Measuring Detector Radiation Damage

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Abstract:

Scintillator counters are used as fast accelerator loss monitors. These devices are capable of seeing losses from single RF buckets that are 20 ns apart. The booster uses these fast lost monitors as a tool to understand the beam. [1]. Radiation damage to the optical components of the detectors compromises their performance. The adhesive that is used to make the detectors is most affected. We wish to study how radiation affects the optical properties of the optical cement.

Damage:

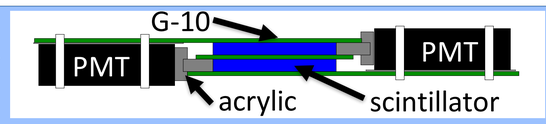


Figure 1: *Fast Lost Monitor (FLM). Consists of two black photomultiplier tubes, three green G-10 plates, two acrylic plastic pieces (grey area) and two scintillators (blue plates).*

Figure 1 shows an FLM. This detector consists of two scintillator bars and two photomultiplier tubes (PMT) and G-10 plating. Figure 2 shows two scintillator assemblies that were exposed to radiation. The darkest part of the assembly on the right is the adhesive that sticks the scintillator to the acrylic plastic. We will measure the transparency of the glue samples as a function of radiation exposure .

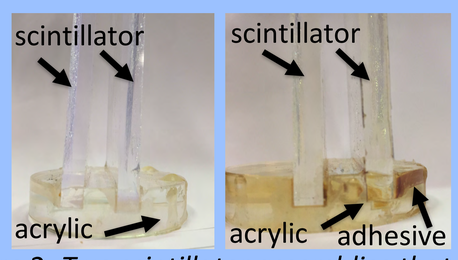


Figure 2: *Two scintillator assemblies that underwent low (left) radiation dose and high (right) radiation dose. The darkest part of the picture right is the adhesive.*

Glue Samples:

Figure 3: *Photograph of two samples of optical cement: BC-600 (left) from St.-Gobain Crystals [2] and EJ-500 (right) [3] from Eljen Technologies. The samples are about .300 inch thick and ¾ inch in diameter.*

Transparency Measurements:

The transparency measurement setup is illustrated below. We use a 405 nm laser that sends a 40 picosecond wide pulse.

