RADIATION DOSE MONITORING USING OFDR AND ENHANCED BACKSCATTERING OPTICAL FIBERS

Massimo Olivero[1*], Alessandro Mirigaldi[1], Wilfried Blanc[2], Mourad Benabdesselam[2], Franck Mady[2], Carlo Molardi[3], Daniele Tosi[3], Alberto Vallan[1], Guido Perrone[1]

1 Politecnico di Torino, Torino, Italy
2 Universitè Côte d'Azur - CNRS, Nice, France
3 Nazarbayev University, Astana, Kazakhstan
**massimo.olivero@polito.it*

An in-situ real-time dosimeter capable of evaluating both the cumulative dose and the radiation intensity profile is demonstrated using an enhanced back-scattering optical fibre interrogated with a high-resolution optical back-scattering reflectometer. Particular interesting are possible applications in the biomedical field, such as in tumour therapy.
Keywords: Radiation dose measurement, distributed fibre sensors

1. Introduction

X-ray imaging and tumour radiotherapy are the typical biomedical applications of ionizing radiations. Besides for the monitoring of the dose, these applications often require the evaluation of the intensity distribution on the target organ. The most common measurement approach is to use GafChromic (GaF) films, which contain a special dye that polymerizes upon exposure to radiation, with a subsequent increase of its optical density [1].
Optical fibres are an attractive alternative for measuring ionizing radiations because they combine minimal invasiveness with the possibility of remote interrogation and, most important, real-time measurement. Standard telecom optical fibres exhibit little sensitivity to ionizing radiations, but it is known that aluminium co-doping enhances the radiation-induced losses. Indeed, exposing a fibre to radiations increases the Rayleigh scattering, hence the propagation loss. Being this a local effect, it is possible to evaluate the radiation intensity profile by measuring the loss spatial distribution along the fibre. Optical Time Domain Reflectometers (OTDRs), commonly used for telecom networks, do not have sufficient spatial and intensity resolution for monitoring radiotherapy applications. Recently, a new class of instruments, called Optical Frequency Domain Reflectometers (OFDRs), has been proposed to measure the Rayleigh scattering with very high accuracy and spatial resolution. These instruments have found successful application in distributed strain and temperature sensing.
In this paper, we report on the first demonstration of an OFDR used with an Enhanced Back-scattering Fibre (EBF) for in-situ, real-time, and high-resolution dosimetry.

2. Measurement Setup and Results

The proposed fibre-based distributed dosimeter is composed of a sensing element made with an aluminium doped silicate fibre acting as an EBF, and of an interrogation unit, constituted by an Optical Backscatter Reflectometer (OBR) Luna OBR4600 [2]. The OBR is capable of sensing Rayleigh scattering signatures along the fibre under test with a nominal spatial resolution of about 10 μm. For assessing the performance, a 1 metre long EBF has been positioned under an x-ray beam and connected to the OBR through a standard Single-Mode Fibre (SMF). The x-ray beam has been calibrated in terms of dose rate using an ionization chamber connected to an electrometer. The OBR allows estimating the radiation intensity distribution by comparing the Rayleigh back-scattering profile along the fibre with its reference, taken before irradiation. In details, the two patterns are cross correlated to calculate a parameter called spectral shift, which is related to the localized change of refractive index induced by radiation.
As a preliminary test, both the EBF and a common SMF have been exposed to a high dose rate (700 Gray/min).
Fig. 1 reports the spectral shift versus time (and correspondent dose) for the two fibres. The comparison of the two datasets highlights the much higher sensitivity of the EBF, which exhibits a slope of 138 MHz/Gy. Other tests have demonstrated that the EBF can measure the radiation distribution down to 22 Gy/min with a resolution of 5 mm, obtaining an intensity profile width in good accordance with that estimated from GaF films. Further characterization measurements are ongoing, but these results show that the alumino-silicate EBF can be effectively used as a distributed dosimeter.

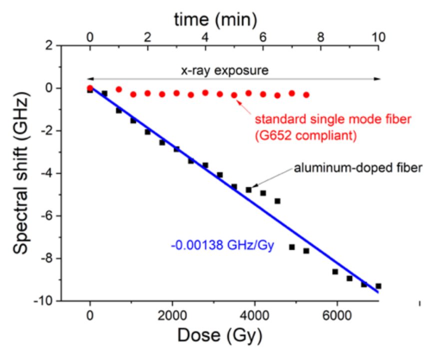

Fig. 1 Measured spectral shift (an indicator of the fibre sensitivity) with dose for a standard SMF (G652 compliant) and the EBF.

References

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