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MEASUREMENT OF RADIATION DAMAGE OF OPTICAL FIBERS DURING IRRADIATION

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Presented by H.Grassmann (*)

Abstract

We are constructing a computer controlled setup for measuring material properties while the material is irradiated. We aim at very small systematic errors and a high measurement precision. The device has to deliver measurements of several different parameters simultaneously. The setup is compact and easy to handle and transport.
For a first measurement we investigate the transmission of optical fibers.

1. EXPERIMENTAL SETUP

1.1. Basic design

The fundamental layout of our device is intended to be as follows : A signal is provided by one or more LED's of different colours. (Lasers or UV lamps could be used as well.) The light pulses emitted by the LED's are transmitted through the optical fibers to be investigated. Part of the fiber is exposed to the radiation field. The signal is than read by a photodiode. The current produced in the photodiode is amplified such that it can be read into a Camac ADC. We used photodiodes because their compactness, stability and robustness had been proven advantageous in similar applications (1). Of course one could use a photomultiplier instead of a photodiode, if wanted.

(*) Contributed paper to the 2nd International Workshop on Calorimetry in High Energy Physics, Capri, Oct. 1991

1.2. Monitoring system

There will be applications where the photodiode, the amplifier and the LED's cannot be shielded against radiation sufficiently. Therefore we also need to precisely monitor any possible change in those components. That can be done using one or several reference LED's which face the photodiode directly, without an optical fiber in between. Any change in the emission of the LED, the photodiode or its window or in the amplification of the electronics can be monitored in that way. To be able to distinguish between changes in the amplifier and the optical system we also can inject test pulses into the amplifier input through a capacitance. Photodiodes also act as solid state counters. If necessary one can correct also for that effect by reading signals without giving LED pulses.

1.3. Configuration for our first test run

Our setup was not yet completed for our first engineering run. We used a simplified monitoring system. The configuration was as follows :

Two long fibers view signals from a red and a green LED each. Part of these fibers is exposed to the radiation of a Co^{60} source. The fibers are read by a photodiode. LED's, photodiode and amplifier are protected against radiation by several centimetres of lead. Also protected by this lead shielding are two shorter fibers which serve for monitoring. As the long fibers, also the short fibers view two LED's (green and red) and they are read by the same photodiode. A schematic view of the setup is shown in Figure 1. Only one of the two long and one of the two short fibers are shown for simplicity.

Subsequent each of the LED's emits a light pulse. The transmitted signal is read by the photodiode for each of the different LED's separately. This measurement cycle is repeated each 10 seconds. The device is driven by an IBM PC controlling a CAMAC crate. We use the photodiode S1790 from Hamamatsu. Our amplifier is a very simple two-stage amplifier based on operational amplifiers LF357, it is not optimise for lowest possible noise.

In our plots we always combine 10 subsequent measurements to one data point.

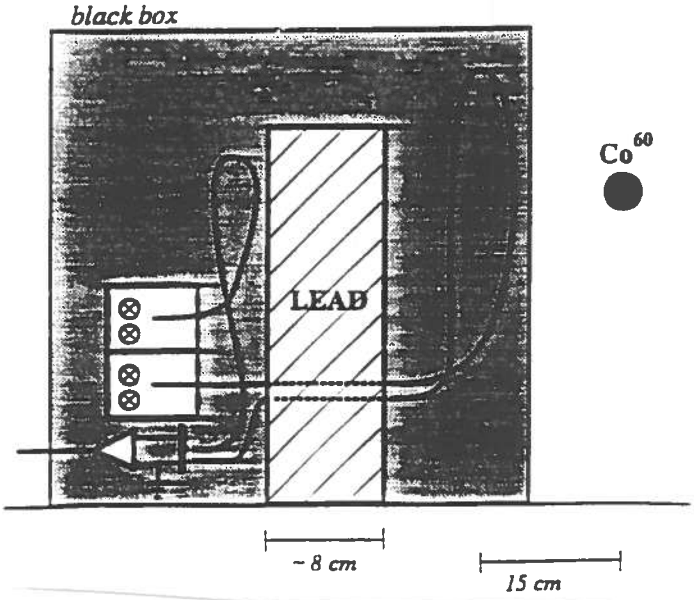

FIG. 1 – Schematic view of the test setup.

