Radiation Damage and Recovery Mechanisms in Scintillating Fibers

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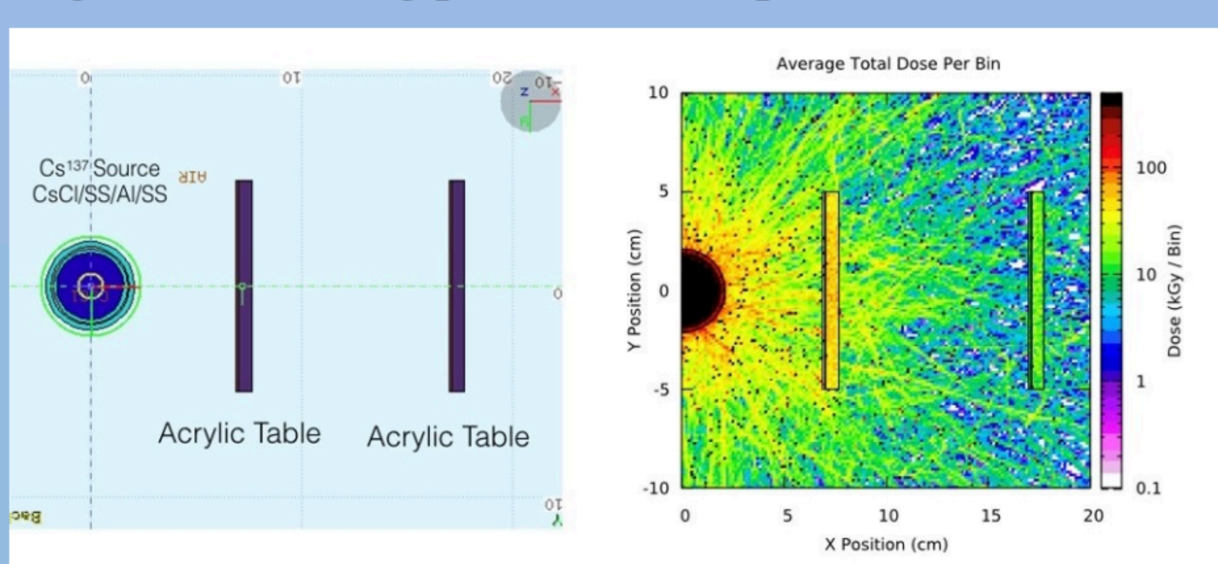
Optical scintillating fibers lose their transparencies when exposed to radiation. Nearly all studies of radiation damage to optical fibers so far only characterize this darkening with a single period of irradiation. Following the irradiation, fibers undergo room temperature annealing, and regain some of their transparencies. We tested the irradiation-recovery characteristics of scintillating fibers in four consecutive cycles.

In addition, three optical scintillating fibers were irradiated at 22 Gy per minute for over 15 hours, and their transmittance were measured each minute by pulsing a light source through the fibers. Here, we report on the in-situ characterization of the transmittance vs radiation exposure, allowing future applications to better predict the lifetime of the scintillating fibers

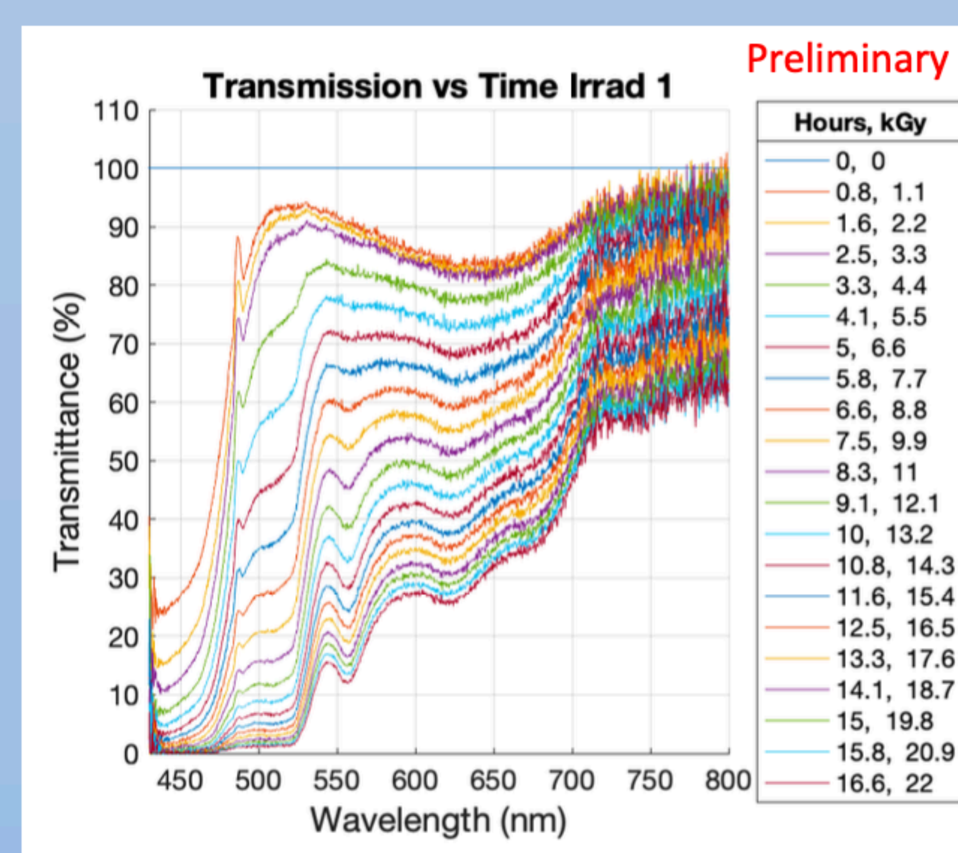
Cs-137 Gamma Source at the University of Iowa RadCore Facility (Activity: 6000 Ci)

