*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-5.185 (2004)*

Set-up for the monitoring of optical fibers under gamma-ray irradiation

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1. INTRODUCTION

Optical fibers will play an important role in the future ITER and DEMO reactors as they will be incorporated into different assemblies to be used in plasma diagnostics, sensing, remote control and signal transmission over optical channels. [1]. Optical links are needed for plasma diagnostics to pick-up the optical signal and to carry it to remote locations through a noisy electromagnetic environment, under high temperature, high gamma-ray dose rate and high neutron fluences [2]. Under irradiation optical fibers exhibit both a radiation-induced absorption (RIA) and radiation-induced luminescence (RIL) [3] – [5]. The first effect distorts the transmitted spectra 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 superposed on the signal to be measured. Most of the investigations on this phenomenon were performed over the visible and near-IR part of the spectrum (above 400 nm and bellow 2000 μm). New techniques were developed to reduce the degradation of the optical transmission of optical fibers to be subjected to ionizing radiation. As the UV spectral band (200 nm – 450 nm) of the optical spectrum is of great interest for plasma diagnostics specially designed optical fibers with an enhanced UV response were investigated under both gamma-ray and neutron flux irradiation.

2. EXPERIMENTAL SET-UP

Our previous work focused on the evaluation of various types of optical fibers, from different manufactures, in order to assess off-line their capability to resist transmission degradation under irradiation, and sometimes combined with temperature stress. In this paper we report our results concerning the development of a PC-controlled set-up to be used for on-line investigation of gamma radiation effects (both absorption increase and radiation induced luminescence), at room temperature. The optical characteristics of large core diameter optical fibers (400 μm – 600 μm) have to be monitored in real time with a multi-channel optical fiber spectrometer (Figure 1). The mini spectrometer can performed spectral measurements over three bands (200 nm – 650 nm, 650 nm – 850 nm, 850 nm – 1080 nm,

with a resolution of 1.5 nm over the first spectral interval and a resolution of 0.5 nm on the other two). The data acquisition integration time is programmable by the user and varies from 3 ms to 65 s. Spectral averaging and boxcar functions are available. The spectrometer input is coupled to different signal sources, depending on the type of investigation (emission or absorption) through an optical fiber multiplexer. The multiplexer can multiplex 8 channels with a reproducibility of 99 %, optical throughput 60 %, and a maximum switching time of 200 ms. The common output can be switched to a reference position, when no signal enters the multiplexer. For radioluminescence measurements the investigated optical fiber is exposed to gamma radiation into a 3.5 m deep water pool is connected to the spectrometer with one end, where a SMA connector is mounted. For the optical absorption investigations, both optical fiber sample ends have SMA connectors and are coupled one to the spectrometer and one a deuterium lamp, the sample fiber being immersed in the water pool. The 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). Each sample optical fiber is connected in an appropriate manner to the spectrometer and to the lamp thought two 400 μm core diameter optical fiber probes.

The multiplexer's operation as well as the data acquisition from the mini spectrometer are controlled by a PC. For these tasks we developed special virtual instruments (VIs) using the National Instruments LabVIEW graphical programming environment.

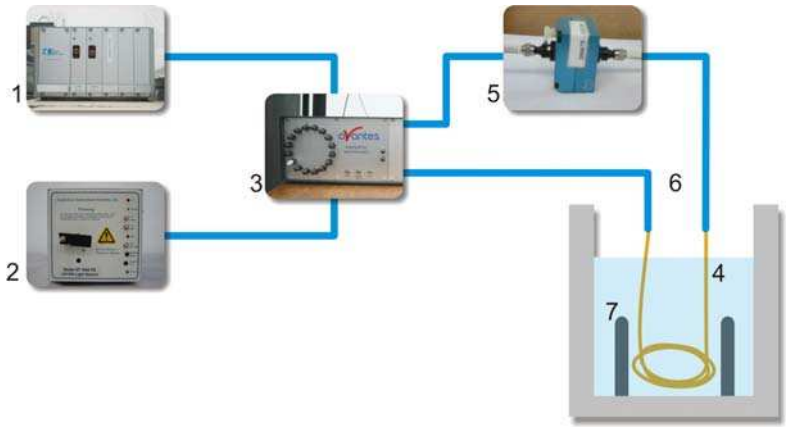

Figure 1. The set-up used for the evaluation of optical fibers transmission and radioluminescence during gamma-ray irradiation: 1 – mini spectrometer; 2 – deuterium lamp; 3 – optical fiber multiplexer; 4 - sample optical fiber; 5 – variable attenuator; 6 - optical fiber probes; 7 – gamma source submersed in a water pool.

