COMPARISON STUDIES OF TILE/FIBER SYSTEMS MANUFACTURED FROM KHARKOV INJECTION MOLDED AND KURARAY SCSN-81 SCINTILLATORS

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We present the results from measurements of light output, light yield uniformity, and recovery after radiation damage of tile/fiber systems made from the scintillator produced by the injection molding technique in Kharkov. The tiles were trapezoidal in shape, 131x90x122 mm^3, with a Kuraray Y11 multi-clad WLS read-out. The results are compared with those obtained using the tile/fiber systems manufactured from the Kuraray SCSN-81 scintillator and tested under the same conditions. The light yield uniformity is found to be improved by masking. Effects of milling, polishing, painting of tile edges and mirroring the fiber end were studied.
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INTRODUCTION

The main goal of this study has been to compare the characteristics of the tile/fiber systems made of Kharkov and Kuraray scintillators. Kharkov scintillating plates for the tile/fiber system were produced by the injection molding technology [1]. The industrial granulated polystyrene PSM-115 was mixed with primary 1.5% pTP and secondary 0.02% POPOP scintillating dopants. The mixture was loaded into a standard injection molding machine including a peculiarly designed mold. Special studies were made to find optimum molding parameters for producing best-quality scintillating plates under given conditions. The plate dimensions were 240x210x4 mm^3 that corresponds to the machine active volume (250cm^3). It took two minutes to manufacture such a plate. The variation in thickness over the plate area and from plate to plate did not exceed 2%. The RMS of the light yield distribution measured at the center of plates by the use of a collimated ^{90}Sr source was 2.7%. Two tiles were cut from each plate. Keyhole grooves were milled near the edge as shown in Fig. 1.

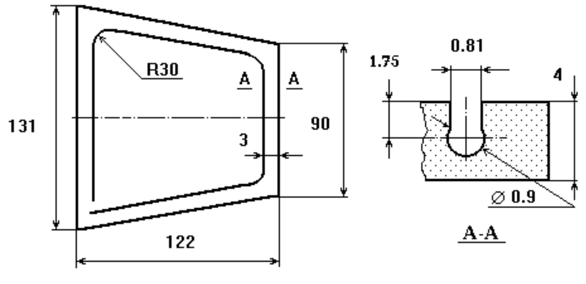

Fig. 1. *Sketch of tile and groove.*

The edges of some tiles after machining were kept milled, while the rest were polished or painted with a white paint. All the tiles were wrapped all around in Tyvek and some of them were masked with a black paper. The Kuraray double clad Y11-200 (∅ 0.83 mm) mirrored or non-mirrored fibers were inserted in the grooves. The total length of each fiber was 70 cm. Tile/fiber systems just of the same design but with the use of a Kuraray SCSN-81 scintillator were manufactured with the same tools and technology. We have manufactured 10 tiles of the Kharkov injection molded scintillator and 6 tiles of Kuraray SCSN-81 scintillator. The mean thicknesses of Kharkov and Kuraray tiles were 4.48± 0.09 mm and 3.90±0.08 mm, respectively (Table 1).

Table 1. *The results of comparative studies of tile/fiber systems made from Kharkov and Kuraray SCSN-81 scintillators. The tile is wrapped to Tyvek. The WLS fiber Kuraray Y11 is non-mirrored.*

Manufacturer	3.0 Mrad	4.0 Mrad	5.3 Mrad
Kharkov	0.49±0.04	0.35±0.03	0.31±0.03
Kuraray	0.44±0.04	0.40±0.04	0.37±0.03

All the tiles were investigated under identical conditions with the same pieces of apparatus.

LIGHT YIELD OF THE TILES

The non-wrapped tiles were placed between the ^{90}Sr source and the photomultiplier, and the photomultiplier current was measured to obtain the relative light yield. It can be seen from Table 1 that the relative light yields of injection molded and SCSN-81 scintillators are 1.00± 0.02 and 0.75±0.02, respectively. After introducing the correction for the tile thickness differences, the Kharkov-to-Kuraray scintillators' light yields ratio is 1.16±0.04.

