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#11-213 Neutron Beam Monitoring Using Nitrogen-doped Optical Fiber

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For the last three decades, the number of active irradiation facilities is continuously increasing, for various needs, from fundamental research to radiation testing or medical applications. To develop and guarantee the facility's technologies, requests for its control and reliability are becoming more and more precise and multiply the number of beam diagnostics from the source to the final beam. Among the different kinds of beam diagnostics, the control of the beam dimension and its particles flux characterization are the most crucial needs for irradiation facility operators. Moreover, information about the available integrated dose or dose rate also helps following the evolution of the irradiation from the user's standpoint. For these three characterizations (beam dimension, flux and the dose rate), beam monitoring sensors based on the use of optical materials are showing very high interest for their response under radiation.
Fiber-based sensors mainly exploit the optical and structural properties of the pure or doped amorphous silica structure. The emerging and fast development of various manufacturing processes (chemical vapor deposition, sol-gel, 3D printing, polymers) allow defining and manufacturing materials with very diverse properties useful for sensing. Optical fibers combining extremely low losses and sub-millimetric volumes are now available and are progressively used in harsh environments for both data transfer and sensing
Under irradiation, the optical fiber properties are modified by different radiation effects, the amplitudes of these changes are depending on both the dopant and the beam parameters such as dose, dose rate, flux, fluence, beam particle type and energy. The radiation induced behaviours of the optical fibers are known in three categories [1]. The first one, which will not be treated in this paper, is the compaction. This appears for neutron fluences [2] largely exceeding those encountered in our experiments. The second effect is described as an opacification of the optical fiber material under radiation and is called radiation-induced attenuation (RIA) [1]. This darkening is cumulative with the dose absorbed by the optical fiber and can be used for dose monitoring. Finally, the last induced effect is a light emission induced by the energy transferred from the radiation or particle strike with the matter. When a particle or a photon interacts the doped SiO2 structure, the energy loss is high enough to ionize the atoms of the structure. The presence of selected dopants adds new defect levels into the SiO2 bandgap which may trap the recombining electrons. These trapped electrons recombine by radiative decay which can emits a photon guided by the optical fiber. This process is named radiation induced luminescence (RIL). The RIL intensity is a function of the particle flux and can be used after calibration to monitor the beam flux, and then the beam profile. This last phenomenon is the one employed in this work, based on a small-size (50µm doped core, 250µm coating) optical fiber that already demonstrated very efficient radiation detection performances under both X-ray and high energy protons [3].
For this study, we used this RIL phenomenon to monitor the flux of a 14 MeV neutron beam at the GENEPI2 (Intense Pulsed Neutron GEnerator) facility (Grenoble, France) [4]. We characterize the evolution of the fiber response in terms of RIL vs the neutron flux between 1x106 n.cm-2.s-1 and 3x107 n.cm-2.s-1 and fluence, defining eg. the threshold limit for the detected flux. During this experimental campaign using a specific doped optical fiber, we demonstrate the potential of this nitrogen-doped optical fiber to monitor in situ the flux evolutions and the adaptability of this kind of sensors to extend the neutron flux range.

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