UV TRANSMISSION FOR LARGE DIAMETER OPTICAL FIBRES

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The investigations carried out during 2003 were focused on the evaluation of the optical transmission of large core diameter ***UV enhanced optical transmission*** optical fibers to be used in fusion installations as light guides for plasma diagnostics. Several types of commercially available optical fibers were investigated. For the purpose of this investigation, optical fibers with core diameters of 400 μm were tested. As neutron irradiation effects on UV optical fibers are studied for the first time, optical fibers of 200 μm core diameter were also evaluated.

Pure silica optical fibers with an UV enhanced response (core of a high hydroxyl content type), having low (150 ^{0}C) and high (350 ^{0}C) temperature jacket materials, were investigated. The optical fibers OFS1 and OFS2 are from the same producer, while those denoted by OFS3 - OFS7 originate from another producer. We were interested both on the dose steps and total dose effects, as well as on the reproducibility of radiation-induced degradation of the optical transmission.

The optical transmission of the optical fibers samples was evaluated off-line: pre and post irradiation measurements were carried out at room temperature, for both neutron and gamma-ray irradiation. The laboratory set-up we developed enables the investigation on optical transmission of UV hardened optical fibers, in the spectral range 200 – 1000 nm, with spectral resolution of 1.5 nm (or better), and 12 bits amplitude resolution of the transmission readings. The set-up is based on a CW operating deuterium source, and a miniature, multi-channel optical fiber spectrometer coupled to a PC via a USB link.

All the optical fiber samples were 24 cm long, and were irradiated over a 3 cm length, at their middle point (for the neutron irradiation case). For the absorption measurements, temporal SMA 905 connectors were mounted to each optical fiber. Each sample was coupled to the deuterium source and to the spectrometer channel through two 1.5 m solarization resistant, 400 μm core diameter optical fiber patchcords. As the SMA connectors were not exactly tailored for each optical fiber core diameter and because of their inherent mechanical misalignment, a variable absorption offset is present in our measurements. To reduce as much as possible this inconvenience, several measurements were carried out on each sample, at each irradiation step, over all spectral bands. Table 1 specifies the optical fibers investigated, their characteristics and the total fluences employed.

Table 1. The optical fibers samples characteristics and the neutron fluences used for the irradiation.

	Characteristics				Fluence (n/ cm^2)		
Optical fiber type	Core diameter (μm)	Cladding diameter (μm)	Buffer/ Jacket material	T_{max} (^{O}C)	Step 1	Step 2	Step 3
OFS1	200	240	Plastic	125	5.8×10^{11}	6×10^{12}	6×10^{13}
OFS2	400	425	Plastic	125	5.8×10^{11}	6×10^{12}	6×10^{13}
OFS3	200	220	Al	400	5.8×10^{11}	6×10^{12}	6×10^{13}
OFS4	200	220	Polymide	350	5.8×10^{11}	6×10^{12}	6×10^{13}
OFS5	400	440	Tefzel	150	5.8×10^{11}	6×10^{12}	6×10^{13}
OFS6	400	440	Polymide	350	5.8×10^{11}	6×10^{12}	6×10^{13}
OFS7	400	480	Tefzel	150	5.8×10^{11}	6×10^{12}	6×10^{13}

