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Grating Formation in a Phosphorus-doped Germanosilicate Fibre

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Abstract: Refractive index changes as high as $\sim 5 \times 10^{-4}$ in a phosphorus-doped germanosilicate fibre were observed for the first time without hydrogen loading during grating formation with a 193 nm laser. Dynamics was studied and it was found that Type IIa gratings was easily formed in this fibre.

Summary: The possibility of using high dopant concentrations in phosphorus-doped silica fibres makes it very attractive for making compact fibre amplifiers and lasers, particularly for single frequency DFB lasers. Phosphorus doping, however, reduces the 240 nm germanium oxygen deficient centres (GODC) in germanosilicate fibres and makes grating formation very difficult in these fibres when writing at this wavelength[1]. Grating formation in phosphorus doped silica fibres has been observed only after low temperature H_2 loading and writing at 193 nm[2] or at 248 nm after the H_2 loaded fibres were heated to react the H_2 with the glass to form a strong absorption at ~240 nm[3]. It has also been found that Type IIa gratings formed in germanosilicate fibres are much more stable than Type I gratings[4]. Such stable gratings are very desirable especially for applications at higher temperatures because they lengthen the device lifetime. Type IIa gratings, however, take a long time to form when writing at around 240 nm (>10kJ/cm^2). We report, for the first time, index changes as high as 5.4×10^{-4} in phosphorus-doped germanosilicate fibres without H_2 loading and observation of Type IIa formation after short exposure to a 193 nm laser (~3 kJ/cm^2). The dynamics of the process was also studied.

The fibre has ~8 mol% P_2O_5, ~19 mol% GeO_2, 0.3 NA and a core diameter of 3.0

μm. The 193 Laser was a Lambda Physik EMG201 ArF excimer and was operated at a repetition rate of 24 Hz. A phase mask supplied from QPS Semiconductors Inc in Canada was used and the laser beam was focused in order to increase the intensity. A 4.8 mm long section of the phase mask was masked out for writing 4.8 mm long gratings. The Type IIa grating in figure 1 was formed after an exposure of ~10 minutes at 200 mJ/cm^2/pulse. An index modulation of 2.6×10^{-4} (5.2×10^{-4} total index change) was inferred. The misfit between the data and theory for the side lobes is due to insufficient resolution in the measurement and possible birefringence in the fibre. Figure 2 shows the growth of total reflection from a grating and the change of Bragg wavelength during grating formation. This dynamics is typical of Type IIa gratings[4]. Two different mechanisms were suggested. One of which has a faster time constant and gives a positive index change and the other one has a slower time constant and gives a negative index change[4]. Type IIa gratings were observed to be much more stable than Type I gratings, but they can only be formed after a long exposure at ~240 nm (>10 kJ/cm^2). Figure 3 compares the growth of gratings at two different pulse intensities. The growth of the gratings is very similar when plotted against fluence but saturates at different levels. The saturated index changes at different intensities were plotted in figure 4 with a tentative linear. The data are scattered but do not show the quadratic dependence which would be expected from a two photon effect.

To conclude, we have observed $\sim5\times10^{-4}$ index changes in a phosphorus-doped germanosilicate fibre and ready formation of Type IIa gratings in this fibre. Recently, an index change as high as $\sim1\times10^{-4}$ was reported in a telecommunication fibre at 193 nm[5] and once again demonstrating the advantage of writing at this wavelength.