- In situ measurement is a critical parameter to see the radiation damage as a function of time and to develop necessary steps during the data taking process with a particle detector.



Fluka simulation of the gamma source and the sample holders

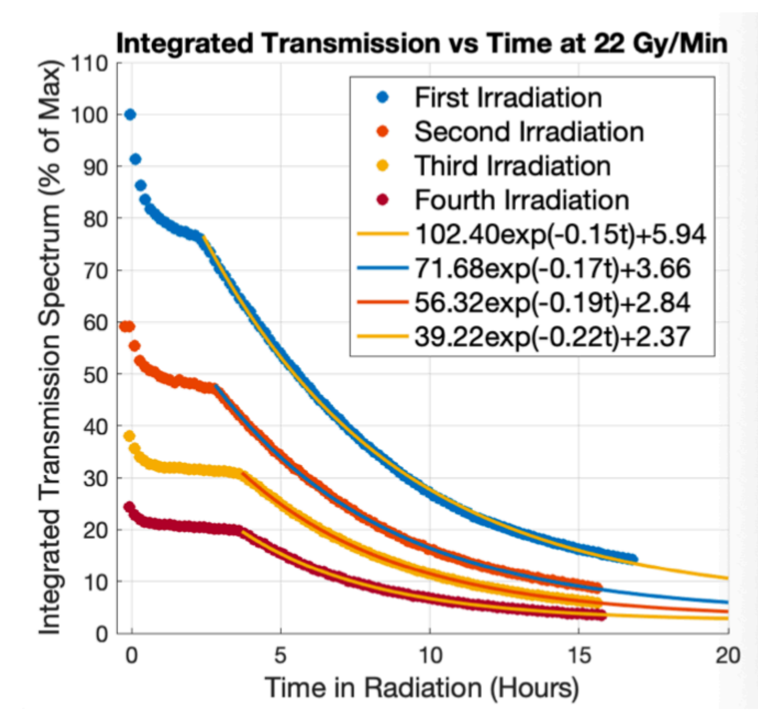
- This study was performed on 3 different optical fibers; a blue wavelength shifting (WLS) fiber, a green WLS fiber, and an orange WLS fiber.
- The fibers were exposed to Cs-137 for over 16 hours.
- A xenon light with with emission spectra from 400 nm to 800 nm was used.

