TW5-TPDC-IRRCER
IRRADIATION EFFECTS IN CERAMICS FOR HEATING AND CURRENT DRIVE, AND DIAGNOSTIC SYSTEMS

***Deliverable*: In-situ thermal annealing and photobleaching of gamma and neutron irradiated aluminium jacketed silica optical fibres**

D. Sporea, Adelina Sporea*, B. Constantinescu**, and I. Vata***

**National Institute for Lasers, Plasma and Radiation Physics, Magurele*
***"Horia Hulubei" National Institute of R&D for Physics and Nuclear Engineering, Magurele*

1. Introduction

The present paper reports the development of the experimental setup and the associated software to be used for the in-situ evaluation of thermal annealing and photobleaching of gamma and neutron irradiated aluminium jacketed silica optical fibres, in order to asses their possible use for plasma diagnostics in fusion installations (i.e. ITER).

Optical fibers are, along with mirrors and windows, passive optical components of great interest for use in the future International Thermonuclear Experimental Reactor (ITER) as they will be included in: plasma diagnostics systems (i.e. light-guides), remote handling assembles, distributed sensors and optical data communication links. Optical guides (fiberscope) are needed for plasma diagnostics to pick-up the optical signal and to carry it to the diagnostics instrumentation remotely located, through a noisy electromagnetic environment, under high temperature, high gamma-ray total dose/ dose rate and high neutron fluences. When irradiated, the optical fibers exhibit both a radiation-induced absorption (RIA) and radiation-induced luminescence (RIL) or radioluminescence. The first effect distorts the transmitted spectral to be evaluated, as in some spectral bands the attenuation becomes radiation dependent, while the second one deteriorates the signal-to-noise ratio, as additional optical signal is superimposed on the signal to be measured. Both effects are dependent on the wavelength, the irradiation conditions and the optical fiber type. Most of the investigations on this phenomenon were performed up to now over the visible and near-IR part of the spectrum (above 400 nm and below 2000 nm), targeting both the optical communications applications and the development of light guides in the visible spectral range. Under different irradiation conditions, optical fiber can exhibit some recovery phenomena of the radiation induced optical absorption (i.e. temperature related effects, photobleaching). For this reason, in-situ measurements of the optical absorption during the irradiation proved to be a useful tool in evaluating the dynamics of the radiation induced color centers responsible for the change in the absorption spectrum. Few on-line investigations were carried out on the UV optical absorption of irradiated optical fibers, as these optical fibers exhibit generally a poor transmission in this spectral band (200 nm – 400 nm). As the UV spectral band of the optical spectrum is of great interest for optical fibers used in plasma diagnostics, our previous work focused on the *off-line* evaluation of enhanced UV-response and solarization resistant optical fibers, after they were subjected either to gamma-ray or to neutron irradiation.

Optical fibre is susceptible to damage that causes increased attenuation along the fibre. This attenuation is due to the creation of colour centres in the fibre. These colour centres are formed by radiolysis and/or trapping the electron and/or radicals in different defects produced by radiation.

The reliability of the fibre can be affected by irradiation. The factors that alter the fibre ability to survive in these hostile environments are the dose rate and the type of irradiation field. The type of particles and their energy spectrum determine the mechanism by which the crystalline damage occurs.

2. The setup for neutron irradiation

Neutron irradiation will be carried out, in-situ, at "Horia Hulubei" National Institute of R&D for Physics and Nuclear Engineering–IFIN-HH Cyclotron facilities. The neutron field is produced by bombarding of a thick Beryllium target with deuterons. The neutron fluences will be measured using Ni foils and track detectors which are sensitive to neutrons above 100 keV.

The experimental arrangement consists from an oven schematically represented in Figure1. Two identically ceramic cylinders are used for the oven construction. The experiment simultaneously uses two optical fiber samples. One of the samples (which will be subjected to the combined neutron and temperature stress) passes through a ceramic cylinder, together with a Nickel dosimeter, a heating wire and a thermocouple. The other samples (which will be subjected only neutron irradiation) pass through the second ceramic cylinder together with the second Nickel dosimeter. The heating wire is connected to a power supply, having a variable voltage (max. 24 V). The power dissipated by the heating wire is maximum 50 W.

The temperature inside the oven is manually controlled and adjusted. The neutron fluencies are measured by the Ni dosimeter method. The temperature distribution inside the oven was measured. The variation along the optical fibre is less then 20%. Maximum temperature which can be reached inside the oven is 300 ^{0} C.