The optical fiber samples were irradiated at the National Institute of R&D for Physics and Nuclear Engineering – "Horia Hulubei" U-120 Cyclotron facility, which is based on the reaction $^9Be + d \rightarrow n + X$, using a deuteron beam (13 MeV) and a thick beryllium target (165 mg/cm^2). To obtain the desired neutrons fluences the samples are located downstream at distances from 10 to 40 cm of the Be target. The fast neutrons facility is provided with a biological shield build from borated paraffin bricks of 20 cm thickness, leaving a free volume(100x50x50 cm), for neutron irradiation. The absolute neutron flux was measured using activation detectors. The neutrons flux above 1 MeV is estimated with a relative error of about 20 % . The measured production yield, at 10 cm distance from the Be target, is 2.13×10^8 n/cm^2 s μA. The maximum neutron flux achievable in our set-up, at a distance of 10 cm from the target, is 2×10^9 neutrons /cm^2 s μA, corresponding to a deuteron beam intensity of 10 μA. The neutron and gamma components of the mixed radiation dose are 138Gy/C (Gray/ Coulomb) respectively 2.38 Gy/C, at 30 cm distance from Be target. The neutron dose rate at 5 μA current was 2.52 Gy/h. At maximum beam power, the highest temperature of the target does not exceed 50°C. The main results concerning the neutron induced optical absorption in irradiated optical fibers (400 μm core diameter), in the UV-visible spectral range are given bellow (Figures 1-3). In the visible - near IR spectral region the optical transmission of the fibers are not affected by the neutron irradiation For this report, a sample includes specimens of different optical fibers subjected to the same irradiation, simultaneously. The legend for the Figures 1 - 3 is : **red** – sample 1 irradiated by neutrons (the first step fluence = $5,8 \times 10^{11}$ n/cm^2); **blue** – sample 2 irradiated by neutrons (the first step fluence = $5,8 \times 10^{11}$ n/cm^2, and the second step fluence = 6×10^{12} n/cm^2); **green** – sample 3 irradiated by neutrons (the first step fluence = $5,8 \times 10^{11}$ n/cm^2, the second step fluence = 6×10^{12} n/cm^2, and the third step fluence = 6×10^{13} n/cm^2).

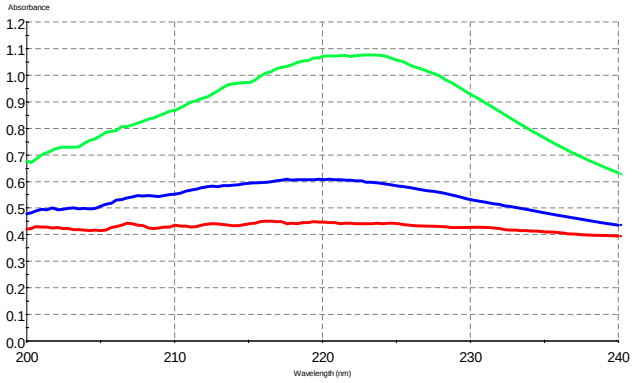

Figure 1. The optical absorption for the optical fiber OFS5, in the spectral interval 200 nm – 240 nm.

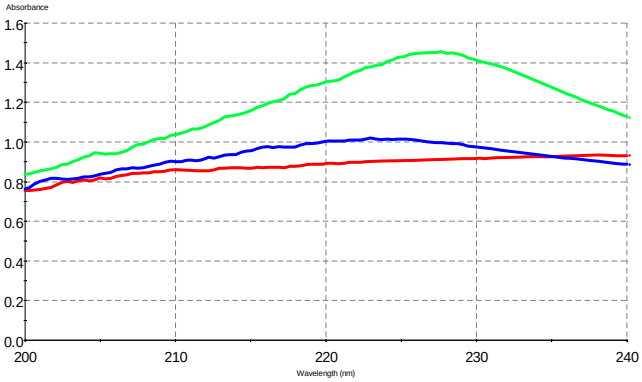

Figure 2. The optical absorption for the optical fiber OFS2, in the spectral interval 200 nm – 240 nm.

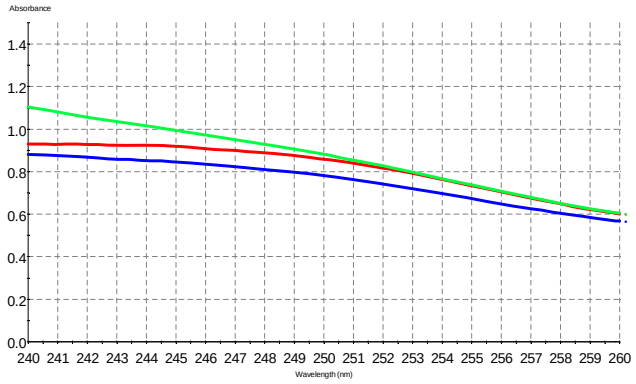

Figure 3. The optical absorption for the optical fiber OFS2, in the spectral interval 240 nm – 260 nm.

The optical fibers OFS6 and OFS7 give similar results as the optical fiber OFS5.

