Analysis of Radiation Damage in Quartz Samples for CMS SRPD Detector

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University of Maryland Radiation Facilities • Reactor • Co-60 • Accelerators

ABSTRACT

It has been observed that the normally highly transmissive GE214 quartz tubes become opaque seemingly from intense irradiation. Using the University of Maryland Linear Accelerator, we irradiated two samples, one eighteen times and the second fifteen times. We observed the transmittance of each sample after each irradiation using a Jenway 6700 Series spectrophotometer. We found that while successive irradiations of the same amount does not cause significant changes in transmissivity, significant changes in amount of radiation deposited per irradiation does have a significant change.

INTRODUCTION

The Spectator Reaction Plane Detector (SRPD) at the Compact Muon Solenoid (CMS) experiment of the CERN Large Hadron Collider (LHC) uses GE214 fused quartz glass. The experiment uses the glass to transmit Cerenkov light, produced by a particle shower from detection events, through wavelength shifting fibers that convert the light to a region where the photomultiplier tubes (PMTs) are sensitive (Zboray, 2016). However, there is concern over consistent degradation of the transmissivity of the quartz over long periods of exposure to large amounts of ionizing radiation. The University of Maryland has a Varian Clinac-6 Electron Linear Accelerator capable of producing a 5 MeV (± 1 MeV) electron beamline to simulate the radiation the sample will be enduring. We then used a Jenway 6700 Series spectrophotometer, which is a machine capable of measuring the absorbance and transmittance of a material through a spectrum of wavelengths, to measure the damage to the sample.

METHODS

The samples were irradiated in two different ways dubbed “Scheme A” and “Scheme B”. Scheme A entailed irradiating the sample at 150 Hz for 1,800 pulses 10 times, and scanning after each irradiation, followed by eight irradiations of 18,000 pulses, again scanning after each time. Scheme B irradiated the sample at 1,800 pulses five times, then 18,000 pulses five times, then 180,000 pulses five times. However, 180,000 pulses was unable to ever be reached due to hardware limitations and so each irradiation with a goal of 180,000 pulses was just done until the thermocouple on the linac wall read 200℃. In both cases we wrapped the sample in tin foil to keep it dark and placed radiochromic films to measure dosage applied. We removed the sample from the foil in a dark room and scanned it approximately four times from 190 nm to 1100 nm in the spectrophotometer between each irradiation. We also briefly examined how heating affects the samples by scanning separate samples before and after heating them to 200℃ then cooling them.

