Conclusions: Novel cylindrical metal-coated optical fibre devices can be fabricated by coating the waist of a tapered fibre with a metal layer. The devices exhibit strong resonant coupling between the fundamental fibre mode and the surface plasma mode, which depends on the external refractive-index and the wavelength, as well as other parameters. Applications include optical sensors and spectral filters.

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Evolution of the 660nm radiation induced band in a low OH low Cl optical fibre

O. Deparis, P. Mégret, M. Decréton and M. Blondel

Indexing terms: Optical fibres, Radiation effects

A radiation induced absorption band at 660nm was observed *in situ* in a low OH, low Cl optical fibre exposed to gamma rays up to 1.5MGy. It is proved that this band can be definitively suppressed by a pre-irradiation for which the total dose and the dose rate are key parameters.

Introduction: Applications of fibroscopy in a nuclear environment must sometimes cope with very high gamma and neutron fields: this requires optical fibres to maintain a good light transmission for several tens of metres in the entire visible range. In this range (400 – 700nm), the level of induced loss is at least one order of magnitude higher than in the standard telecommunication range, i.e. the near infrared. Among the candidates for such an application, a multimode step-index pure silica core optical fibre with aluminium coating and very low OH and Cl contents in the core gives new perspectives [1, 2]. The synthetic silica core, produced by an original sol-gel technique, provides this fibre with a good radiation resistance [2]. In particular, the 600nm radiation induced absorption band associated with the NBOHC colour centres was found to be practically absent from post irradiation induced loss spectra [2], as well as from *in situ* recorded spectra [1]. However, as previously observed in low OH and low Cl fibres [3], the presence of a radiation induced absorption band is expected around 660nm. This band is thought to be endemic to silica, with both low OH and low Cl contents. It might be due to an unidentified impurity [3].

Experiment: The fibre under test is a new type of fibre supplied by the Fibre Optic Research Centre of Moscow. It was produced by a sol-gel technique on a basis of KS-4V glass, without using $SiCl_4$ as a raw material. It has both low OH and low Cl contents, <0.2 and <20ppm, respectively, and an aluminium coating. The gamma irradiation tests were performed in the CMF facility of SCK·CEN (at Mol, in Belgium) which uses spent fuel as a gamma source. The irradiation was performed in two steps, at constant temperature (60°C) and dose rate (4.97kGy(SiO_2)/h). During the first step, an irradiation was performed up to 0.8MGy(SiO_2) and it was followed by a 3 day recovery period out of the facility. During the second step, another irradiation was performed at the same dose rate up to 1.5MGy(SiO_2), and it was followed by an 8 day recovery period. The fibre length exposed to radiations (L) was 6.65m. Basically, the measurement system consists of a white light source, a coupler injecting the same light level into reference and test fibres, and an optical spectrum analyser. A detailed description of the experimental setup can be found elsewhere [1]. The radiation induced loss (in dB/m) was measured *in situ* from 400 to 1400nm (steps of 10nm). It is computed by eqn. 1 from the values of the optical powers measured at the output of the irradiated (test) and reference fibres, $P_T(\lambda, t)$ and $P_R(\lambda, t)$, respectively, and from these values measured before irradiation ($P_{T,0}(\lambda)$ and $P_{R,0}(\lambda)$, respectively).

$$A_{induced}(\lambda, t) = -10\left[\log\frac{P_T(\lambda,t)}{P_{T,0}(\lambda)} - \log\frac{P_R(\lambda,t)}{P_{R,0}(\lambda)}\right]/L \qquad (1)$$

Results and discussion: Post-irradiation spectral measurements performed on the same type of fibre, reported that the induced loss was monotically increasing with decreasing wavelength in the visible range [2]. Our *in situ* results show that this shape of the spectrum is only established for doses higher than 50–100kGy (Fig. 1, curves (vi)–(viii)). At the beginning of the irradiation (Fig. 1 curves (i)–(v)), an absorption band grows rapidly around 660nm and then decays more slowly with increasing dose. In the past, similar results have been observed, with the same radiation-induced band at 660nm in low OH, low CL pure silica core fibres, exposed to gamma rays [3]. The origin of this band was attributed to an unidentified impurity. It was also found that this band increased at first but decreased at doses higher than 2kGy.

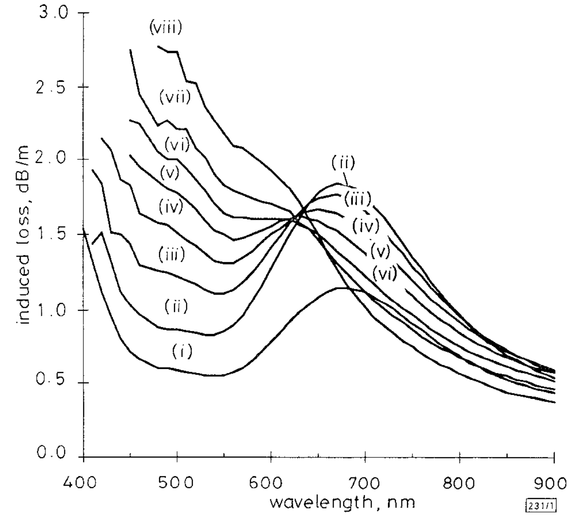

Fig. 1 *Radiation-induced loss spectra for different values of absorbed dose during first irradiation*

(i) – (viii): 3.4, 7.0, 14.2, 27.5, 57.6, 126.2, 272.8 and 792.4kGy (final dose)

Although the decrease is observed here at a later stage, 60 instead of 2kGy, we think that the band around 660nm observed here has the same origin as in [3]. The two studies do deal with similar fibres (low OH, low Cl cores), but at different dose rates. The higher dose rate of our experiment, one order of magnitude higher that the experiment in 1984, could explain the difference in intensity and dynamics of the observed band.