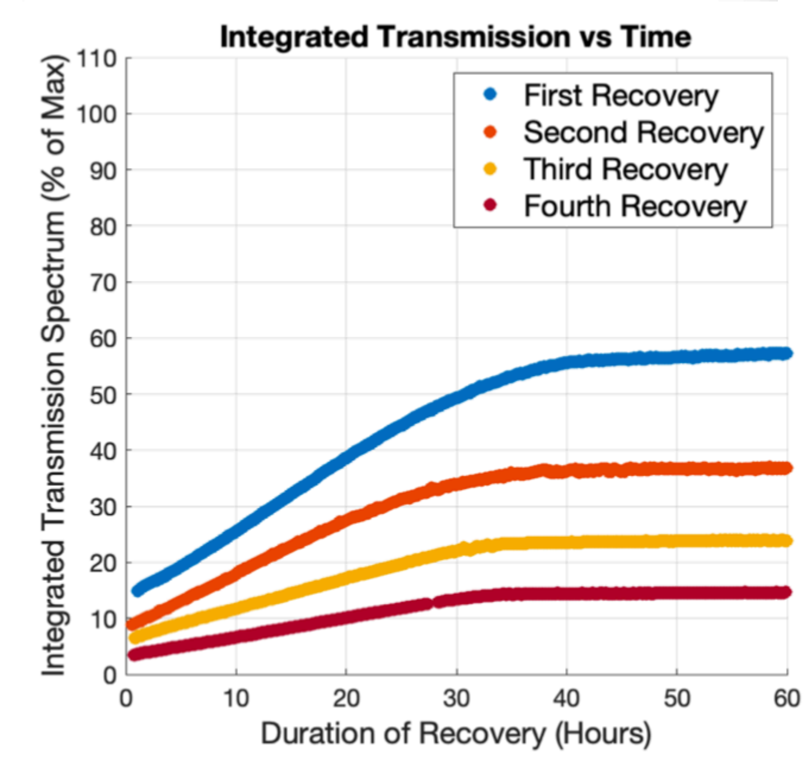


- The light transmittance was measured as a function of wavelength using a spectrometer.
- The transmission at the peak wavelength (500-550 nm) drops roughly from %90 to %20.
- There is a linear trend between the total dose and the transmittance (%).
- Once the final results are ready, the paper will be submitted to a journal.
- In-situ radiation damage measurements on the optical fibers and detector components is important for the HEP experiments.

- The fibers were exposed to Cs-137 at 22 Gy/min over 16 hours each time.
- A xenon light with with emission spectra from 400 nm to 800 nm was used.
- The plots show Integrated transmission as a function of Time in Radiation and Duration of Recovery.

Preliminary





WLS Fibers:

- **B-2(200)**
  - Exhibited the most optical recovery from radiation damage: Maximum peak intensity 59 days post-Irrad is 95% baseline
  - Intensity peak shifts from 540 nm to 618 nm
  - Potential applications in novel optical devices
- **B-3(200)M**
  - Irradiation caused optical "recovery" far beyond baseline spectra (137% baseline)
  - Potential applications in novel optical devices
- **O-2(100)MSJ**
  - Permanent optical damage after irradiation (85.5% maximum recovery)
  - Recovery plateaus around 29 days post-Irrad
  - LED-recovery candidate

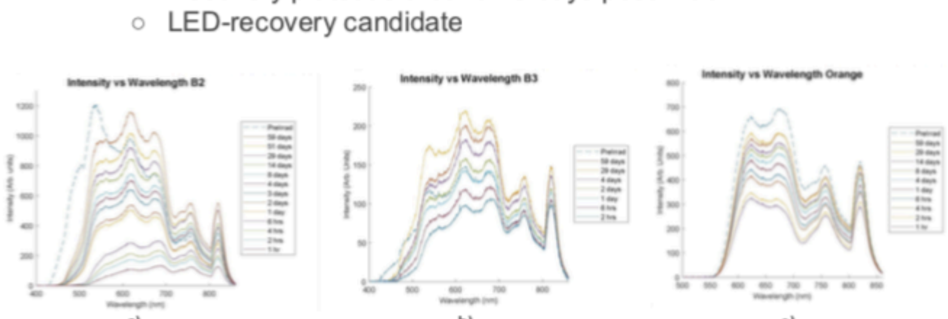
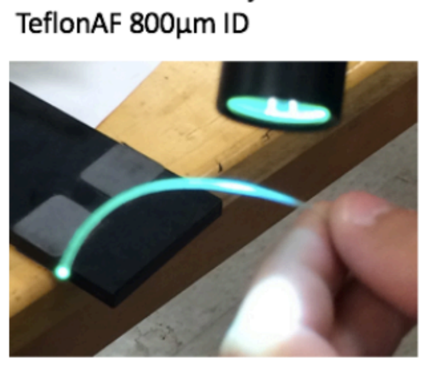


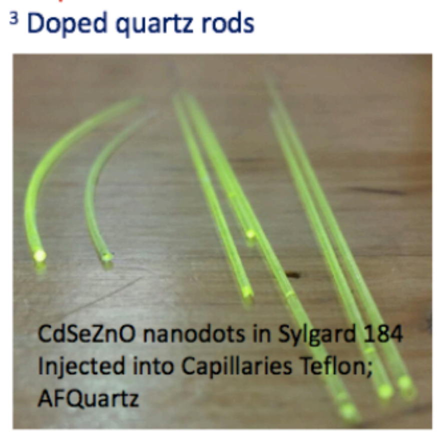
Fig. 2: Recovery spectra for the three investigated fibers a) Spectra for fiber B-2(200) b) Spectra for fiber B-3(200)M c) Spectra for fiber O-2(100)MSJ

