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656

Bragg Gratings in Ce^{3+}-doped Fibres Written by a Single Excimer Pulse

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Abstract: Gratings with up to 2.4% reflection have been demonstrated in Ce^{3+}-doped fibres, written by a single excimer pulse at 248nm, for the first time. The grating strength is shown to be related to Ce^{3+} concentration. Part of the grating was found to be stable for more than 10 hours at 600°C.

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Fibre gratings have become very attractive as wavelength selective components in optical fibre systems because of ease of manufacture and use. UV-written Bragg gratings in germanosilicate fibres have been extensively studied by various authors[1]. After our first report on UV-induced photosensitivity in germanium-free Ce^{3+}-doped fibres[2], Broer et al demonstrated a Bragg grating of 17% reflectivity with 30 minute exposure at 292nm[3]. Here we report Bragg gratings written in Ce^{3+}-doped fibres by a single pulse from a KrF excimer laser (Lambda Physik Model EMG 150 MSC) and also demonstrate that Ce^{3+}-doped fibre gratings are comparable to those in germanosilicate fibres both in terms of strength and stability.

To write gratings, the output of an excimer laser (0.1J pulse with a duration of 20ns and a beam size of 5mm $\times$ 20mm) was focused onto the coating-stripped fibres by cylindrical lenses in an interferometer arrangement[4]. Four fibres of similar composition (SiO_2, P_2O_5, and Al_2O_3, see ref.5 for details) but different Ce^{3+} concentrations (0 to 11,700ppm) were tested. The spectral response of a typical grating is shown in figure 1. The FWHM bandwidth of 0.15nm in the figure is limited by the resolution of the optical spectrum analyzer. The gratings were written around 1550nm and their reflectivities were estimated using the end face reflection as a reference. The grating length was estimated to be 13mm from the 7GHz FWHM measured from a similar grating in a germanosilicate fibre and the index change was then calculated. The induced index changes in the four fibres are given in figure 2. No measurable grating was written in the fibre without Ce^{3+} ions and saturation is evident at high Ce^{3+} concentrations. The highest grating reflection of 2.4% was obtained in the fibre containing 11,700ppm of Ce^{3+} ions.

The stability of the gratings was also tested. A grating was placed inside a furnace and was heated at a rate of 8°C/min up to 700°C. The reflection was monitored continuously. The reflection was found to decrease by a few percent even at temperature as low as 150°C. Another decay component was also noted at around 600°C, where the reflection quickly decreased to a very low level. The second decay component was further characterised by monitoring the time dependence of the reflection from fresh gratings at temperatures of 300°C, 400°C, 500°C and 600°C. The results are shown in figure 3. For the gratings at 300°C and 600°C, the decay component made up most of the reflections. When the grating writing conditions were slightly improved (by better alignment of the writing interferometer), a much more stable component appeared (see curves at 400°C and 500°C in figure 3). The stable component can account for much as

90% of the total reflection (see curve at 500°C in figure 3). The grating tested at 500°C in figure 3 was further tested at 600°C for more than 10 hours without noticeable degradation. The same grating was finally heated up to 1200°C in 20 minutes and was found to disappear totally at 1150°C. The dependence of decay rates on temperature in figure 3 has also been used to calculate the activation energy of the associated electron traps. The result is 0.22eV (1700cm^{-1}).

We have also compared the gratings in Ce^{3+}-doped fibres with that in our best germanosilicate fibre, written under the same conditions. Similar performance was observed.

In conclusion, we have demonstrated that Ce^{3+}-doped fibre gratings have similar performance to germanosilicate fibre gratings in term of both grating strength and stability. Our results support the theory that photoelectrons released from Ce^{3+} sites are trapped at sites with different stabilities.

Reference

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3. M.M. Broer, R.L. Cone and J.R. Simpson: "Ultraviolet-induced distributed-feedback gratings in Ce^{3+}-doped silica optical fibres", Optics Letters, **16**, 1991, pp.1391-1393.

4. J.-L. Archambault, L. Reekie and P,St.J. Russell: "High reflectivity fibre gratings written by a single excimer laser pulse", to be published.