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Серия: Ядерно-физические исследования (36), с. 34-37.

LIGHT TRANSPARENCY OF THE FIBERS

We have cut 24 fibers, 70 cm long, from a bundle of Kuraray Y11 fibers. Both ends of the fibers were polished. All the fibers were tested in the same tile. The scintillator was excited with a ^{90}Sr source. The fiber was read out by a FEU-84 photomultiplier. The RMS of the relative light transparency of 24 fibers was 5.5%.

LIGHT YIELD OF TILE/FIBER SYSTEMS

The setup used for measuring the light yield of tile/fiber systems is sketched in Fig. 2. The best 10 fibers with RMS of 1.6% were selected for use in the tile/fiber systems. Several fibers were mirrored. The tile was excited by an ^{90}Sr source and the fiber was read out at one end by a PMT3 (FEU85) through the air gap. The 1 mm thick scintillator counters PMT1 and PMT2 were used as a trigger.

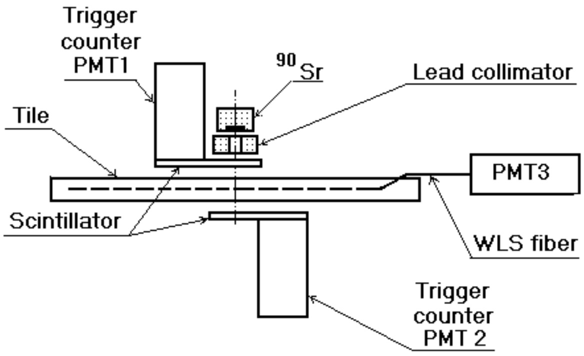

Fig. 2. *Experimental setup for the light yield measurements.*

For absolute light yield measurements the signal from PMT3 was digitized by a QDC that used the signal coincidence from PMT1 and PMT2 as a trigger. Relative light yields were measured by registration of the photomultiplier current of PMT3 without triggering.

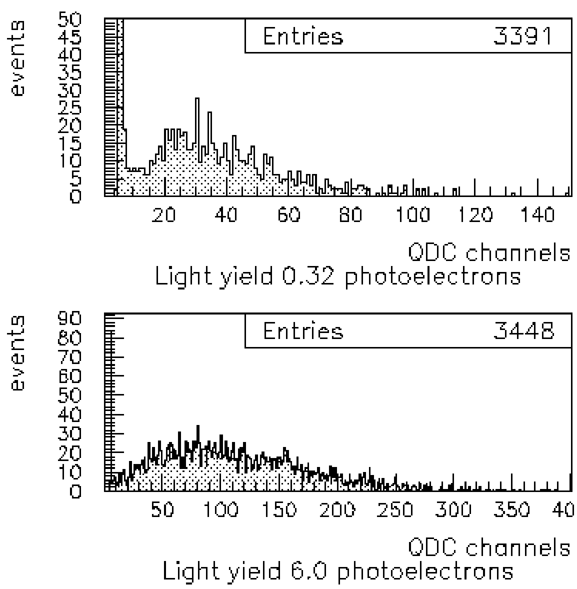

Fig. 3. *An example of the pulse spectra.*

Fig. 3 shows an example of the pulse spectra to obtain the number of photoelectrons. The results obtained with the source position at the center of the tile are shown in Table 1. The relative light yields of the 10 tile/fiber systems with Kharkov and Kuraray scintillators are 1±0.13 and 1.14±0.10, respectively. The absolute light yields with non-mirrored fibers for Kharkov and Kuraray scintillators are 5.2±0.6 and 5.0±0.3 photoelectrons, respectively. The correction for the tile thickness changes these values to 1.31±0.12 and 5.75±0.4 for the Kuraray scintillator. So, the light yield of the tile/fiber system from the Kharkov scintillator is equal to or slightly less (0.8-0.9) than that for the Kuraray scintillator, though the situation is quite opposite with the light yields of Kharkov and Kuraray scintillators themselves (1.16±0.04). This may be due mainly to a less effective light attenuation length of the Kharkov scintillator. Tile edge polishing does not change the tile/fiber light yield. Painting of the edges increases the yield by about 15% in comparison with the milled edges. Mirroring of the fiber end increases the light yield by 60-70%.

