Photo-induced Refractive Index change in Germanosilicate Optical Fibres:
Electronic Change or Physical Change?

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These gratings can be used:

I. as Bandstop filters
II. to construct bandpass filters
III. as WDM demultiplexers
IV. as reflectors for single frequency fibre lasers
Writing of in-core fibre gratings
Colour Centre Model

old color centres \( (n_o/cm^3) \) \( \Rightarrow \) old colour centres \( (n_i/cm^3<n_o) \)
new colour centres \( (m_1/cm^3) \)

state I \( \Rightarrow \) state II

state II has a different absorption spectrum therefore a different index

In germanosilicate glass

State I = germanium-related oxygen deficient centres (GeO defects or Ge-Ge wrong bonds) (GODC) with an absorption band at 242nm

state II = reduced number of GODC and new bands at 195nm (possibly Ge-related), weak bands at 224nm, 256nm, 183nm and 175nm

To explain the \( 10^{-4} \) index change in IR, it requires several hundred dB/mm change in absorption in UV
Compaction Theory

a) fast injection (20ns) of energy causes local heating
b) local annealing leads to local compaction

UV intensity

Fibre Core
Kramers-Kronig Relation

\[ n(\omega) - 1 = \frac{2}{\pi} \int_{0}^{\infty} d\tilde{\omega} \frac{K(\omega) \tilde{\omega}}{\tilde{\omega}^2 - \omega^2} \]

\[ k(\omega) = \frac{2}{\pi} \int_{0}^{\infty} d\tilde{\omega} \frac{n(\omega) \omega}{\omega^2 - \tilde{\omega}^2} \]

where

\[ \varepsilon(\omega) = (n(\omega) + iK(\omega))^2 \]
\[ \Delta n(\omega) = \frac{c}{\pi} \int_0^\infty d\tilde{\omega} \frac{\Delta \alpha(\tilde{\omega})}{\tilde{\omega}^2 - \omega^2} \]

where

\( \Delta n: \) change in refractive index

\( \Delta \alpha: \) change in absorption coefficient

\( c: \) speed of light in vacuum
Modified Chemical Vapour Deposition

\[ \text{SiCl}_4 + \text{GeCl}_4 + \text{O}_2 \]

burner

substrate tube
**UV-induced absorption change**

**main features:** reduction in 242nm band, increase in 195nm band

**other features:** weak bands at 224nm, 256nm, 183nm, and 175nm
Dynamics of Absorption Change

NA=0.18 (8.3mol% GeO₂), 0.9mJ/mm²/pulse.
Effect of Thermal Annealing

NA=0.2, heating rate=10°C/min, dwell=10mins

![Graph showing the effect of thermal annealing on refractive index change with temperature. The graph depicts the ratio of Δn/Δn_{max} and Δα/Δα_{max} against temperature. The graph includes symbols for different wavelength bands and calculated Δn at 1.5μm and Δn in gratings.]
GeO$_2$ Concentration Dependence

0.6mJ/mm$^2$/pulse, 20mins

- Change in the 242nm band
- Change in the 195nm band
- Change in the refractive index

Change in absorption (dB/mm) vs. Germania concentration (mol%)
Conclusions

I. The Strong UV-induced absorption change in germanosilicate preforms has been resolved with a simple and accurate method.

II. The UV-induced absorption change can account for the $10^{-4}$ index change in fibre gratings.

III. Thermal annealing characteristics of the absorption change is also similar to that of the index change in fibre gratings.