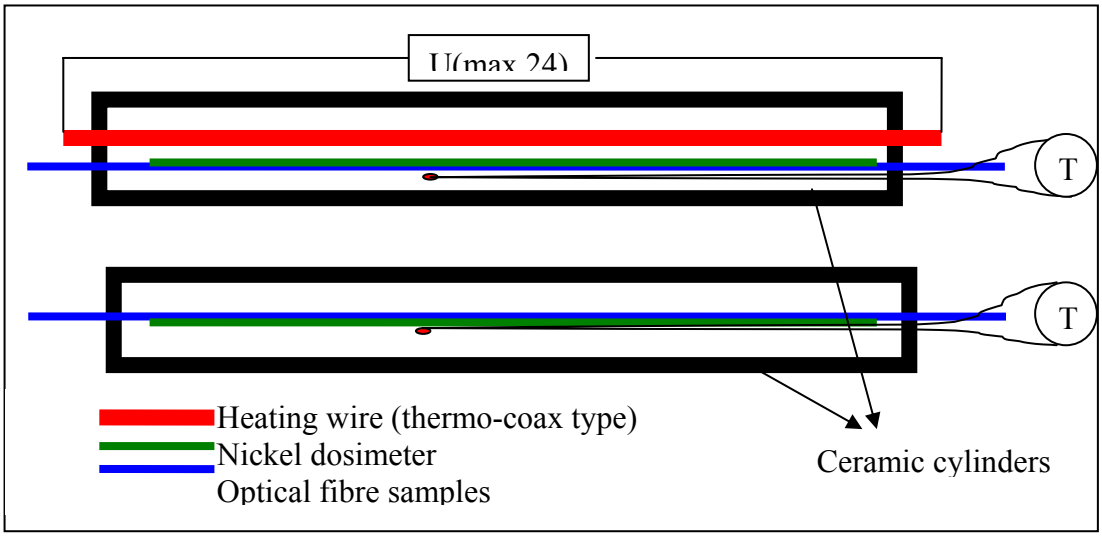

Figure 1. Schematic experimental setup for combined temperature stress and neutron irradiation on optical fibre.

During the neutron irradiation, the optical fiber samples of about 1.2 m long will be positioned as straight cables. They will be irradiated in the middle over a distance of about 30 cm. This geometry is used in order to make possible the shielding of the optical fiber removable connectors (not fixed) and the required optical fiber probes (see also Figure 2). In this way, their irradiation is avoided and hence the degradation of these components is reduced, improving the overall measuring results.

3. The setup for gamma-ray irradiation

The gamma irradiation will be carried out at the ^{60}Co gamma irradiator facility of the "Horia Hulubei" National Institute of R&D for Physics and Nuclear Engineering, in Bucharest. The optical fibre samples will be coiled around the gamma source. The distance from the gamma source to the optical fibre sample coil determines the dose rate. In our case, the dose rate employed will change from 5.1 kGy/h to 6.7 kGy/h. The total length of the irradiated samples will be from 1.5 m to 2.5 m. The entire irradiation setup composed by the gamma source and the optical fibre samples will be placed inside a hot-cell (Figure 2).[1]

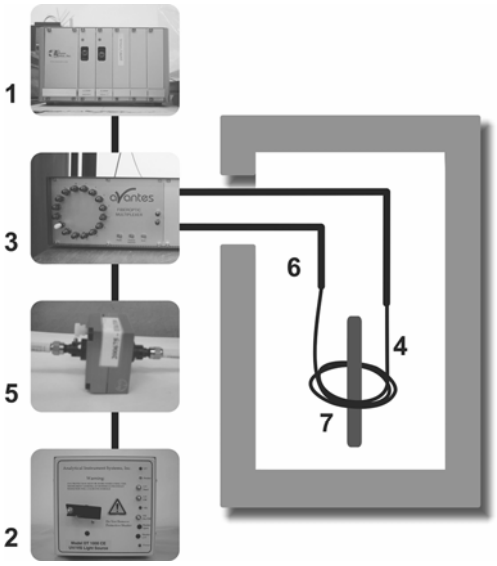

Figure 2. The setup for in-situ gamma-rays irradiation of optical fibres: 1 – optical fibre mini-spectrometer; 2 – deuterium/ tungsten CW source; 3 – optical fibre multiplexer; 4 – optical fibre samples; 5 – variable optical attenuator; 6 – optical fibre probes; 7 – gamma source.

