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Radiation Effect Studies on High Efficiency Mirror (HEM) and Aluminized Mylar For The HF Optical Design

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Abstract

Reflectivity of two materials, high efficiency mirror (HEM) and aluminized Mylar, under intense radiation were compared. In the UV range, Mylar seems to perform better. At longer wavelength (400+ nm) region, there seems to be no significant difference.

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1 Introduction

One of the unique aspects of Compact Muon Solenoid (CMS) is the forward calorimeter (HF). This is a device that measures the energy of the particles close to the beam line. At this position, the calorimeter will absorb large amounts of radiation on the order of 10 megarads over its expected 10-years run. The materials used to build this calorimeter need to function under these large doses of radiation. This study compared the two materials, High Efficiency Mirror (HEM) and aluminized Mylar, for the effects of radiation on their efficiency of reflectivity before and after exposure to radiation. It was found that the effects of radiation on both materials were minimal within the precision of this test. In the 2 visible wavelengths tested, HEM proved slightly superior to Mylar and Mylar proved superior in the Ultra Violet wavelength tested.

2 Setup and Experiment

A laser beam was directed through the center of a protractor table. The reflective sample was mounted at the center using a half-section of one-inch PVC pipe cut in half along the axial line. The pipe section was compressed with a vice and double-sided tape attached the reflective samples to the cut-sides of the pipe. The vice was then released to stretch the sample and remove any ripples. The pipe was mounted on a shaft that pivoted at the center of the protractor table.

The HEM samples were observed to scintillate with the three wavelengths of radiation. The Mylar samples scintillated if they were placed backwards but did not visibly scintillate if placed aluminized side towards the beam.

Initially, a beam collimator consisting of a 1mm hole in a piece of aluminum foil was mounted to the protractor along the 0 mark as shown. This was followed by a beam splitter and a reference photomultiplier (PMT) (Hamamatsu 1161) tube set at a 90^o angle to the beam opposite the measurement quadrants. This provided a very small diameter beam (approximately 1mm) at the point of reflection. A measurement PMT (Hamamatsu E934-01) was placed on the pivot arm of the protractor (see Fig. 1).

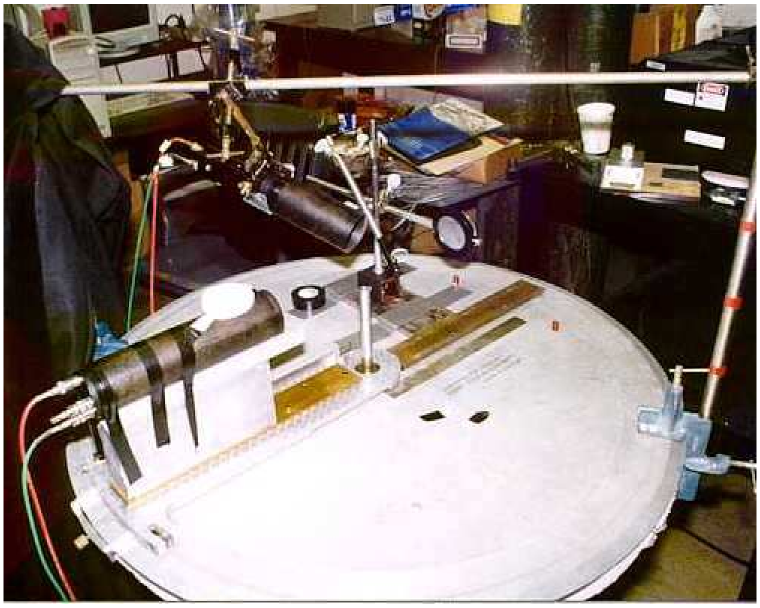

Figure 1: Initial set-up

After the first set of measurements, this setup proved unstable as the table moved slightly and the aperture would get off the centerline of the laser. To stabilize the beam, the collimator and reference PMT were placed on the same table as the laser. The single hole beam collimator was replaced by one consisting of two aluminum foil sheets spaced approximately 2.5cm apart with 1mm holes in each side.