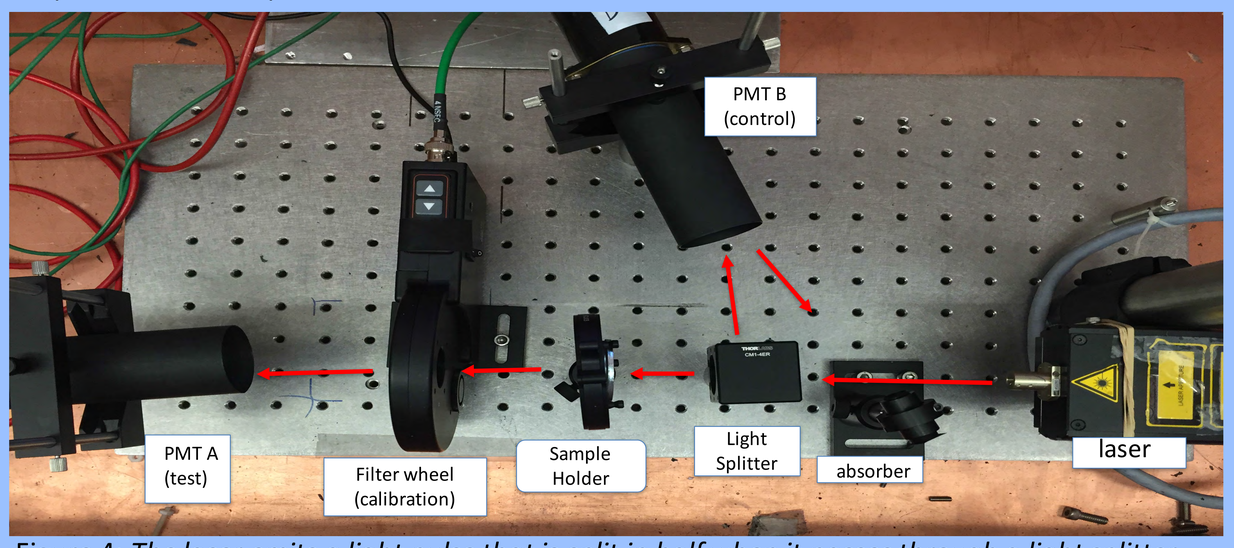


Figure 4: *The laser emits a light pulse that is split in half when it passes through a light splitter. One-half of the light goes to PMT B and the other half passes through the sample, through a filter wheel, and then into PMT A.*

Test Setup Calibration:

We set the gain for each PMT to operate in the linear region. We evaluate the linearity by changing the amount of light the PMT receives by changing the neutral density filter. We then read the pulse height from an oscilloscope.

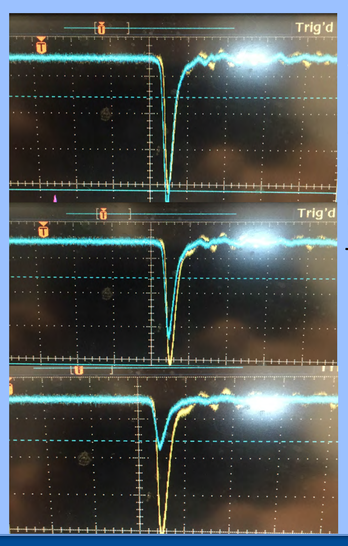


Figure 5: *Oscilloscope traces for the reference PMT (yellow) and the test PMT (blue) for three different neutral density filters.*

P = pulse height
PMT A = P_{AE}
PMT B = P_{BE}
Ratio = P_{AE}/P_{BE}

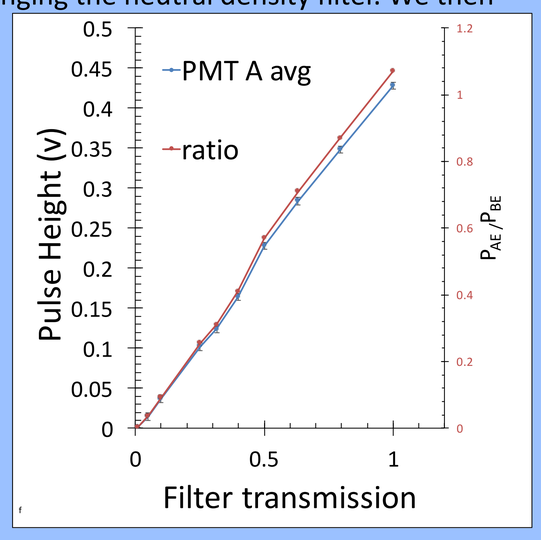


Figure 6: *Pulse height vs. filter transmission for PMT operating in linear region.*

Measuring Transparency:

Transparency is the amount of light passing through the sample (R_S) divided by the amount of light passing through an empty holder (R_E).

$$Trans = \frac{R_S}{R_E}$$

Calculate the ratio of the pulse heights the PMTs are giving off when there is no sample.

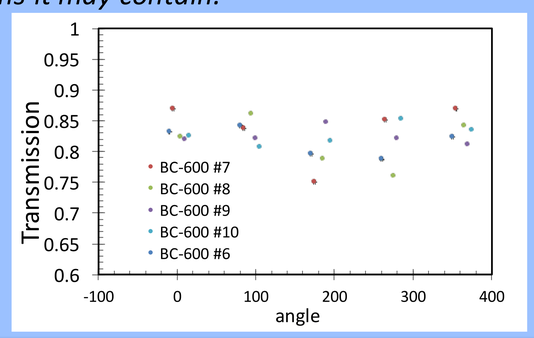
$$R_E = \frac{P_{AE}}{P_{BE}}$$

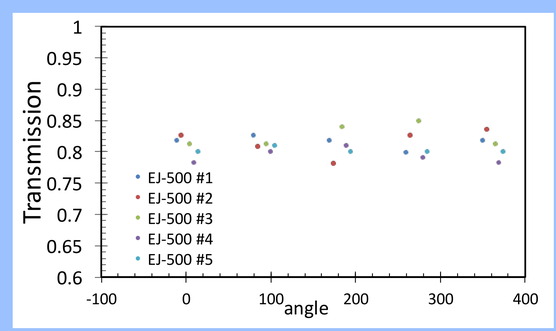
Now, placing a sample in the setup will change the pulse heights of one of the PMTs. Calculate the ratio.