In order to evaluate, in a comparative way, the influence of the irradiation and combined irradiation and temperature stress we developed an experimental setup where an optical fiber can be irradiated at room temperature, while the same type of optical fiber is irradiated when heated. Each optical fiber is located in a plane enabling the irradiation in a cylindrical geometry (with the optical fiber coiled and the gamma source placed in the middle of this coil). The coil diameter accommodated by this setup varies between 11 cm and 13 cm; in this way, the dose rate can be modified. The two planes where the optical fibers samples will be positioned are thermally separated. This irradiation geometry will make possible the simultaneously investigation of two optical fiber samples of the same type.

The temperature of the heated sample is set by an electric heater. It can be changed between the room temperature and about 260 ^{O}C. This setup will be also calibrated by a PC-based thermocouple instrument from National Instruments.

4. The data acquisition setup and the associated software

For the evaluation of irradiation induced effects in the studied optical fiber sample, an optical fiber multi-channel mini spectrometer, a deuterium light source, a variable optical attenuator, and an optical fiber multiplexer will be used (Figure 2). The mini spectrometer can perform spectral measurements over two bands: 200 nm – 650 nm and 650 nm – 850 nm, with a spectral resolution of 1nm over the first spectral interval and a resolution of 0.5 nm on the second one. The resolution of the A/D conversion is 12 bits. The data acquisition integration time is programmable by the user and can be changed from 3 ms to 65 s. Spectral averaging and boxcar functions are available. The multiplexer can multiplex 8 channels with a reproducibility of 99 %, optical throughput 60 %, and a maximum switching time of 200 ms.

The optical absorption measurements imply the measurement of the dark signal (as a reference signal to compensate for the drift and temperature effects of the spectrometer CCD detecting array), as well as the measurement of the deuterium lamp output (for the correction of the temporal changes of the lamp spectrum). The three signals (dark signal, the emission of the deuterium source, and the signal propagating from the lamp through the fiber to be measured) are further utilized to compute the spectral optical absorption of the optical fiber sample, according to the formula:

$$A_\lambda = -10 \cdot \log_{10}\left(\frac{S_\lambda - D_\lambda}{R_\lambda - D_\lambda}\right), \qquad (1)$$

where, A_λ represents the spectral optical attenuation (dB); S_λ – the spectral distribution of the signal measured by the spectrometer as the light is passing through the sample optical fiber; D_λ – the spectral distribution of dark signal measured by the spectrometer; R_λ – the spectral distribution of deuterium lamp output, measured by the spectrometer.

In the “absorption acquisition” mode of operation, the optical fiber multiplexer is used to connect the spectrometer’s input slit either to the output from the deuterium lamp or the sample optical fiber to be evaluated as it is coupled to the light source. For the case the signal from the deuterium lamp is too strong, an attenuator, mounted on-line with the light source, is used to control the signal level. The spectral characteristic of the attenuator is almost flat; it decreases slightly below 300 nm. This fact does not affect the overall measurements of the optical fibers’ spectral attenuation as far as the attenuator is coupled on-line with the deuterium source; hence its attenuation is rejected as a “common mode” signal.

For the evaluation of the irradiation induced optical absorption both with and without heating we developed a special data acquisition programmed using the graphical programming environment LabVIEw. The programmed controls the optical fiber multiplexer and the mini spectrometer for data collection. The use of the multiplexer makes possible time-shared optical

absorption measurements for both optical fibers (the one kept at room temperature and the other heated). The measuring setup and the programmed are employed for both gamma-ray and neutron irradiation.

Up to four different acquisition channels can be selected. The programme will be operating over the 200-800 nm spectral range. The programme stops when the "REPEAT" button is not activated. When this button is active data are collected and saved continuously. The information is saved on the PC hard-disk in Excel compatible format. The interface makes also possible:

A. the selection of the date when the measurements are done (day & month);
B. the identification of the optical fibre sample coupled to each channel;
C. the selection of the channels to be measured;
D. the specification of the optical fibre sample length;
E. the selection of the optical sample type (product code).

A variable delay can be entered by the operator to separate measuring cycles. The virtual instrument we developed has also a display interface where the operator can follow the running of the programmed and the current results (in a graphical form).

The research to be carried out during 2006 will address the in situ measurements of both Al coated and polyimide coated optical fibers under gamma and neutron irradiation, when the optical fibers are subjected to both the irradiation and heating up to 240 ^{O}C.

References

[1] **Sporea D. G.**, **Sporea R.**, "*Setup for the in situ monitoring of the irradiation-induced effects in optical fibres in the ultraviolet-visible optical range*", Rev. Sci. Instr. 76, (2005).