Performance Measurements of Optical Scintillating Fibers after Repeated Exposure to Radiation

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***Abstract*—We report the preliminary results from repeated irradiations of optical scintillating fibers exposed to gamma radiation. Optical fibers degrade in radiation fields, but exhibit some recovery once removed. Study of repeated irradiations are difficult to find in the literature. We find that a UV-blue optical wavelength shifting fiber exhibits permanent degradation, the recovery is incomplete, and an interesting two step damage process that appears to affect which wavelengths are darkened at different rates.**

I. Introduction

OPTICAL scintillating fibers are commonly used in high energy physics experiments. These fibers become dark after exposure to radiation. The characterization of this darkening is necessary to calibrate detectors as they operate. More importantly, the fiber's performance under exposure to radiation should be understood before being selected for an application. If not, the experiment can be faced with the expensive task of replacing scintillators before planned.

Many collaborations have used published research on radiation damage to predict how their detector components will handle the radiation. There is an issue with assuming that scintillators will behave the same after repeated exposure to radiation.

Optical fibers will become dark in response to radiation, but will clear up after the exposure stops [1]. This annealing can naively be thought to 'reset' the clock on the fiber. We find that optical fibers are damaged more quickly early on in exposure, but that the damage takes longer with more dose.

We report results from exposing 3 separate optical scintillating fibers to 4 distinct irradiations. The fibers were irradiated at 22 Gy / minute for 15 hours, and allowed to recover fully before irradiating again.

We characterize the decays and recoveries of the light transmittance, to allow predictions to be made for performance of the fibers in potential experiments.

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The figure enclosed is an in progress analysis that is near complete, and is an example for one fiber.

II. Experimental Setup

Two Kuraray brand B2(200) UV-Blue wavelength shifting optical fibers were connected in parallel to a Ocean Optics PX-2 Xenon broad spectrum light source on one end and a 2 channel Ocean Optics spectrometer on the other end. One fiber, the control, was kept in a lead sarcophagus with the spectrometer and light source, and the other fiber was fed into a cesium 137 gamma radiator.

The light source was pulsed 50 times with 50 ms pulse widths every 10 minutes. The 50 measurements were averaged and saved. Each measurement was integrated to get the total light yield transmitted through the fiber. This integrated light yield was plotted as a function of time, to understand the total light loss across all wavelengths experienced by the fiber.

III. Results

We observed an immediate and rapid reduction in light transmittance through the optical fibers that leveled off for a short period of time. Interestingly, this 'shelf' of constant transmittance lasted longer with each radiation. We suspect that this corresponds to a rapid reduction in the UV component of the fiber, while the red and infrared components are less affected by the radiation. It is interesting to note the shift in how long it takes this second drop off to begin with repeated irradiations. This mechanism is unclear to the authors.

A natural recovery was observed, as expected, that took near the same time with each irradiation.

The recoveries were not total, and we observed that each radiation damaged the fiber more thoroughly, permanently attenuating the light transmittance of the fiber with each irradiation.

We observed a lower limit to radiation damage that implies a minimum but non zero transmittance even at at extremely high doses.

See Figs. 1 and 2, where we include preliminary attempts to characterize the decay rates. The second fit parameter in 1 shows the decay happening more slowly with each irradiation.

IV. Discussion

A single radiation dose and recovery study of a fiber can lead to a misleading understanding of how the fiber will respond to a cycle of radiation exposure and recovery, a situation commonly found in modern collider experiments. This shows the importance of studying repeated irradiation and recoveries

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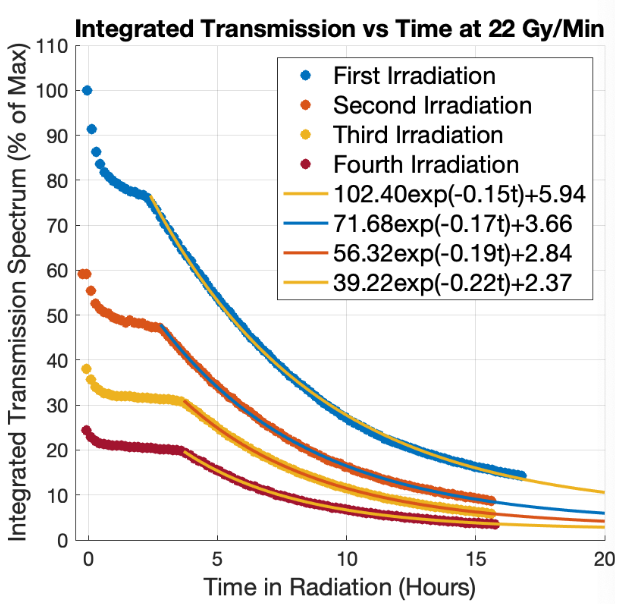

Fig. 1. Spectrometer, control fiber, and quartz fiber in lead sarcophagus.

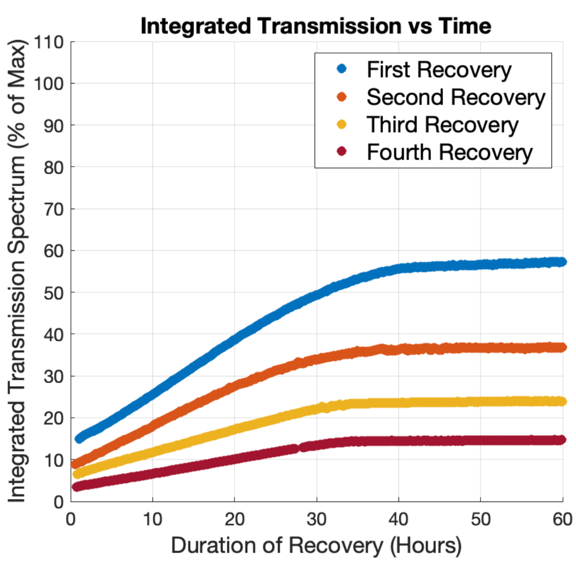

Fig. 2. Spectrometer, control fiber, and quartz fiber in lead sarcophagus with lid.

of a given scintillator, to understand how it will behave in an experiment.

V. Conclusion

While a single irradiation and recovery implies a wavelength shifting fiber in a radiation application could have a nice long life - so long as there are pauses in irradiation - we found that repeated irradiations cause permanent damage, and that there is a maximum recovery after exposure.

This maximum recovery gets lower with each repeated irradiation. A user could have a false sense of confidence about the performance of an optical fiber if they only perform one irradiation to characterize the fiber's response to radiation.

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[1] Bicken, B., et al. "Recovery and permanent radiation damage of plastic scintillators at different dose rates." IEEE transactions on nuclear science 38.2 (1991): 188-193. ISSN 0168-583X