The ”Protractor Table” was set up so that the collimated laser beam passed through 0-center-180 mark. On the same ring stand as the collimator, a reference Photomultiplier Tube was mounted. This tube sat above the beam and had a signal sent to it from a small beam splitter located in the beam after the collimator. This allowed a set part of the beam to come into a PMT and give a reference beam before the beam entered the protractor table(see Fig. 2).

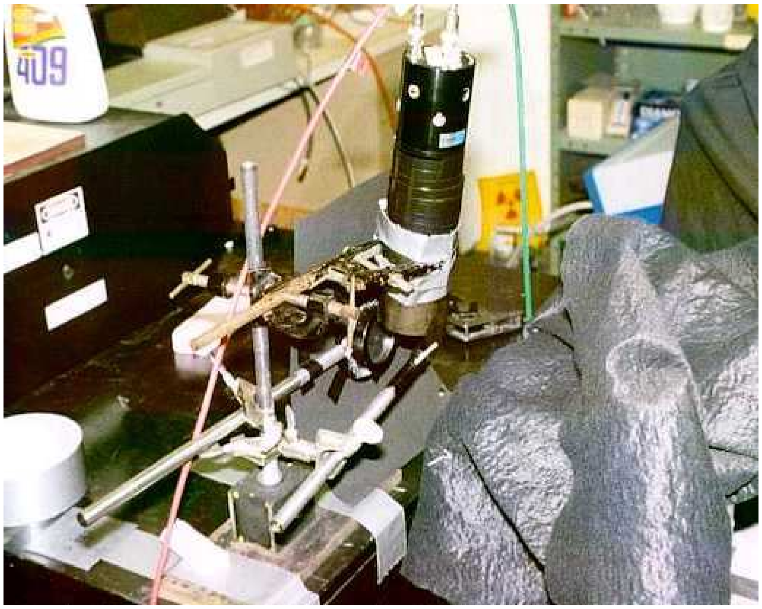

Figure 2: Final set-up

The beam then went onto the center of the circular ”Protractor Table” and was directed into a second PMT. The alignment was maintained using a removeable scintillating mask with cross hairs in the center of the PMT. The table was moved so the beam went through the central shaft then onto the crosshairs in the PMT mask set at straight from the LASER. Since the PMT’s were about 5cm in diameter, any stray light from the reflecting surface that was within about 10^o entered the surface of the PMT and was part of the measurement. The outputs of the PMT’s were observed on a digital oscilloscope.

The voltages were set to give similar integrals of voltage Vs time plots on the scope. The integrals of the pulses were not very stable so five pulses were recorded and averaged. Since the laser was very intense, neutral density filters were necessary to attenuate the pulse so it didn’t saturate the PMT’s thereby loosing their sensitivity. Initially, the first runs were done with a one thosuandth neutral density filter. After a few trials it was noted that some reflections had larger signals than the non-reflected signal. At that point, it was decided the PMT’s were being saturated by the laser beam so more filters were added to make a combined attenuation of 10-5.3. This combination yielded more sensitive readings after the high voltages were set so the two PMT signals matched each other. However, the beam was invisible so a one hundredth filter was removed for alignment and then replaced for readings.

A run consisted of sending the beam straight through with no reflector first. Five readings were taken and then the measurement PMT was swung 30^o and the reflector was placed on the shaft. The reflector was rotated so the beam hit the center of the PMT. This made an angle of 70^o from the normal to the surface and the incident and reflected beam. Smaller angles were not reliable as the beam width was not covered by the sample and some beam was not reflected into the PMT. This process was repeated for every 10^o down to a 30^o angle where the apparatus interfered with a more head-on measurement. This process yielded angle measurements of 70^o to 15^o in 5^o increments from the normal to the reflective surface. At the end of each run, the direct, non-reflecting measurement was repeated. Each set of runs was repeated for two Mylar samples and two High Efficiency Mirror (HEM) samples. One sample had no radiation exposure and the other had a 10 Megarad dose from a Cs^{137} source. Runs were done for wavelengths of $337nm$, $420nm$ and $446nm$ using different dyes. Each angle measurement was taken five times and averaged. The averages were then divided by the average measurement of the reference beam. These ratios were then averaged and normalized by dividing by the average of the PMT ratios taken with no reflection to give a percentage. These percentages were plotted against angles and compared.