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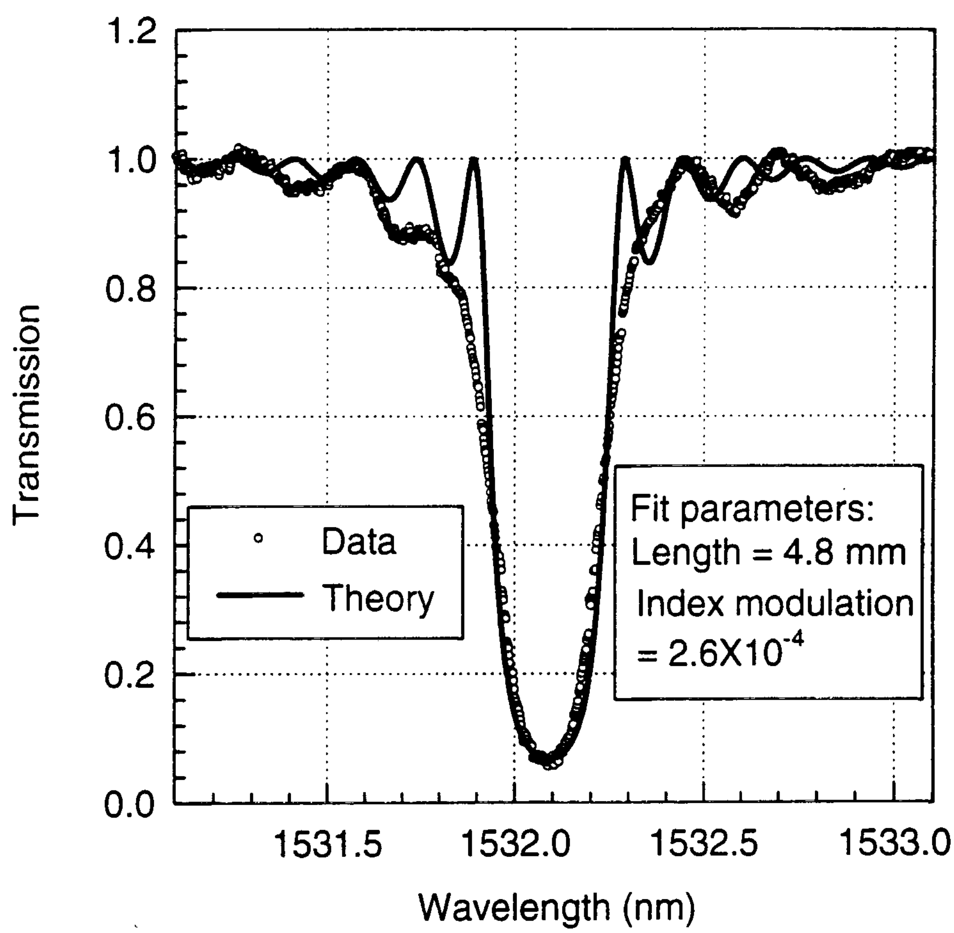

Figure 1 Transmission of a grating and a theoretical fit to it.