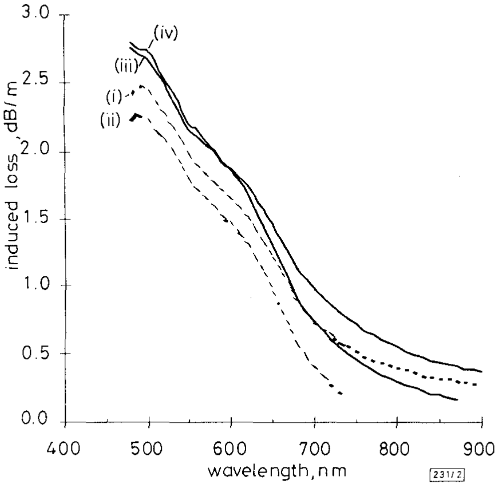

Fig. 2 *Radiation-induced loss spectra after first and second irradiation and during second irradiation*

(i) First, 77h recovery time
(ii) Second, 195h recovery time
(iii) 0.8MGy (start dose)
(iv) 1.5MGy (end dose)

The present study thus confirms the appearance of this 660nm band for specific fibres, but also shows that this band can be suppressed when a sufficiently high dose is reached. The dose rate probably plays a role in this bleaching process. Another interesting point to check is whether or not the suppression of the band is definitive. Induced loss spectra recorded *in situ* after the first irradiation show that the 660nm band does not appear again (see Fig. 2(i)). Furthermore, the band does not reappear during the second irradiation (see Fig. 2(iii) and (iv)) up to the final dose of 1.5MGy, which is about twice the dose reached at the end of the first irradiation. As expected, the band is also absent from the spectra recorded after the second irradiation up to a recovery time of ~195h (see Fig. 2(ii)). In the study mentioned above [3], the 660nm band was again observed during an additional irradiation performed after 10h of recovery at room temperature, which followed a pre-irradiation up to 5.3kGy. In this case, the 660nm band was reduced by the pre-irradiation and the subsequent recovery, but not definitively suppressed. This highlights the important role of the total dose, and of the dose rate when the 660nm band is meant to be suppressed using pre-irradiation.

Conclusion: A radiation induced absorption band at 660nm was observed *in situ* in a low OH, low Cl aluminium coated pure silica core fibre exposed to gamma rays at a dose rate of 4.9kGy/h. After a rapid increase, it was found to decrease with increasing dose for doses higher than 10–100kGy. For this reason this band could be the same as the 660nm band observed in the past in low OH and low Cl silica fibres, and thought to be endemic to this type of silica. The suppression of the 660nm band by the radiation itself was found to be definitive. The band does not appear again during the 3 day recovery period after the first irradiation (total dose of 0.8MGy). Moreover, it does not appear again during a second irradiation (up to 1.5MGy), or during a subsequent recovery period. This proves that the 660nm band can be definitively suppressed by a pre-irradiation for which the total dose and the dose rate are key parameters.

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Interrogation of 60 fibre Bragg grating sensors with microstrain resolution capability

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Indexing terms: Gratings in fibres, Fibre optics sensors

The authors report the demonstration of an instrumentation system capable of monitoring a large number of Bragg gratings using a common source and scanning narrowband filter. The system described monitors five arrays of 12 Bragg gratings sensors for a total of 60 sensor elements with μstrain resolution.

Introduction: It has become clear that fibre Bragg grating based sensors provide a powerful sensing technique which can be uniquely applied to a range of structural sensing applications. Recent work on grating based sensors has focused on the development of a variety of wavelength detection techniques [1 – 9], which provide the capability to multiplex several FBG strain sensors along a single fibre using either the inherent wavelength division addressing capabilities of FBGs or a hybrid wavelength-time division addressing approach. In this Letter we describe a step towards the development of instrumentation capable of monitoring a very large number of Bragg gratings using a common source and scanning narrowband filter. The system uses wavelength division addressing, combined with the sequential addressing of separate fibre arrays via a singlemode fibre switch. As currently implemented, the system has the capability to monitor 12 FBG sensors along each of five fibres for a total of 60 sensor elements. The system is, however, capable of supporting a larger number of sensor elements by expanding the number of arrays sequentially addressed.

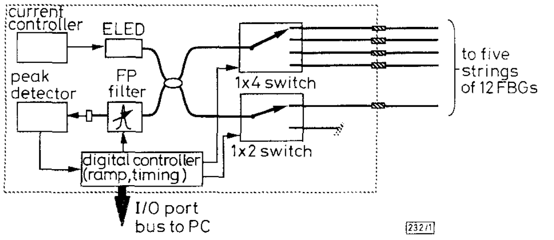

Fig. 1 *60 FBG sensor electro-optics system*

Instrumentation system: The system is shown in Fig. 1. Singlemode optical fibre switches driven under PC control are used to allow the measurement of strain along five independent strings of 12 FBG sensors. The strings are illuminated using a single 1.3 μm ELED source (≃150 μW power) through a 3dB coupler and the switches. The switches used (Dicon), are a 1 × 4 (plus an 'OFF' state) and 1 × 2 implementation. Typical losses of the switches are ≃1dB, and thus do not seriously impact the optical power levels returned from the array.

The system hardware is capable of supporting a pair of the same design of switch, which is available in implementations up to 1 × 32 ports, allowing for the potential to address 64 strings of