3 Results

The average normalized ratios of the pulse integrals were plotted against the angles with the normal of the reflector surface. The pulse integrals were averaged over the 5 samples taken. The ratios of reflective pulse to reference pulse were normalized using the straight-line, non-reflective pulse to give a reflectivity percentage. This percentage was plotted against the angle of reflection measured from the normal to the reflective surface. The plots in Fig. 3 and Fig. 4 were for $337nm$ UV radiation.

In these two plots, it is obvious that at a wavelength of $337nm$, Mylar has a much better reflective percentage than HEM. The difference between the radiated and non-radiated sample is not significant for HEM but slightly significant for Mylar.

For a wavelength of $420nm$, there is a difference between HEM and Mylar. Here, clearly, the HEM is superior as it has much higher percentage of reflection. Again, radiation seems to have little effect upon the percent of reflection for either material.

The plots in Fig. 5 and Fig. 6 were for $420nm$ UV radiation.

For the $446nm$ wavelength, the two materials compare quite similarly.The radiation does not seem to have a significant effect. The plots in Fig. 7 and Fig. 8 were for $446nm$ UV radiation.

4 Conclusions

To the extent of the precision of this experiment, it would seem that HEM has a slight advantage over Mylar in the visible range. In UV, Mylar has a significant advantage.

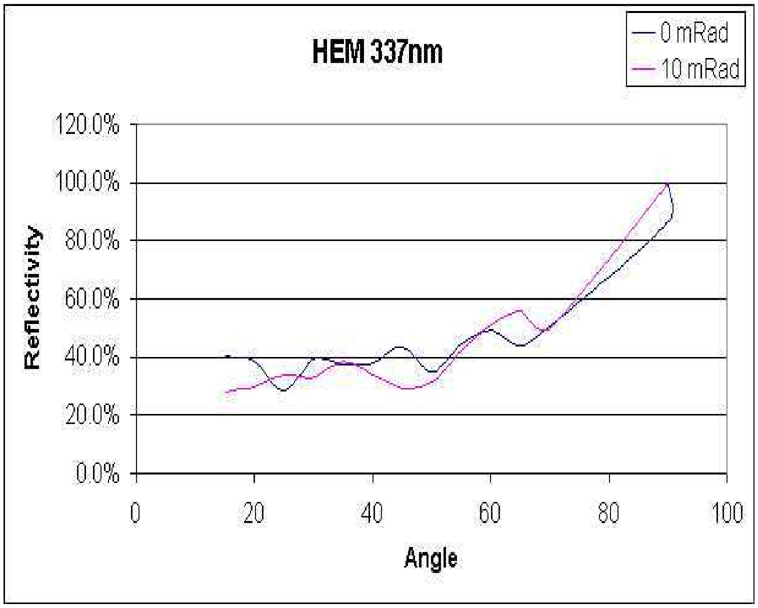

Figure 3: The average normalized ratios of the pulse integrals for irradiated and non-irradiated HEM samples for $337nm$