$$R_S = \frac{P_{AS}}{P_{BS}}$$

Results:

Figure 7: *Light transmission as a function of the orientation of the sample. Left graph measures BC-600. Right graph measures EJ-500. The initial angle was set by a mark on the sample. By rotating the sample, we sent light through different parts of the sample to evaluate any imperfections it may contain.*

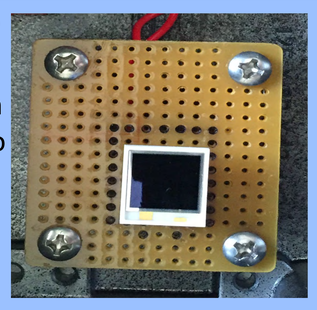




Dosimetry Measurements:

Silicon Photodiode

Figure 8: *1 cm x 1 cm x 300 micron silicon diode.*



We use a 1 cm x 1 cm x 300 µm thick silicon photodiode to measure radiation dose. The diode leakage current is proportional to the radiation dose and also depends on temperature [4].

$$I(\Phi) = I(0) + V \cdot \Phi \cdot \alpha$$

α damage= 3.0×10^{-17} A/cm
Φ = fluence I= leakage
V = volume

$$I(T) \sim T^2 e^{\frac{-1.23(eV)}{2k_B T}}$$

T= Temp (K)
k_B= *Boltzmann constant*

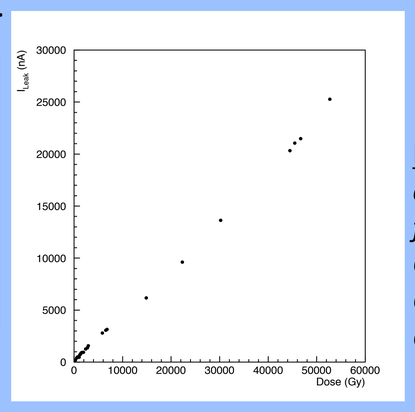


Figure 9: *Leakage current as a function of radiation dose from data collected inside CDF detector. Courtesy of CDF Radiation Monitoring Group.*

We use a thermocouple attached to an Arduino microprocessor to record the temperature as a function of time [5].

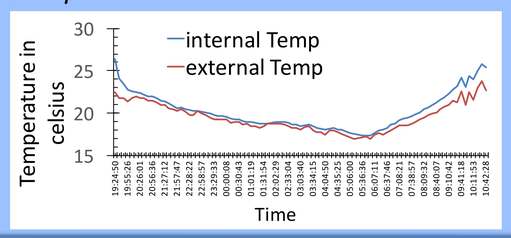


Figure 10: *Data collected overnight from Arduino.*

Summary:

We developed a test setup that will allow us to measure the transparency of optical cement. We have the equipment to measure the radiation dose and the equipment to measure temperature. We made samples of two different glues and measured its initial transparency before exposing them to radiation. We can now put them into the booster and later on measure the transparency as a function of radiation.

References:

[1] Woodworth, Brian. "Booster Beam Profile Measurements via Stripping Foil Losses." Fermilab Undergraduate Poster Session, August 11, 2016.
[2] Saint-Gobain Crystals, 17900 Great Lakes Parkway, Hiram, OH 44234-9661
[3] Eljen Technology, 1300 West Broadway, Sweetwater, TX 79556
[4] Barberis, E. *et al. Nucl. Instrum. and Meth.* A326 (1993) 373-380.
[5] www.arduino.cc