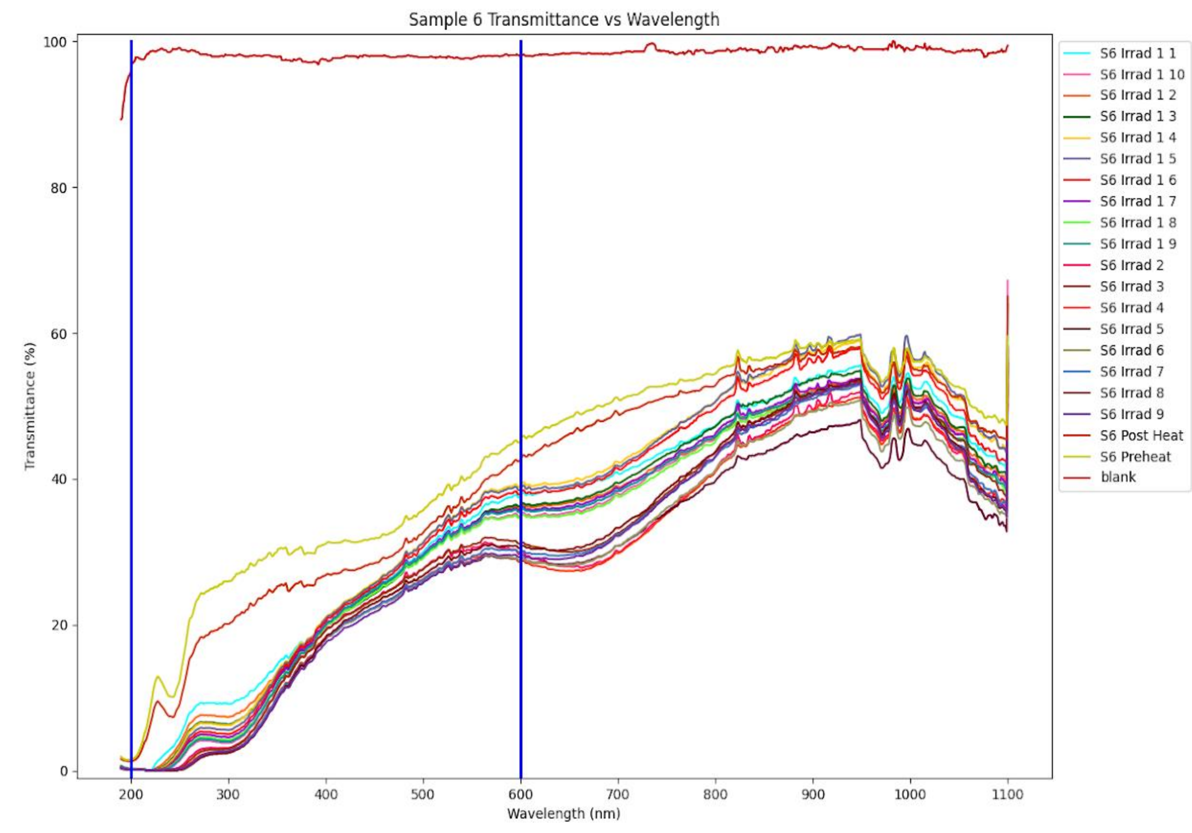


Fig 1. (left) Shows the plotted Jenway scans for irradiation Scheme A.

Fig 2. (below) Shows 3D plot of Jenway scans for Scheme B

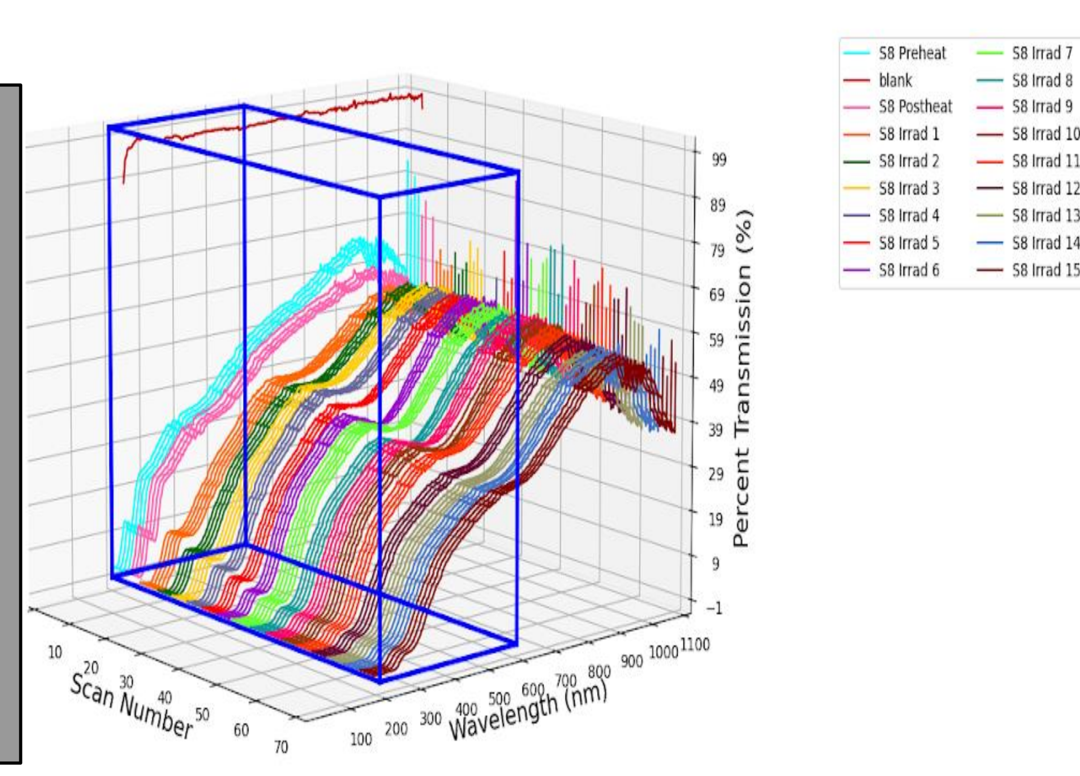
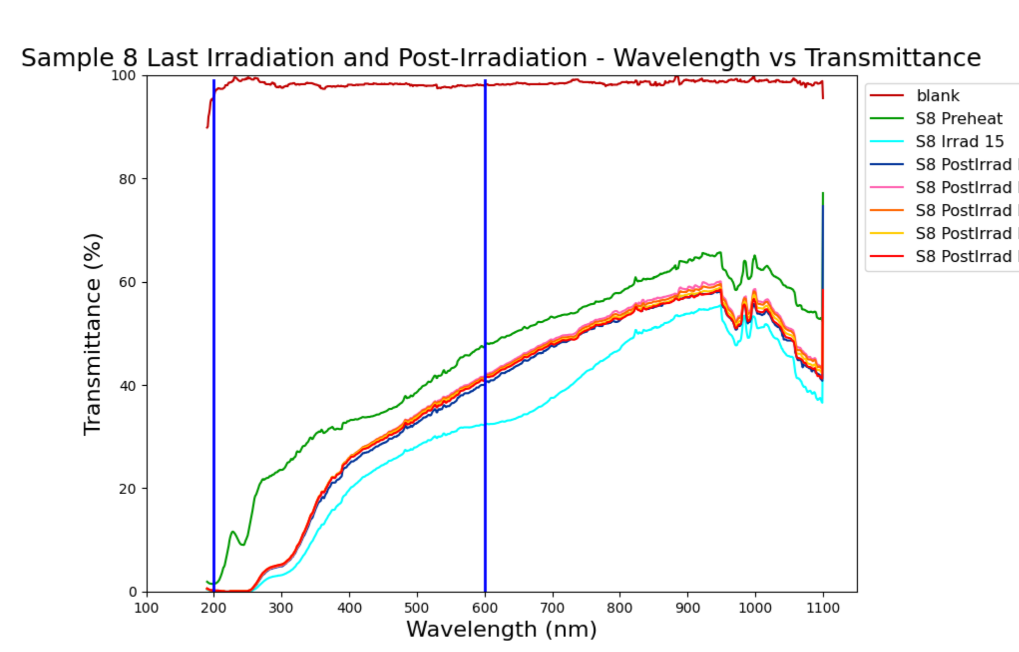
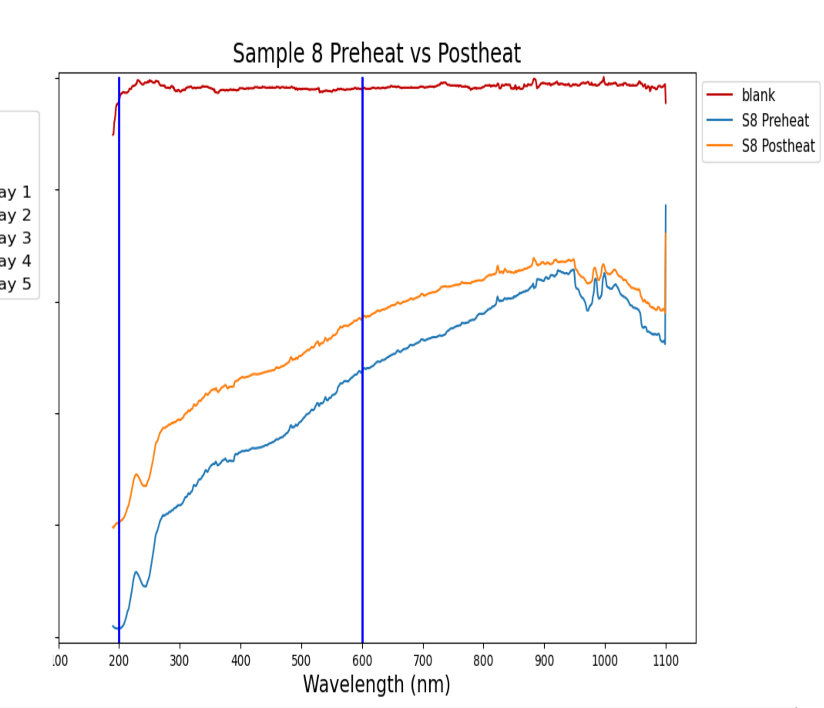