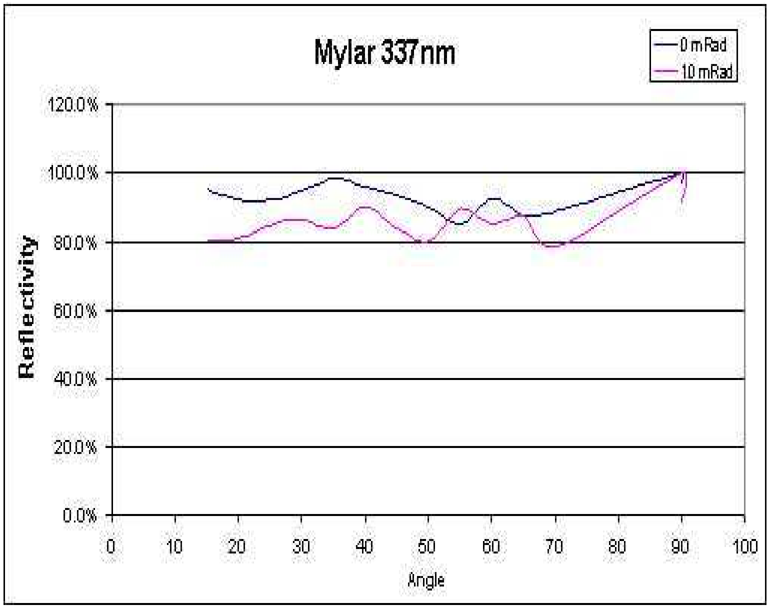

Figure 4: The average normalized ratios of the pulse integrals for irradiated and non-irradiated Mylar samples for $337nm$

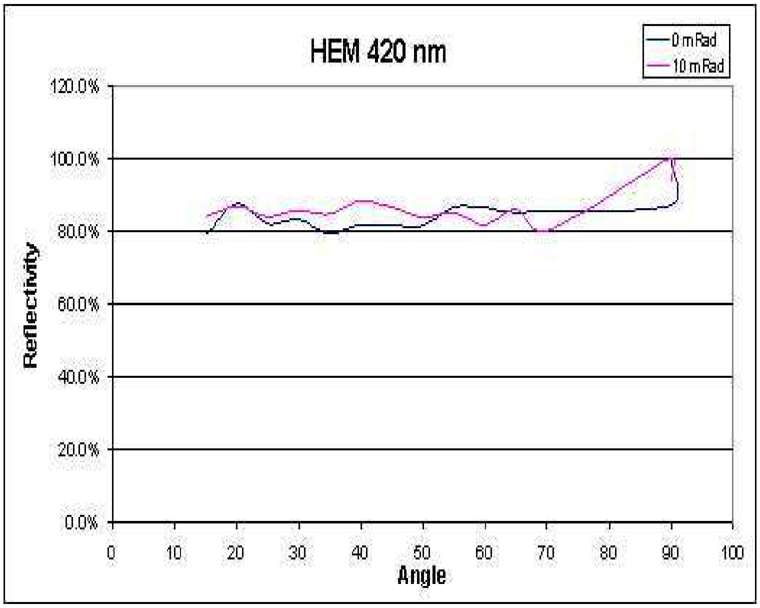

Figure 5: The average normalized ratios of the pulse integrals for irradiated and non-irradiated HEM samples for $420nm$

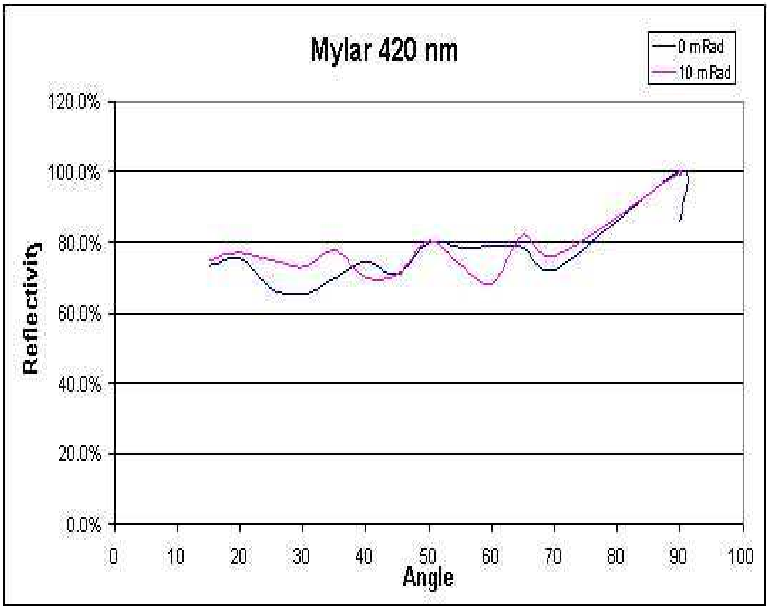

Figure 6: The average normalized ratios of the pulse integrals for irradiated and non-irradiated Mylar samples for $420nm$

