

Presentation and Preliminary Results of DROÏD Project: Development of a Distributed Optical Fibre Dosimeter

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ABSTRACT

DROÏD project is intended to develop a distributed optical fibre dosimeter based on Radiation-Induced Attenuation (RIA). The RIA will be measured by a high resolution Optical Time Domain Reflectometry (OTDR) technique that allows to locate the irradiated fibre section.

The first part of the project focuses on designing a high radiation sensitive fibre. As a preliminary work, the attenuation of several fibres with various compositions has been recorded in situ during and after irradiation. The experimental setup and RIA values are presented and discussed. Several dopants and their combinations have been identified as a good starting point to design a highly radiation sensitive fibre.

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42.81.Cn. Fibre testing and measurement of fibre parameters, 42.81.Pa. Fibre-optic sensors, 42.88.+h. Environmental and radiation effects on optical elements, 78.30.Ly. Infrared spectra; disordered solid, 78.70.-g. Interactions of particles and radiation with matter.

1. PROJECT PRESENTATION

Financed by ANR PIA (*Programme d'Investissement d'Avenir*), DROÏD is a post Fukushima project aimed at improving the security in nuclear plants, in normal or accidental conditions, by developing a distributed dosimeter based on the radiation sensitivity of an optical fibre. This dosimeter will be able to locate the radiation along the fibre with a centimetric resolution by using OTDR.

1.1 State of the Art

Over the past twenty years, several radiations sensors based on optical fibres have been developed and can present two types of architecture. In the first one, the fibre only serves as a waveguide to read an external sensor from

a distance, like a radiation sensitive OSL dosimeter [1]. The OSL sensor is placed at the end of the optical fibre to make one punctual dose measurement. Grouping together several sets in a single cable permits to get several dose values. The drawback of this approach is that the number of dose points is limited by the number of fibres that can be joined within one cable. In the second architecture, which is built upon fluorescent or scintillating polystyrene doped plastic fibres, the waveguide itself becomes the radiation sensor [2]. Radiations induce a light emission within the fibre core that is guided by the fibre and then monitored. However the latter system does not allow to know where, along the fibre, radiation/matter interaction took place.

Today, there is only one report on a system able not only to measure a radiation dose but also to locate where this dose is applied [3]. It uses a phosphorus-doped commercial fibre whose RIA is read by reflectometry. This fibre does not present a dose rate dependence and acts as a good dose integrator with low annealing. So, there is a unique and simple relation between RIA and dose levels. This 140-metre system can detect a minimum dose of 3 Gy over a minimum fibre length of 1.5 m with a maximum measuring time of 4 min.

1.2 Project goals

Within nuclear power plants (NPP), for applications regarding staff radioprotection and environmental dosimetry, the dosimeter specifications, described above, are not suitable. Indeed lower doses must be detected with a better spatial resolution.

The main project goal is to design an improved version of the dosimetry system presented in [3], working on a specially manufactured high radiation sensitive optical fibre and a more accurate and spatially resolved OTDR technique. This paper presents some preliminary results on the radiation sensor fabrication.

2. DESCRIPTION OF EXPERIMENTS

Eleven amorphous silica-based fibres, with various core compositions, have been fabricated by MCVD (Modified Chemical Vapour Deposition). Additional elements, such as rare-earth (Tm, Er) and metals (Al, Mg, Ni) were incorporated using the so-called solution doping technique [4]. The fibre samples of typical length 1.5 m have been irradiated at a dose rate of 10 Gy/h during sixteen hours. RIA has been recorded in situ and during six hours after the irradiation stop.

Using a white light source filtered through a monochromator, fibre characterisation has been carried out on a wavelength domain ranging from 400 to 1550 nm with a 10 nm step. The optical power injected in the fibre under test is less than 10 nW and, as a consequence, photobleaching can be neglected. Furthermore, the small power fluctuations of the halogen bulb are considered in the RIA calculation, as well as the attenuation induced by the radiation on the patch cables.

3. RESULTS

Although RIA has been recorded from 400 to 1550 nm, results presented hereafter focus on 850 nm. Indeed, among the three telecommunication wavelength windows, highest RIA are observed in the first one. Table 1 shows the sample names, composition types and RIA values after 1 Gy. Detailed sample compositions will be provided at the conference.

Name	Compositions	RIA [dB/m] after 1 Gy
H14	Al/P/Er	0.12
L18	Al/Tm	0.1
L22	Al/Tm	0.088
I12	Al/P/Er	0.08
Cr20	Al/P/Cr	0.056
L33	Ge/Al/Mg/Ni	0.046

Table 1: Composition of samples and their RIA at 850 nm.

In reference [5] and [6], several commercial fibres of various types have been characterised. At 850 nm, most of them exhibit after 1 Gy a RIA lower than 0,0016 dB/m (assuming a linear RIA variation as a function of dose). The fibres H14 and L18 reach nearly 100 times the RIA of most sensitive commercial fibres.

During the recovery, which lasted 4.5 hours, 5 points have been recorded at each wavelength for each fibre. To compare the annealing kinetics between fibres, data have been interpolated as a function of time (Figure 1). Past stud-

ies have shown that phosphorus could mitigate fibre recovery in the near IR region [7]. Despite the fact that most tested fibres contained a small concentration of that chemical element, all tested samples present a significant annealing.

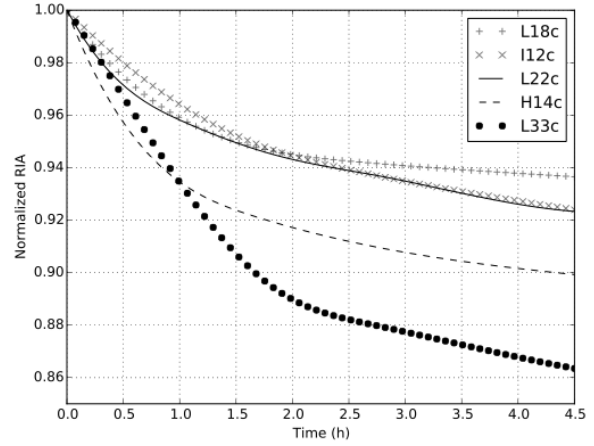


Figure 1: Normalised recovery of highest RIA fibres.

4. CONCLUSION

Eleven fibre samples have been irradiated by gamma rays with 10 Gy/h dose rate during 16 hours. RIA has been recorded in situ and some samples present an interesting radiation sensitivity, twenty times higher than most standard telecommunication fibres, which is suitable for dosimetry purposes regarding staff radioprotection and environmental monitoring. Behind this sensitivity, several dopants and their combinations have been identified as a good starting point to design the highest RIA fibre.

Based on the results of this preliminary study, about sixty new samples have been manufactured and will be characterised.

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