Andra Call for Projects
with the support of the
Investments for the Future Programme

CERTYF

Combined effects of radiation, temperature and hydrogen on optical fibres and silica-based materials

Project supported by Andra under the "Investments for the Future Programme" ("Investissement d'Avenir") - Selected under the Andra Call for Projects: "Optimisation of post-dismantling radioactive waste management", organised in cooperation with the French National Research Agency (ANR).

Duration: 48 months

Project launch:
11/2017

Total project cost:
€2.6 million

Sum covered under the Investments for the Future Programme: €600,000

Type of financial support:
Subsidy

Locations:
Saint-Étienne,
Nice,
Gif-sur-Yvette

Coordinating body: Hubert Curien Laboratory, UMR CNRS 5516, University of Lyon, University of Saint-Etienne

Partners:

- Hubert Curien Laboratory, UMR CNRS 5516, University of Lyon, University of Saint-Etienne
- French Institute for Radiological Protection and Nuclear Safety (IRSN)
- Nice Institute of Physics (INPHYNI)

Contact: Sylvain GIRARD, sylvain.girard@univ-st-etienne.fr

BACKGROUND

Optical fibres are silica glass or plastic filaments which can serve as waveguides for light, and particularly visible and near infra-red light. This property can be used to transmit information. Modification by their environment of the signal transmitted by optical fibres can also be used for measurements (optical fibre sensors).

Optical fibres, and optical fibre sensors, are increasingly considered for integration in facilities associated with harsh environmental conditions: high temperature, radiation levels, presence of certain gases (e.g. hydrogen). This is particularly true in the nuclear, space and high-energy physics sectors.

Taken individually, each of the aforementioned environmental stresses is known to degrade the macroscopic response of optical fibres (changing the structural and optical properties of the silica they are made of), and therefore the signal transmitted. Together, their effects combine, making it particularly difficult to understand and model the degradation mechanisms so that they can be extrapolated or used for developing predictive models. From an experimental perspective, test conditions therefore need to be as close as possible to the target environment, which is very difficult when the operational profile stretches over several decades. This is particularly true for the French Industrial Centre for Geological Disposal (Cigeo), where optical fibre measurement systems will be used for monitoring.

Achieving better fundamental understanding of the mechanisms generated by these environmental stresses seems essential for the deployment of these new technologies in such complex environments. This means working at the different scales (materials, components, systems) involved when optical fibres or silica-based materials are exposed to the combined effects of temperature, radiation and hydrogen. The knowledge gained will be very useful and enable recommendations to be made concerning their qualification procedure.


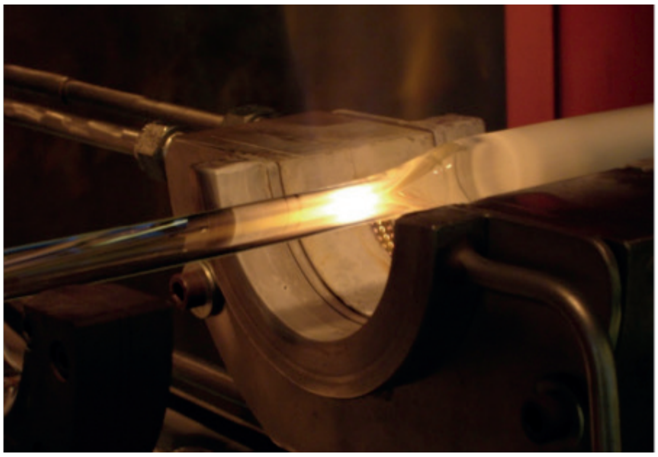

Fig.1. INPHYNI laboratory optical fibre manufacturing platform

UNIVERSITÉ DE LYON · UNIVERSITÉ JEAN MONNET SAINT-ÉTIENNE · IRSN · INPHYNI INSTITUT DE PHYSIQUE DE NICE · ANDRA French national radioactive waste management agency