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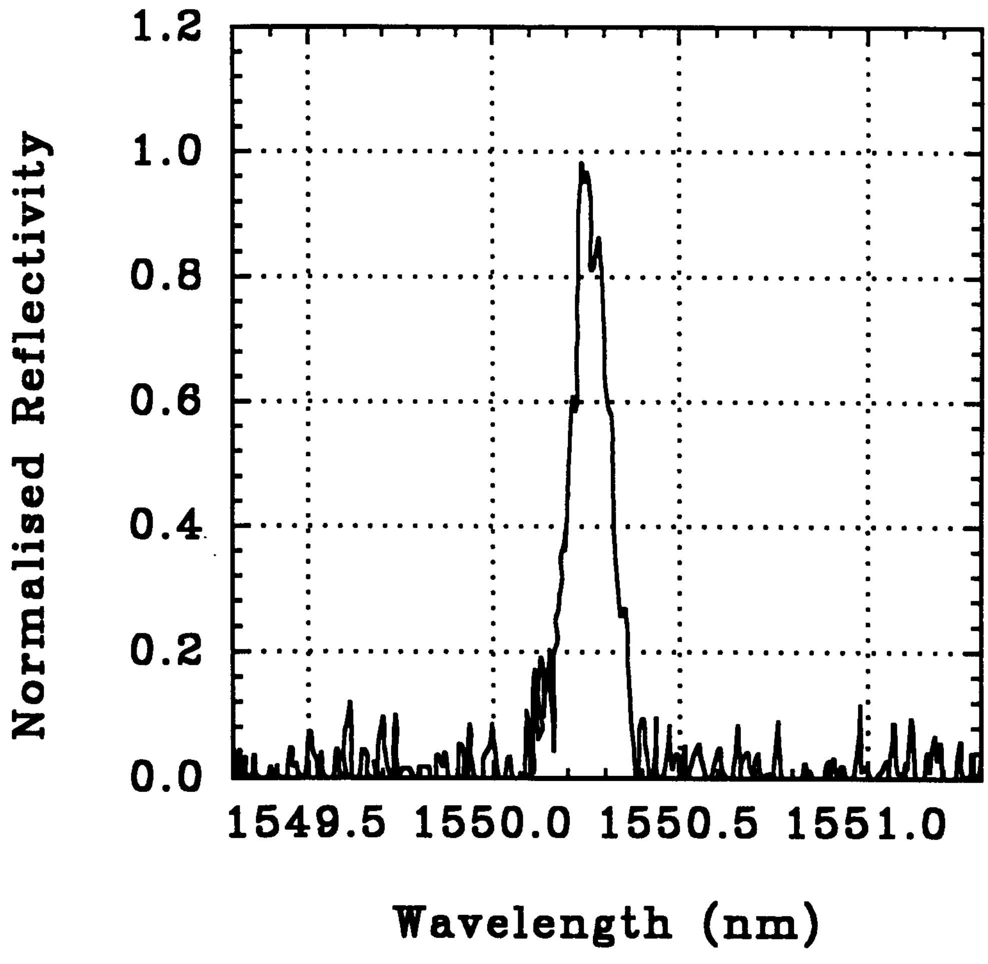
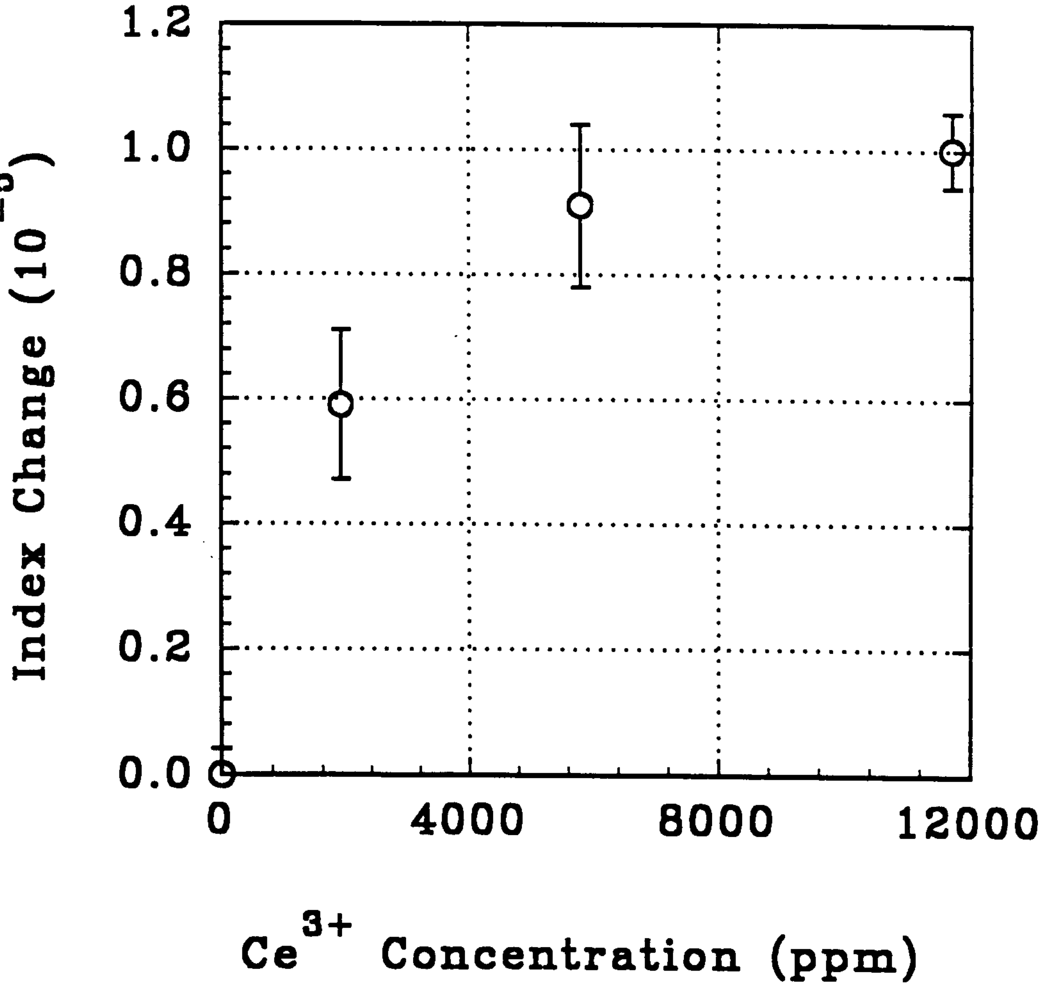
Figure Captions

