of the fringe pattern indicate a relative change in refractive index between the two fibre cores. The fibre was exposed to UV at 266nm by repeatedly scanning the UV light along the length of the fibre until no further shift was observed, after a total scan time of about 1min. The fringes were also found to be stable for at least 30mins after UV exposure, disassociating the index change from defect-centres related to the fast recovery process. As a control experiment, a dual-core containing the pure Al_2O_3 doped core showed no fringe shifts.

The induced index change in the Ce^{3+} doped fibre core was found to be dependent on both UV intensity and Ce^{3+} concentration shown in figures 1 and 2. The index change saturates both at high UV intensity and high Ce^{3+} concentration. One

cause could be a lack of the electron-trapping defect-centres associated with the index change. Despite saturation effects, however, an index change of 1.4×10^{-4} was recorded at a wavelength of $1.064 \mu\text{m}$ in the most heavily doped sample, 11,700ppm Ce^{3+} , for an average UV intensity of 4 kW/m^2 .

The signal wavelength dependence of the induced index change was also measured shown in figure 3. It can be seen that at the critical $1.55 \mu\text{m}$ telecommunication wavelength an index change as large as 6.8×10^{-5} was observed.

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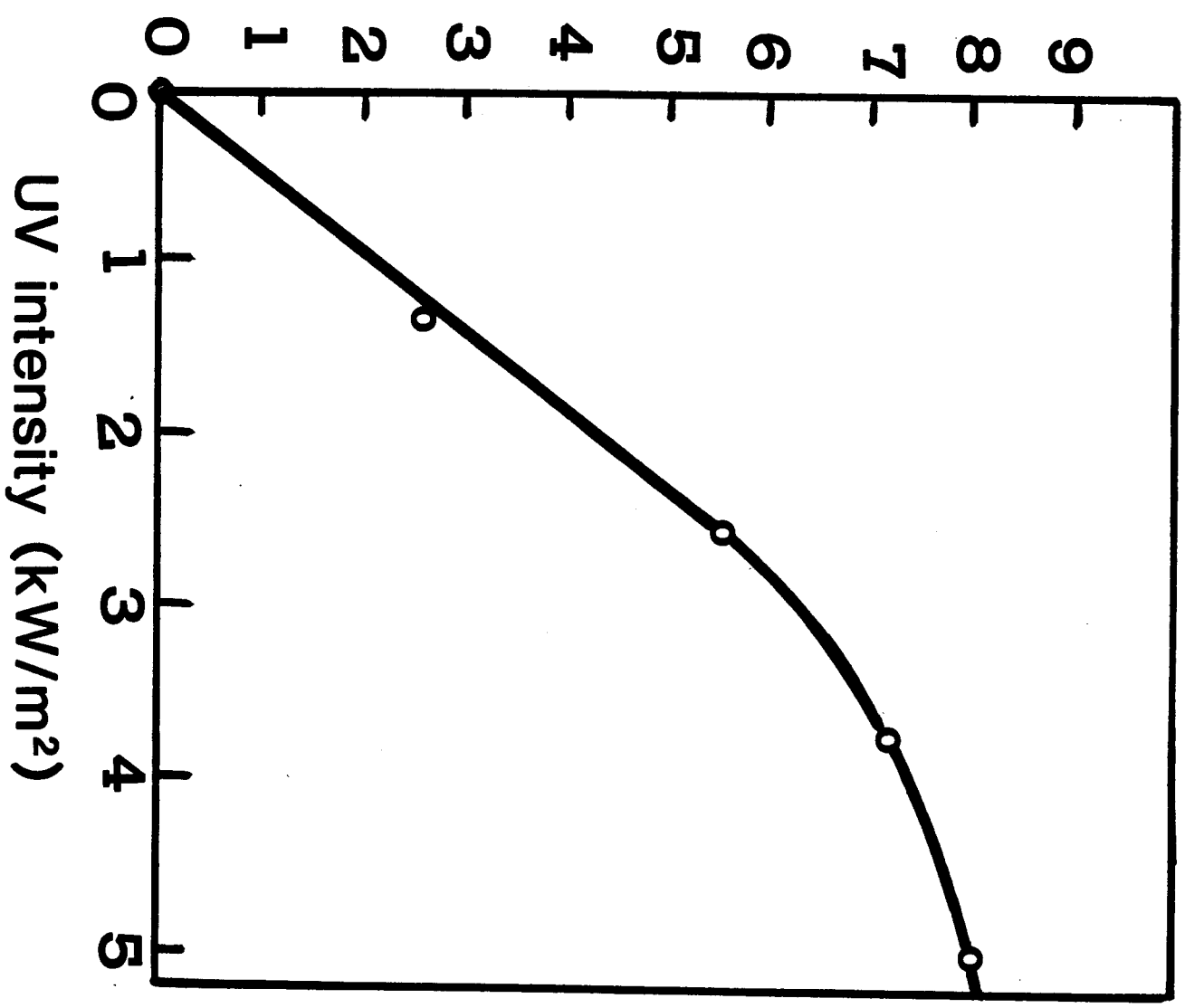
Figure Captions

Figure 1. Average UV intensity dependence of induced refractive index change at 784nm in a fibre containing 5,800ppm Ce^{3+} ions.