2. MEASUREMENT

2.1. The Co^{60} source

The data were taken at the INFN Legnaro, Italy. The Co^{60} source there has an intensity of 5780 Curie. The source is inside a lead container and can be brought out of that container by remote control. The source is installed in a room of about 3m∗5m in size.

From the known source strength and the geometrical configuration we calculated that the exposed part of the fibers absorbed 140 krad/hour. The radiation had a non uniformity of ±25% over the length of the fiber. The total time of exposure was 18 hours, which corresponds to about 2.5 Mrad.

2.2. Measurement procedure

The fibers were green wavelength shifting plastic fibers from Bicron with 1mm diameter, as they are used in the CDF upgrade (2). The long fibers were 120 cm in length, 90 cm where exposed to radiation. The short fibers were about 40 cm long.

- We exposed the fibers to radiation for a time of t = 45 minutes.
- The Co source was removed for t = 17 minutes.
- The Co was activated again for 18 hours.
- We took data for another 30 minutes without Co.

2.3. Results

Figure 2 shows the signal from one of the long fibers over the first 240 krad of radiation. The vertical axis are the ADC channels, pedestal subtracted. The horizontal axis is in seconds.The source was switched on at t = 2400 seconds. Between t = 5050 and t = 6050 seconds it was switched off.

From Figure 2 we see that the signal from the green LED decreases rapidly, while the signal from the red LED remains almost stable. Within our measurement precision we do not observe any recovery or annealing effect after the first 100 krad, when the source was switched off for 45 minutes. The other long fiber behaved the same.

We made the same plots for the short, shielded fibers (not shown): the transmission of green light gets only slightly worse, the signal from the red LED remains essentially stable.

That comparison between the transmission of red and green light in the shielded and unshielded fibers indicates that the system LED+photodiode+amplifier is stable within about 1%. For future runs we will have the full monitor system installed.

Figure 3 shows the change in transmission for red and green light over the full data taking period of 18 hours corresponding to 2.5 Mrad. Shown in Figure 3 are the signals from the unshielded fiber number 2, the unshielded fiber nr. 1 has the same behaviour. We observe that the unshielded fiber has a clear maximum in Δ transmission/Δ radiation at 400 krad for both red and green light. We do not observe this effect in the shielded fiber.

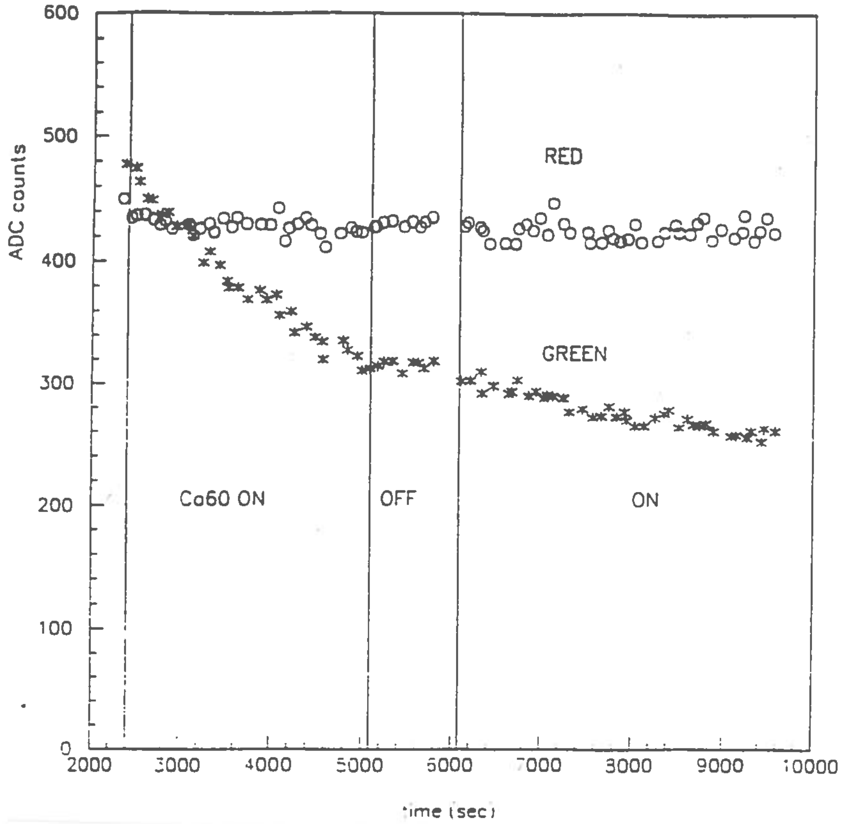

FIG. 2 – Loss in transmission during the first 240 krad.