1. Spectral response of a Ce^{3+}-doped fibre gratings.

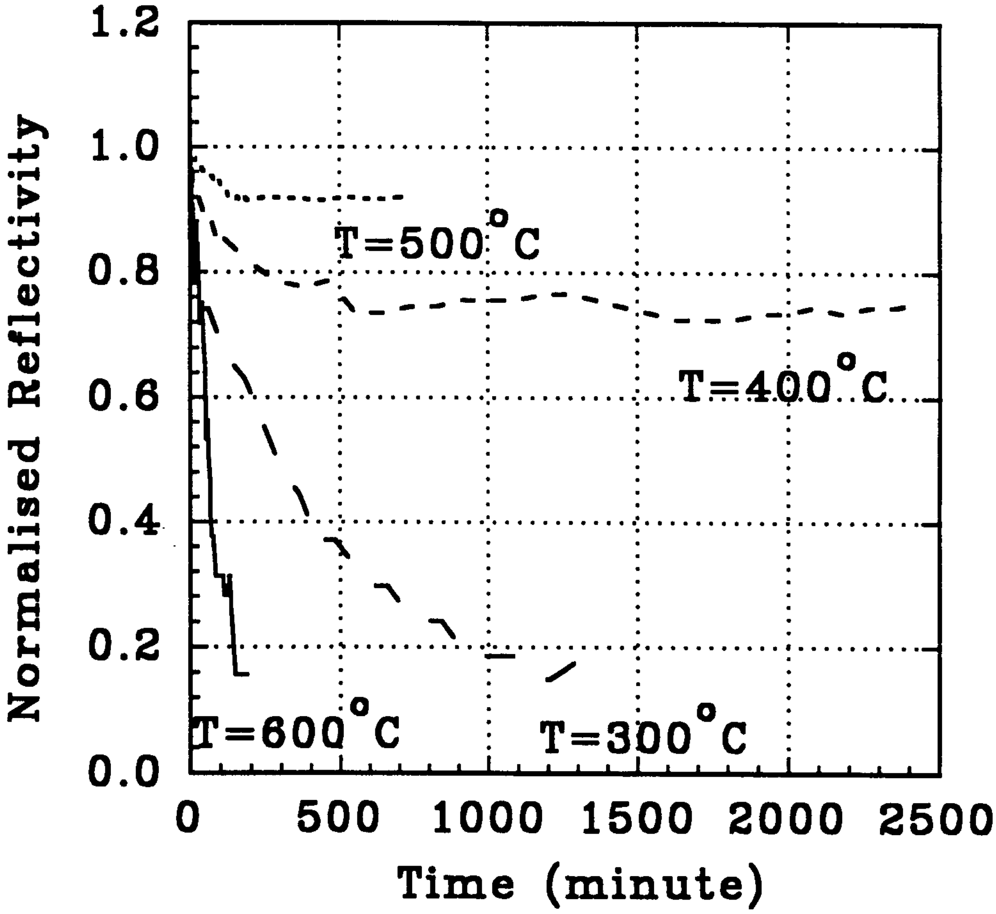
2. Ce^{3+} concentration dependence of the induced index change in the Ce^{3+}-doped fibre gratings written under the same conditions.

3. Stability of the Ce^{3+}-doped fibre gratings at various temperatures. For the measurements at 400°C and 500°C, the alignment in the writing interferometer was improved.


1.2
1.0
0.8
0.6
0.4
0.2
0.0
1549.5
1550.0
1550.5
1551.0
Normalised Reflectivity
Wavelength (nm)



Index Change (10^{-5})
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
4000
8000
12000
Ce^{3+} Concentration (ppm)



1.2
1.0
0.8
0.6
0.4
0.2
0.0
Normalised Reflectivity
0
500
1000
1500
2000
2500
Time (minute)
T=500°C
T=400°C
T=600°C
T=300°C