Our investigations lead to the following conclusions:

- Some of the investigated optical fibers (i.e. OFS5 - OFS7) could be used, at wavelengths higher than 300 nm, to transmit optical signals in fusion installations, under neutron flux with fluences up to 10^{13} n/cm^2. The optical fiber OFS2 can be used under these irradiation conditions only above 400 nm.
- A peak of the optical absorption, which increases with the fluence used, appears in the spectral band 220 - 230 nm, for all the optical fibers, depending on the optical fiber type.
- For the optical fiber OFS2, an additional absorption peak develops at about 280 nm, a phenomenon which has to be further investigated at high fluences.
- If we consider the bias line, imposed by the connectors losses, to have a value of 0.4 a.u. (absorbance units, on a logarithmic scale) for a non-irradiated optical fiber, the best performing optical fibers of 400 μm core diameter exhibit a peak of the optical absorbance of 0.6 a.u., for a fluence of 10^{12} n/cm^2, and a peak of 1.1 a.u., for a fluence of 10^{13} n/cm^2.
- The optical fibers with a core diameter of 200 μm are more sensitive to neutron irradiation, even for fluence levels as low as 10^{11} n/cm^2.
- The width of the optical absorption peak differs from manufacturer to manufacturer, for the same core diameter, meaning that the fabrication conditions and ingredients used play a

significant role in the fiber behavior under neutron irradiation. The tail of this peak reaches a wavelength of 380 nm, for the worst case optical fiber.

For the gamma irradiation the investigations focused on the modification of optical transmission of three types of optical fibers (OFS5, OFS6, and OFS7), of 400 μm core diameter, subjected to irradiation doses up to 1050 Mrad in steps. The fibers were divided into two samples (1 and 2). One set was gamma irradiated, while the other was subjected to a gamma irradiation and temperature stress cycling. Examples of the results obtained for the gamma-ray irradiation of some optical fibers are given in Figure 4. The legend is: **blue** – (sample 1) total gamma irradiation dose - 1050 krad; **red** - (sample 2) total gamma irradiation dose - 710 krad; **green** – (sample 2) total gamma irradiation dose 710 krad, followed by a heating for 4 h, at 140 ^{O}C (OFS5 and OFS7), and at 250 ^{O}C (OFS6). Similar data are available for OFS6 and OFS7.

The investigations on gamma irradiated optical fibers indicated:

- For the gamma irradiation the peak of the optical absorption occurs between 230 nm and 240 nm.
- This peak maximum value increases as the total gamma irradiation dose increases.
- The thermal treatment applied after gamma irradiation produces a recovery of the optical transmission and a blue shift of the absorption peak (about 1 - 2 nm);
- The recovery observed after thermal treatment is not a complete one, even after prolonged heating (4 h) at the highest temperature supported by the fiber jacket material (140 ^{O}C and 250 ^{O}C respectively, depending on the fiber type), the absorption peak is present.

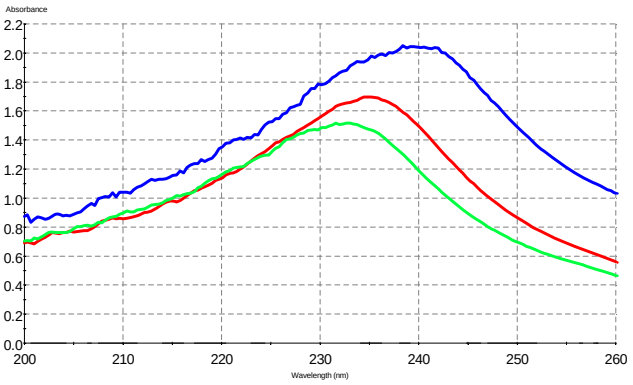

Figure 4. The optical absorption for the optical fiber OFS5, in the spectral interval 200 nm – 260 nm.

Next year, we shall perform some in-situ measurements on the gamma-ray induced changes in the optical characteristics of large core diameter optical fiber for plasma diagnostics.

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LIST OF MOBILITIES TO THE EURATOM ASSOCIATIONS

To the Association EURATOM/ CEA sur la Fusion Controlée, Cadarache, France

- Sending institution: University of Craiova, Craiova
- Nicolae Pometescu (16.10-14.11.2003)
- Gyorgy Steinbrecher (17.10-15.11.2003)
- Iulian Petrisor (31.10-29.11.2003)

Dana Constantinescu (31.10-29.11.2003)

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