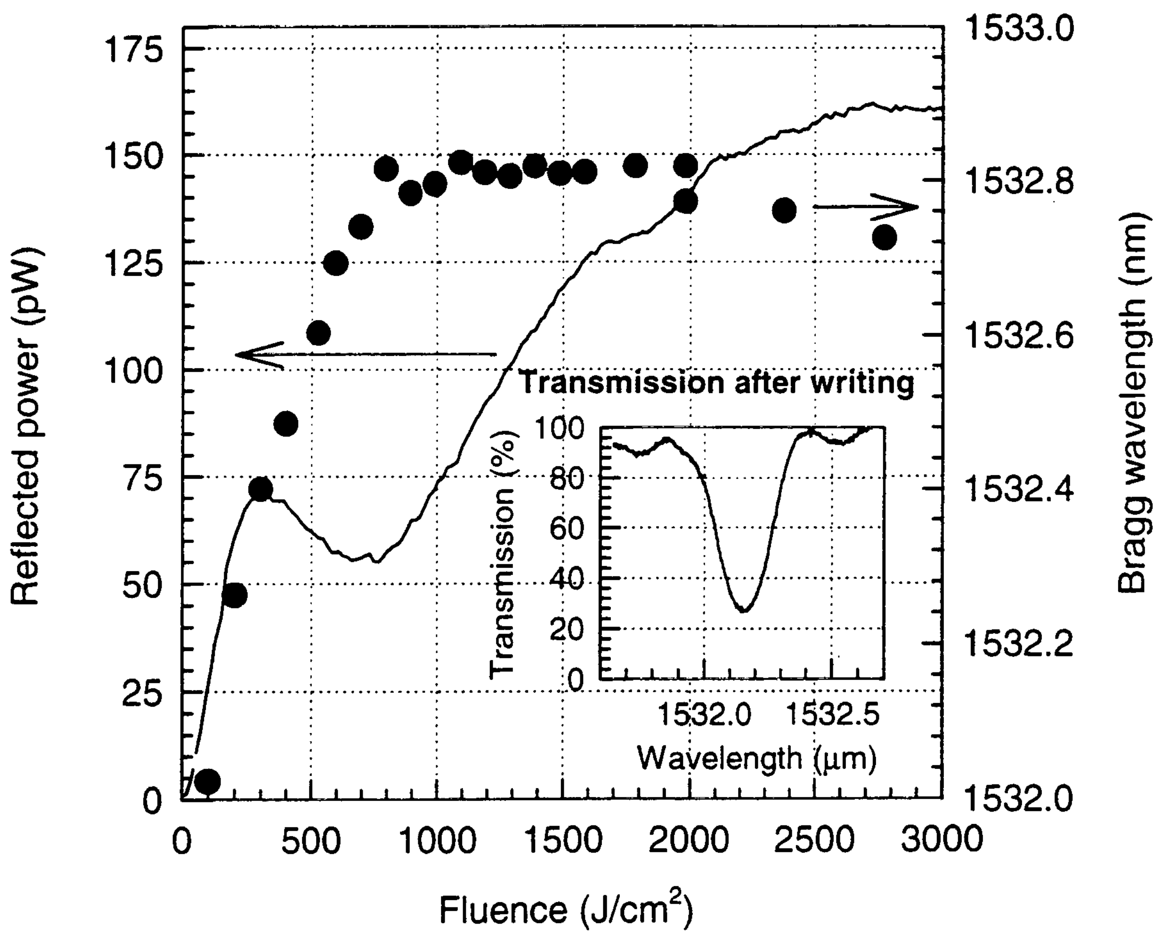

Figure 2 Growth of index modulation and change of Bragg wavelength while writing at 165mJ/cm^2/pulse