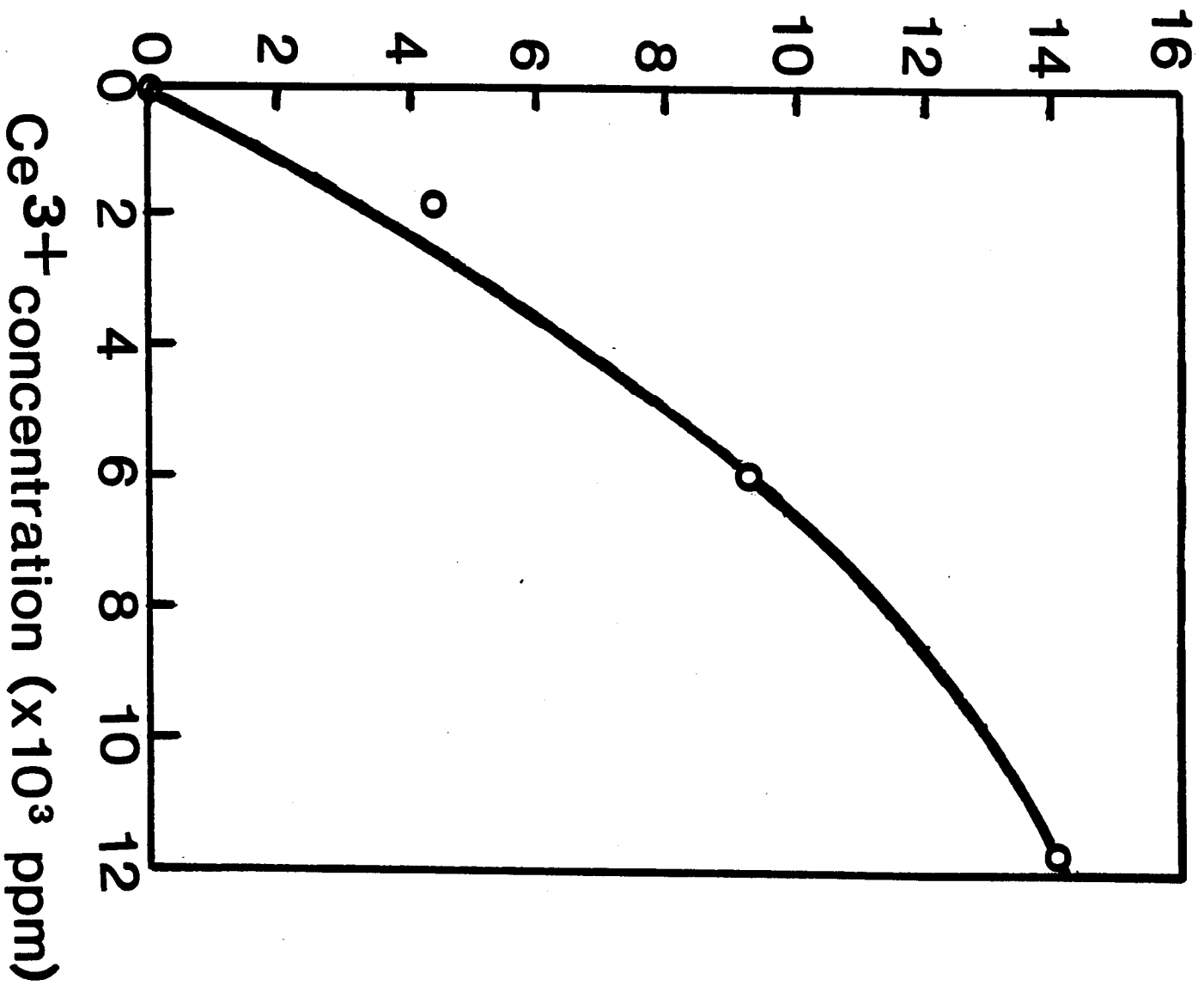
Figure 2. Ce^{3+} concentration dependence of induced refractive index change at 1.064 μm with an average UV intensity of 4kW/m².

Figure 3. Signal wavelength dependence of the UV-induced index change in a fibre containing 5,800ppm Ce^{3+} ions with an average UV intensity of 4kW/m².

Induced
index
change
($\times 10^{-5}$)



Induced
index
change
($\times 10^{-5}$)



Induced
index
change
($\times 10^{-5}$)