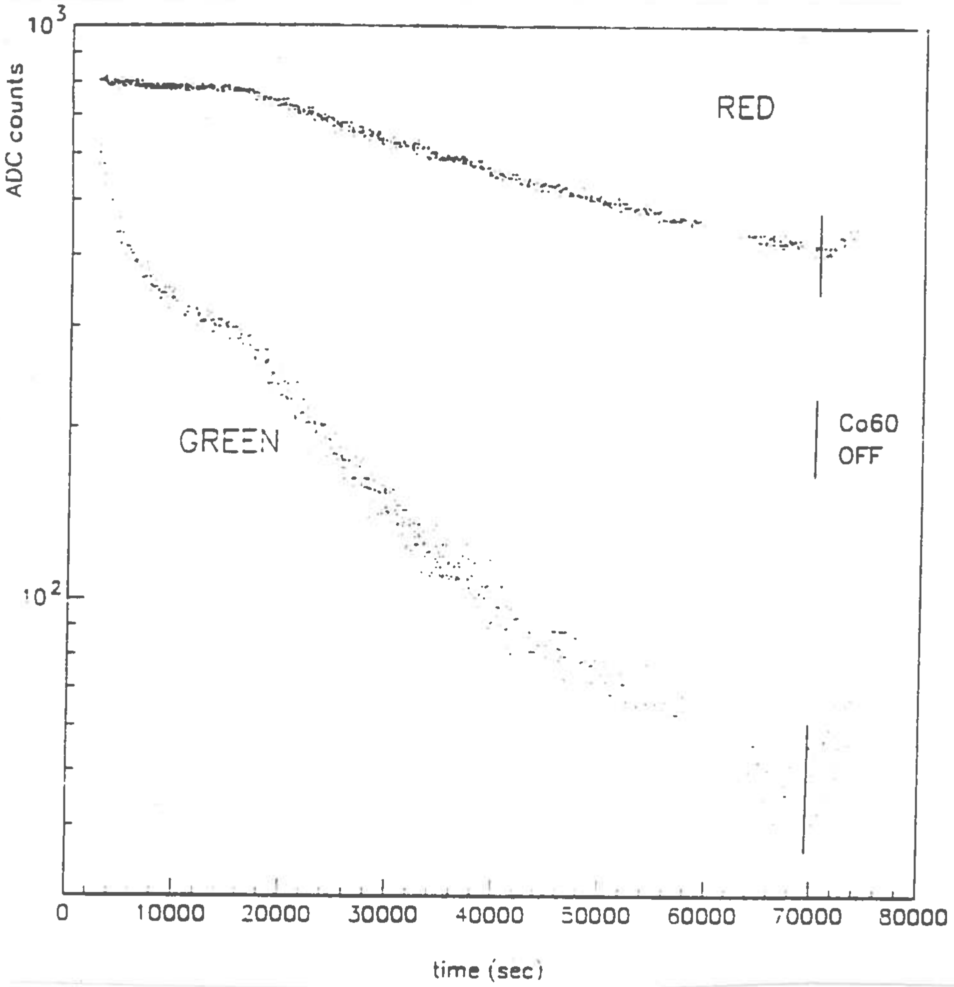

FIG. 3 – Loss of Transmission over the total exposure of 2.5 Mrad.

Therefore it must be caused by a response of the fiber itself to radiation, rather then by a problem in our electronics system. At the time being we don't know any explanation for this 'kink' at 400 krad. We will need confirmation.

After 2.5 Mrad the transmission left in the unshielded fiber 1 (2) for green light is 8%(11%) and for red light 57%(58%).

We also see a recovery effect after 2.5 Mrad of 10% in 30 min.

Therefore we expect that the transmission as a function of absorbed radiation will strongly depend on the intensity of the radiation.

3. CONCLUSION

The first run with our on-line radiation monitor setup showed that the device is working. We are able to do detailed measurements with small systematic errors. As first results we find evidence for a 'kink' in the transmission of red and green light at 400 krad. We also observe annealing effects. More measurements with a completed device will be done in the near future.

LITERATURE

(1) H.G.Moser et al.,'a compact and inexpensive radiation monitoring device', DESY red report 84-063.
(2) J.Freeman, this conference, CDF plug upgrade.