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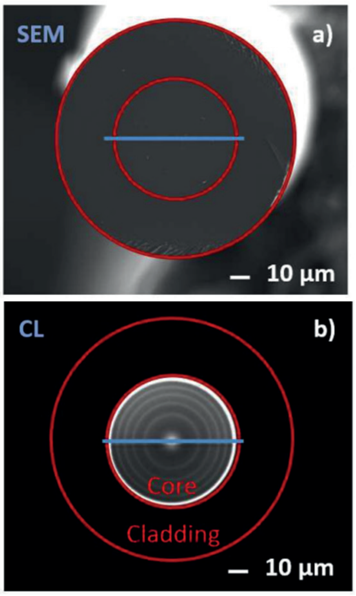
▶ Fig.2. The IRSN IRMA gamma irradiation facility (^{60}Co) to test the behaviour of optical fibres under irradiation



▶ Fig.3 Spatial distribution of point defects in a multimode fibre:
a) scanning electron microscope (SEM) image of the fibre;
b) location of luminescent defects in this optical fibre using cathodoluminescence (CL).

OBJECTIVES

CERTYF is a fundamental research project with the aim of improving the understanding of the basic mechanisms governing the degradation of optical fibres (loss of some optical properties via a radiation-induced attenuation phenomenon) in complex environments combining the following stresses: temperature (ambient temp. - 300°C), radiation (doses up to the order of MGy) and hydrogen (until the fibre has been saturated with the gas). In order to achieve this objective, several challenges will need to be addressed by the partners:

- provision of representative samples of different classes of fibre (fibres for telecommunications or dosimeters, or radiation-tolerant fibres), that are fully understood and known. The Inphyni laboratory manufacturing platform will make this possible (Fig.1);
- design of an experimental programme for the representative samples, varying the different parameters and characterising their effects combined with changes in radiation-induced attenuation. To this end, experiments using X- and gamma-rays will be performed at the Hubert Curien Laboratory and IRSN respectively (Fig.2);
- identification of point defects generated in the optical fibre by combining various spectroscopic techniques such as absorption spectroscopy, confocal microscopy, or cathodoluminescence (Fig.3);
- construction of a multi-variable, multi-scale physical model that can reproduce the growth kinetics of radiation-induced attenuation in line with the parameters studied, applied individually or simultaneously.

PROJECT SEQUENCE

The CERTYF project will be carried out over four years and will be split into two phases of 24 months each. The first phase will be exploratory and will focus on a systematic study of the parameters influencing the radiation-induced attenuation for various categories of optical fibre, in order to produce an initial version of predictive physical models for optical fibres. The second part of the project will focus on consolidating these models and producing recommendations for integrating optical fibres or optical fibre sensors in complex environments.

EXPECTED RESULTS

Innovation

The physical models developed under CERTYF will be used to quantify the vulnerability of an optical fibre or optical fibre sensor for a given application subject to a complex environment. They will also serve to direct radiation resistance (hardening) research with a view to increasing the resistance of optical fibres.

Economic impact

The fundamental knowledge obtained during CERTYF will be used to accelerate the inevitable integration of optical fibres within facilities associated with complex radiation environments. The intrinsic advantages of these solutions (low cost, potential for multiplexing and producing distributed sensors) will enable the development of new generations of sensors, and information systems that offer better performance and radiation resistance.

Impact on radioactive waste management

Thanks to their high bandwidth, small size and good radiation resistance, optical fibres offer both improved performance with regard to competing sensor or data transfer technologies, and a volume and weight reduction for the systems associated with these applications. In particular, there are plans to use them to provide deformation and temperature measurements along the high-level waste disposal cells to deduce changes in handling clearances during the operating phase.

Application and commercialisation

The knowledge and skills acquired under CERTYF will be able to be transferred to issues other than radioactive waste management. Many severe environments include a combination of the parameters studied, particularly in the oil, space and nuclear industries, along with high-energy physics and nuclear fusion research facilities (Megajoule Laser, ITER)