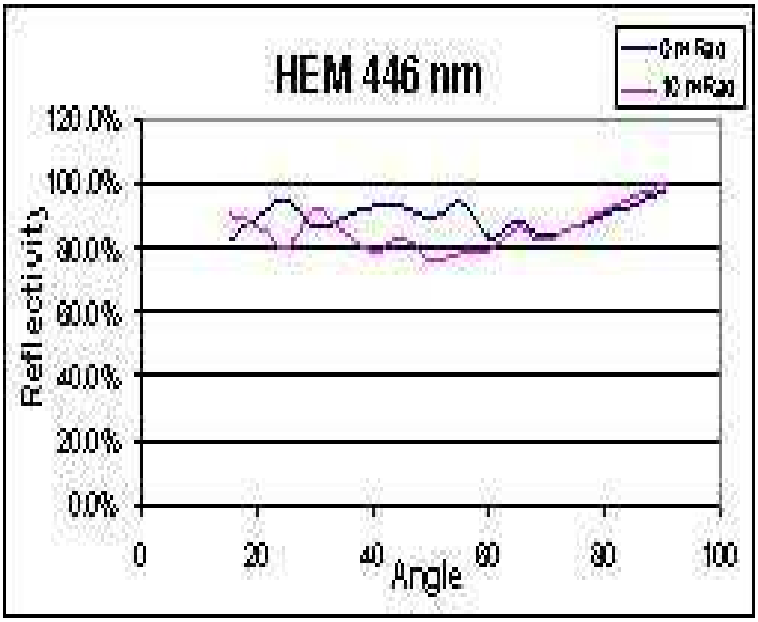

Figure 7: The average normalized ratios of the pulse integrals for irradiated and non-irradiated HEM samples for $446nm$

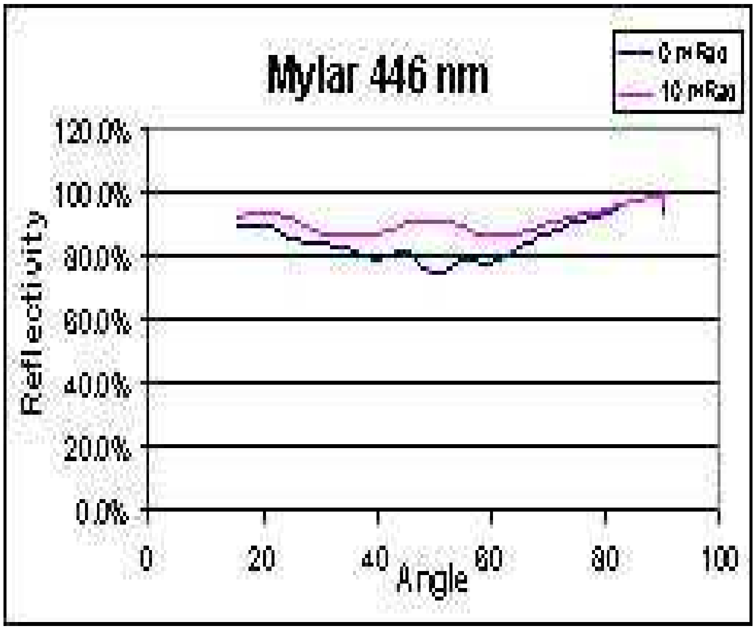

Figure 8: The average normalized ratios of the pulse integrals for irradiated and non-irradiated Mylar samples for $446nm$