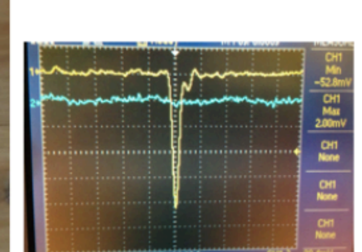
Radiation-Hard WLS Fibers

[1] Quartz rods with surface coating
[2] Capillaries
[3] Doped quartz rods

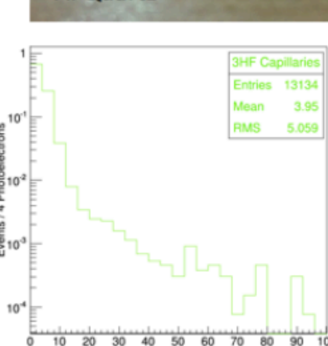
3HF+Meltmount injected TeflonAF 800µm ID







3HF Core Quartz WLS Capillaries



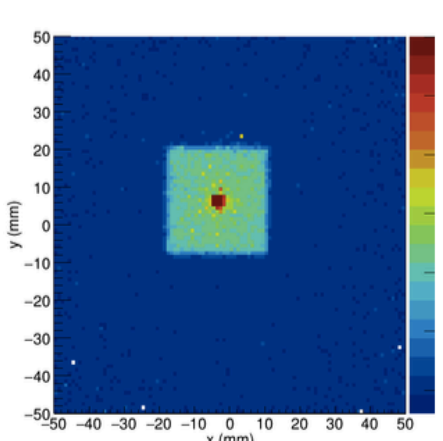
Expected Anthracene Fiber Pulse:
~200 KeV/mm x 0.25mm x 40 photons/KeV x 2% transmission x 20% QE ~ 8 p.e.
Typical Observed Pulse:
~ 8-9 p.e.

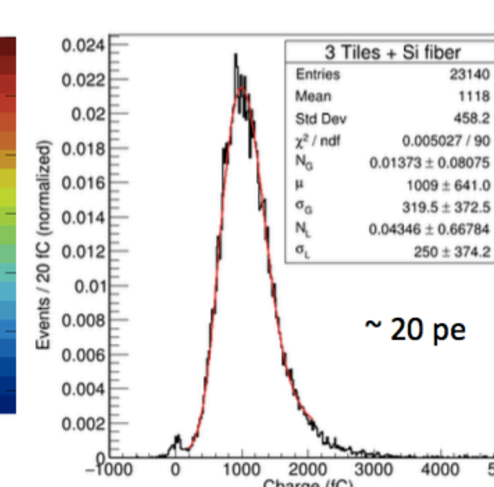
WLS Capillary Fiber with RadHard Components - Response to 150 GeV muons

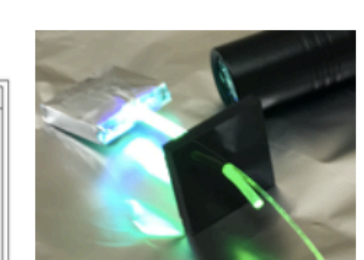
Three 5mm thick blue scintillator tiles (2.5 cm x 2.5 cm) with a silicone-based WLS fiber going through the center, coupled to a SiPM.

The WLS fiber is a Pt-cured silicone capillary (2.3 mm OD, 1 mm ID), certified for gamma sterilization, with a silcone gel conveying 3HF (3HF tested to 100 Mrad at FNAL).

Histogram: Wire Chamber selected muons passing through the tile, 1 mm away from the Fiber and SiPM







Capillary WLS fibers:
Silcone gel core doped w/3HF
Larger: Silicone Capillary
Smaller: Teflon AF capillary

Optical fibers are excessively used in HEP experiments to carry scintillation light from scintillators to the photon sensors. Their response to the repeated exposure provides an important information for the experiments. The darkening and recovery curves of the optical fibers provide such information about the annealing process. The investigation of in-situ recovery mechanisms is critically important for the future experiments.

In parallel to the studies on radiation damage and recovery mechanisms, the search for radiation-hard wavelength shifting fibers should continue on all grounds. The production of the radiation-hard fibers in larger quantities should be followed by the investigation of their radiation damage and recovery properties.