Fig 3. (b. left(Shows self repair over time

Fig 4. (b. right) Shows annealing scans and decrease in transmissivity between successive scans





CURRENT RESULTS AND CONCLUSIONS

As shown in the figures, significant changes to transmittance of the samples was really only seen when changing pulse number per irradiation (ie: when switching between 1,800 and 18,000 pulses). This is especially clear in the 200 - 500 nm and 600 -700 nm ranges. Large drops in the 300 nm range for Scheme A can be explained by possibly being a peroxy bridge defect or germanium presence in the quartz causing absorbance and B1 bands (Marshall et al., 1997). And, while outside the range of the PMT sensitive region, both samples experienced a pronounced dip in transmittance at around 650 nm following irradiation. This may be an indication of the non-bridging oxygen hole center defect (NBOHC) (Skuja et al., 2011). Annealing the sample saw a roughly 10% decrease in transmissivity possibly caused by oxygen-vacancy centers (Devine, 1990).

Research is still ongoing into the self-healing and radiation hardness aspects of the quartz samples. The trend shown in the figures demonstrates that in the PMT sensitive region, large changes in dosage deposited significantly changes the transmissivity of the samples. Further plans are focused on gathering more accurate measurements for the annealing and high end irradiations, as well as looking into quartz shielding methods.

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