

## Background

The use of optical fibre distributed sensors for temperature sensing is a powerful way of monitoring, quasi simultaneously, thousands of points avoiding the requirement of optimum positioning of discrete temperature sensors. Their range of applications is rapidly expanding in the industry and nowadays this fibre optic sensing technology is mature for industrial applications such as fire detection inside buildings and tunnels, process vessel monitoring, leak detection in cryogenic storage vessels (liquid natural gas, ammonia, ethylene) or oil wells and the measurement of energy cable thermal distribution for the power supply industry. These applications rely on the well known immunity of fibre optic sensors to electromagnetic interference and the ability of fibre sensors to be operated in hazardous environments.

On the other hand, the nuclear industry shows a growing interest for the possibilities offered for temperature sensing applications. Raman distributed fibre optic temperature sensors are attractive for the monitoring of large nuclear infrastructures such as containment buildings of nuclear power plants, coolant loop systems and nuclear waste repositories. Its radiation tolerance needed to be assessed up to high gamma total doses.

## Objectives

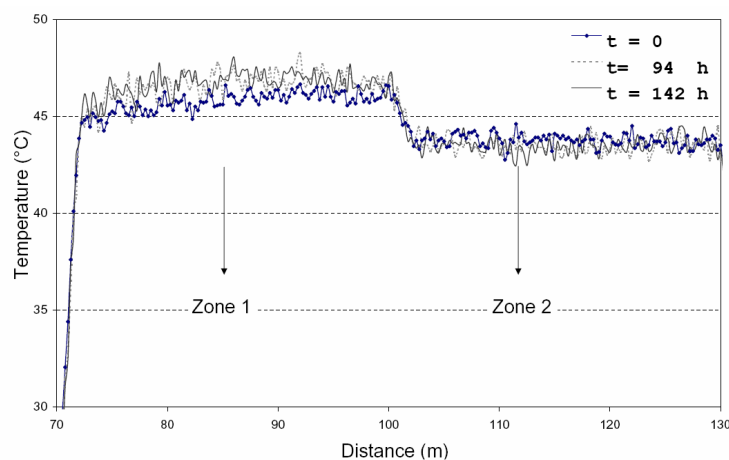
A major problem in the application of optical fibres in nuclear environments is the presence of ionizing radiation fields that induce an increase of the optical fibre attenuation. This radiation-induced degradation of the measurement signal could be critical since most commercially available distributed temperature sensors derive the temperature profile from the measurement of the Raman backscattered light intensity along the fibre, using optical time domain reflectometry techniques. The objective is therefore to investigate whether such a distributed sensing system can withstand radiation doses that can be encountered in nuclear facilities.

To do so we relied on commercial grade multimode fibres in a double ended Raman detection scheme to cope with radiation induced losses. We evaluated the double-ended Raman detection scheme up to more than 300 kGy in the  $^{60}\text{Co}$  gamma irradiation facility BRIGITTE (SCK•CEN).

## Principal results

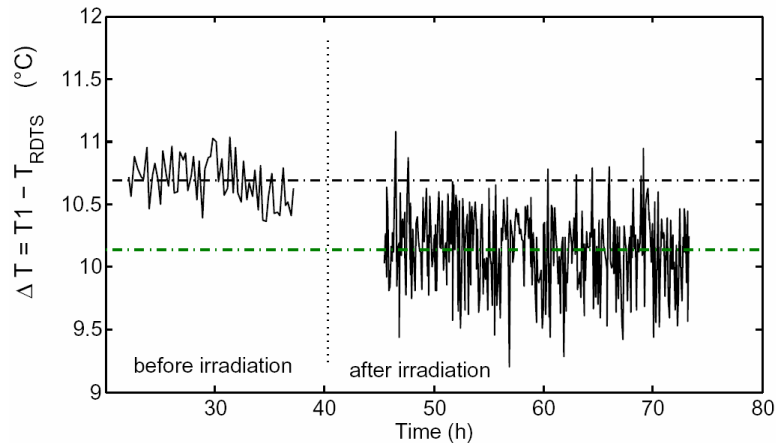
We used an industrial Sensa DTS 800 system to perform the temperature distributed measurement. The DTS 800-M8 uses 50-125  $\mu\text{m}$ , graded index, multimode optical fibre of up to 8 km in length, in either a double-ended (loop) or singled-ended configuration. Its spatial resolution is 1 m and its accuracy is  $\pm 0.5$   $^{\circ}\text{C}$  between 0 and 85  $^{\circ}\text{C}$ . The system can cope with a maximal total loss of 17 dB at its operating wavelength of 1064 nm.

The dual loop arrangement performs well under gamma radiation. When the temperature remains constant in each zone, the Raman Distributed Temperature sensor (RDTS) read-out remains constant, within its accuracy of  $\pm 1$   $^{\circ}\text{C}$ , as shown in this for zones 1 and 2.



*Evolution of the temperature profile as a function of the irradiation time (acrylate-coated fibre).*

The total attenuation, including radiation loss and connection loss, is about of 6.3 dB for the polyimide-coated fibre and 7.5 dB for the acrylate-coated fibre. These losses could therefore be compensated by the SENSE DTS800 system, with its dynamic range of about 17 dB, up to the MGy dose level. The figure below shows the difference between the two temperature measurements for fibre 1 in zone 1 (with the highest dose rate).



*Temperature difference between the RDTs and the thermocouple T1 in zone 1 as a function of time, recorded before and after a gamma irradiation of 326.8 kGy.*

This difference is lower than 0.5 °C, which falls within our measurement errors (thermocouple accuracy is  $\pm 1$  °C and RDTs resolution  $\pm 1$  °C). A long-term accuracy lower than 0.5 °C is nevertheless sufficient for the monitoring of large nuclear infrastructures.

Our results have shown that double-ended RDTs systems can cope with power losses induced by ionising radiation beyond 300 kGy. No specific calibration technique is needed to correct for the radiation effects in commercially-available optical fibres, making double-ended RDTs systems applicable for temperature monitoring and fire detection in large nuclear infrastructures.

### Future work

Distributed sensors based on stimulated Brillouin scattering also have an interesting potential for distributed strain and temperature monitoring in the nuclear industry. Since the sensing information is frequency-encoded, it should also exhibit a good radiation tolerance. We will investigate the radiation effect on the Brillouin shift for application in ionizing radiation environments.

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### Main reference

A. Fernandez Fernandez, P. Rodeghiero, B. Brichard, F. Berghmans A.H. Hartog, P. Hughes, K. Williams and A.P. Leach, "Radiation-tolerant Raman distributed temperature monitoring system for large nuclear infrastructures", to be published in IEEE Transaction in Nuclear Sciences, December 2005.