In the case of the radioluminecence determination, in order to accommodate the detection of gamma-ay induced emitted optical signal having a wide dynamic range, we developed a software module which evaluates the peak value of the emitted spectrum and modifies the integration time of the spectrometer in X 1; X 10 and X 100 steps. For each step the amplitude span of the detected signal can be as high as 3500 counts. In this way, we are able to investigate emission signals over more than 5 decades. In this mode of operation, the user has to select only the type of fiber to be investigated, and the programme automatically acquires spectra over the selected channel at programmed time intervals, adjust the integration time so that the detected signal is located above a noise level and bellow the upper limit of 3500 counts. After each measurement, all data are normalized to the scaling factor and are saved in and Excel like files. Each file name includes the time stamp (day/month/year/ minute/hour) for an easy correlation of data with external changes (i.e. increase of the dose rate, temperature rising, etc.). The user interface displays the current integration time and the peak value of the luminescence signal for the acquisition under way. For the case of the absorption measurements, the another VI is used so that the operator selects the fiber type and its length (data used to compute the optical attenuation in dB/m).

3. RESULTS

Figure 2 indicates the spectra acquired from a fluorescence lamp for the case of two attenuation values for the variable attenuator. One can notice that low value spectra are difficult to interpret in such a situation. In order to have a good assessment of the luminescence spectral detected by the spectrometer the integration time is switched automatically when the signal detected reaches a noise level or the saturation level When data are saved on disk, the scaling factor is considered in order not to distort the results and make them comparable.

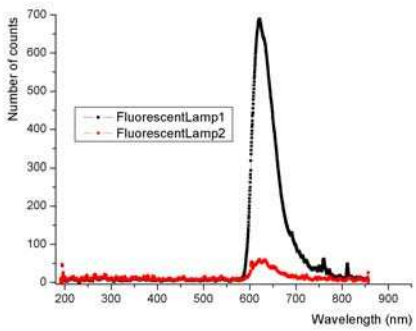

Figure 2. The spectrum of a fluorescence lamp for two positions of the optical attenuator.

In Figure 3 are illustrated, as a simulation (off-line measurement) the absorption spectra of an optical fiber about 25 cm long for the case of the non irradiated optical fiber and for two total irradiation doses, over the spectral range from 200 nm to 800 nm.

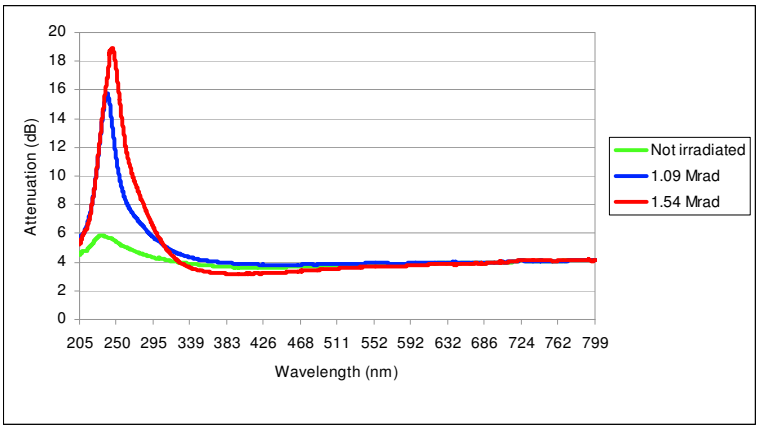

Figure 3. The spectral attenuation of a 400 μm core diameter UV enhanced transmission optical fiber: green – non irradiated; blue – gamma-ray irradiated with a total dose of 1.09 Mrad; red – gamma-ray irradiated with a total dose of 1.54 Mrad.

4. ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of the European Union and the Romanian Ministry of Education and Research under the Grant ERB 5005 CT 990101/1999, in the frame of the EU's Fusion Programme. The content of this paper is the sole responsibility of its authors and does not necessary represent the views of the Commission or its services.

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