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#2-91 Optimization of Radioluminescent Fiber Dosimetry for Space Missions

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Abstract - Optical fiber-based dosimeters are valuable tools for space missions, enabling the measurement of the dose received by humans or equipment in a spacecraft or onboard satellites. These devices could serve to detect the premises of solar eruptions allowing to protect more efficiently through mitigation techniques both electronic systems and humans. In space, especially for human radioprotection, the monitoring of dose rate (or particle flux) is a key functionality for those applications. Accurate dosimeters with low dispersion in their radiation sensitivities are essential for ensuring reliability and safety. A very efficient technique based on specialty silica-based optical fibers consists in measuring the radioluminescence generated by radiation in the fiber. This generated photons intensity, propagated along the fiber to a detector, is directly proportional (through the radiation sensitivity coefficient) to the particle flux or dose rate. By integrating the dose rate over a period, one can calculate the dose received by the fiber during that period.

We investigated here the dosimetric properties of two differently doped multimode silica-based radioluminescent optical fibers under 40 keV mean energy fluence X-rays. One fiber under test has its core doped with copper , while the other has a cerium/copper-co-doped core fiber. The dose rates studied ranged from 5×10^(-3) Gy(SiO_2)/s to 1.5Gy(SiO_2)/s and for each of the tested sample, we did a series of tests by varying the dose rate to measure the radiation sensitivity coefficient expressed in number of photons received per second and for a dose rate of 1 Gy/s. It should be noted that in previous studies, we showed that the copper-doped fiber is also able to monitor the dose rate deposited by [illegible]rays or protons. The results obtained here under X-rays can therefore be extrapolated to other environments, even mixed ones.

We performed in this work a systematic study of the parameters affecting the value of this radiation sensitivity coefficient: the influence of a pre-irradiation of the radioluminescent fiber, the influence of the sensor probes-manufacturing process and the influence of the cerium doping of the copper glass. For this purpose, we repeated the calibration of 112 different probes that have been characterized through 112 irradiation runs. The effect of pre-irradiation was studied by considering four different pre-irradiations conditions on 4 sets of 14 probes for both the copper and copper/cerium-doped optical fibers. The pre-irradiations conditions were pristine (no pre-irradiation), 250kGy, 1MGy and 2MGy(SiO2). The influence of probe manufacturing was demonstrated by investigating the variation coefficient of radioluminescent signals across the same set of probes. The results are extremely promising with a measured mean variation coefficient of their sensitivities of 13 % for the copper-doped probes and 17% for copper/cerium-co-doped ones. This demonstrates the high potential for fiber-based dosimetry using copper-doped optical fibers.

Furthermore, the variation coefficient for copper-doped fibers varied from 20% in the pristine condition to 9% after 2 MGy of pre-irradiation. In contrast, for copper/cerium-co-doped fibers, the variation coefficient increased from 12% in the pristine condition to 27% following 2 MGy of pre-irradiation. These results highlight the importance of pre-irradiation for the stability of the radioluminescence, suggesting that pre irradiated copper doped fiber may offer more consistent and accurate performance for dosimetric applications after pre-irradiation.

To further investigate the effect of copper/cerium co-doping on the RIL and explain the larger variation observed between the probes, a spectral analysis will be conducted by replacing the photomultiplier tube by a spectrometer for the detection. All other parameters will remain as in the previous analysis. This approach will allow us to better understand the origin of the largest observed dispersion for this fiber compared to the copper one and clarify the respective role of cerium and copper ions in the sensor response.

Previous studies highlight the presence of two distinct peaks in the RIL spectrum of copper/cerium co-doped fiber: one at 460 nm associated with cerium ions activation and another at 540 nm link to copper ions activation. We expect that one of the contributions will dominate the RIL process of the co-doped fiber, potentially leading to the observed dispersion for high dose.
From an applicative point of view, the copper-doped fiber demonstrates very promising performances with low dispersion in its radioluminescent signal. We will therefore discuss the potential performances of these fibers for dosimetry in the low dose rate space environments.

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