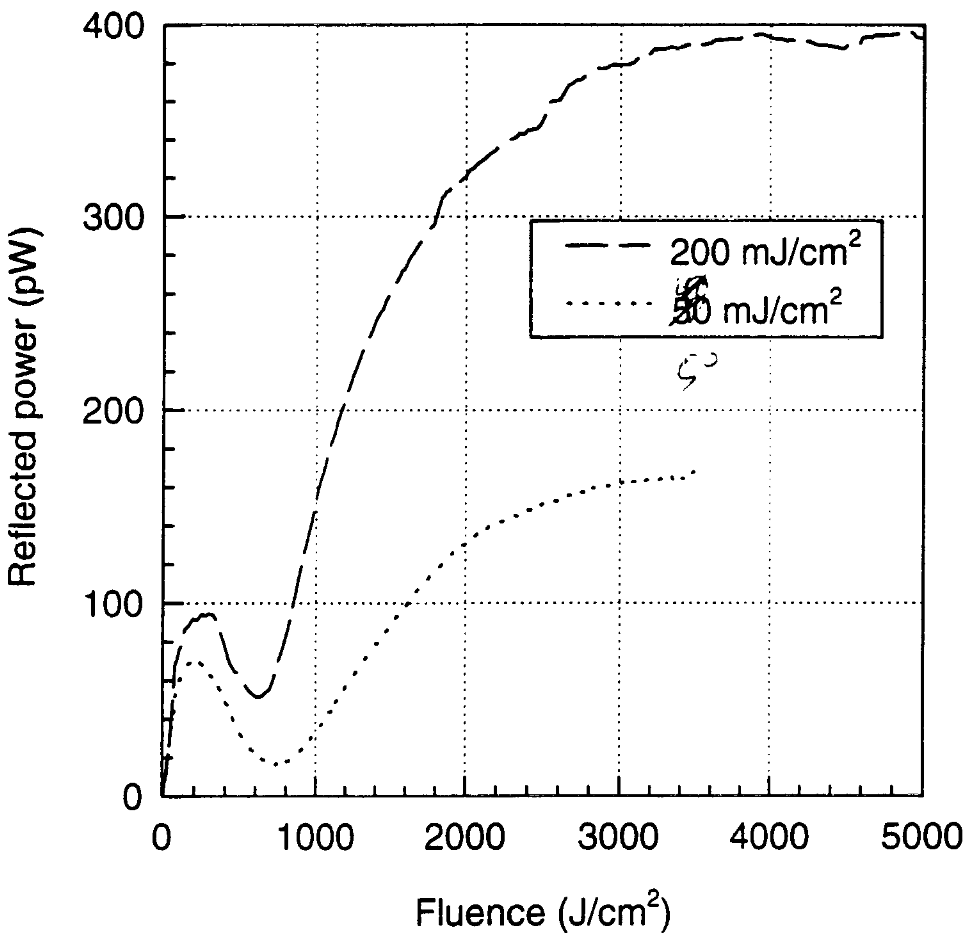

Figure 3 Grating growth at two different intensities.

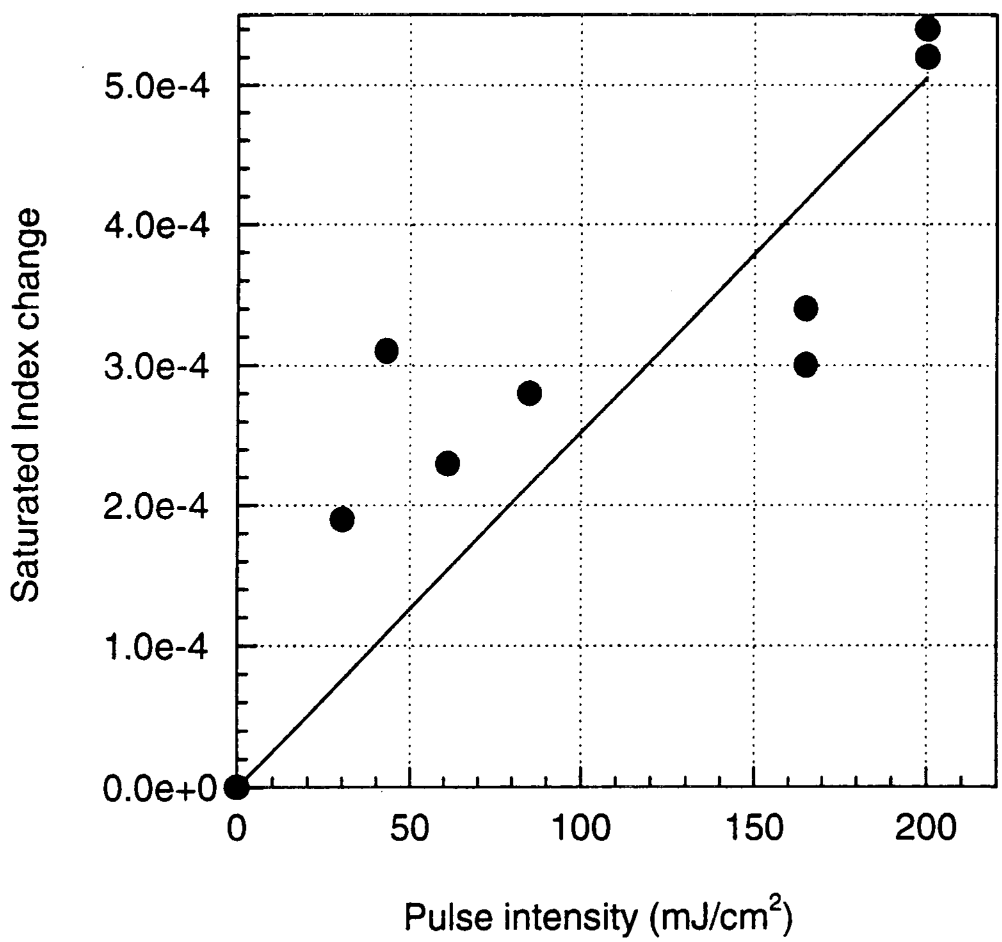

Figure 4 Saturated index changes at different pulse intensities and a linear fit.