LIGHT YIELD UNIFORMITY OF TILE/FIBER SYSTEMS

The setup for relative light yield tile/fiber uniformity measurement is shown in Fig. 2. The trigger counters were removed in this case. The ^{90}Sr source with a 6 mm in diameter collimator moved with a 10 mm step over the tile surface. An example of light yield distribution over a tile/fiber surface is shown in Fig. 4.

The response is fairly flat except in the region around the fiber where it is 10-12% higher. 5-7 % of the light yields in this region are due to the direct fiber excitation. It is seen that the non-uniformity is associated with the area along the fiber. To calculate the RMS, we exclude the data points with a light yield lower by 3σ than the average light yield over the measured area, where σ is the parameter of Gaussian fit for all the data. An example of data and fit is shown in Fig. 4. The results with non-mirrored fibers are summarized in Table 1.

The average RMS values for 10 Kharkov and 6 Kuraray tile/fiber systems are (5.2±0.6)% and (3.6±0.5)%, respectively. So, the tile/fiber system uniformity with a Kuraray scintillator is 1.5 times better than that for the Kharkov injection molded scintillator. The main reason of this difference is probably a smaller effective light attenuation length of the Kharkov scintillator.

Painting, polishing of tile edges change practically neither the RMS nor the MEAN; fiber mirroring slightly (10-20)% improves the uniformity but significantly (60-70)% increases the tile/fiber light yield. We have used the correction masks to improve the light yield uniformity of the tile/fiber system. The masks of 6 mm width were put on the groove area (Fig. 5), on both sides or on one side of the, and then the tiles were wrapped.

RESPONSE TIME OF THE TILE/FIBER SYSTEM

The decay time of tile/fiber systems has been measured, as well as the time needed to collect 90% of the signal charge.

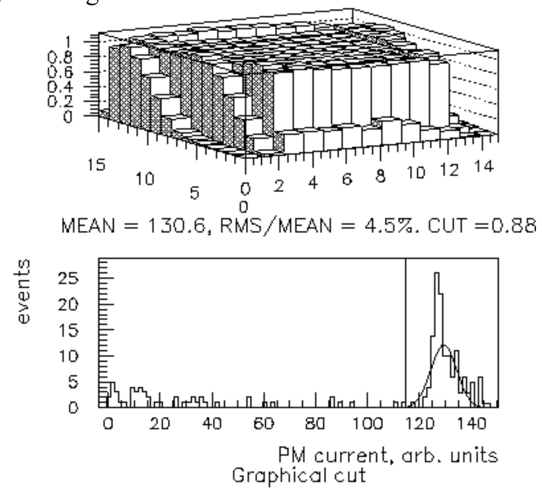

Fig. 4. *An example of light yield uniformity and fit to reject extra data points.*

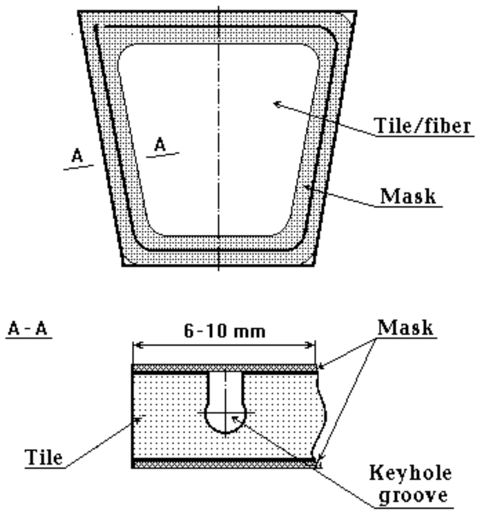

Fig. 5. *Tile mask.*

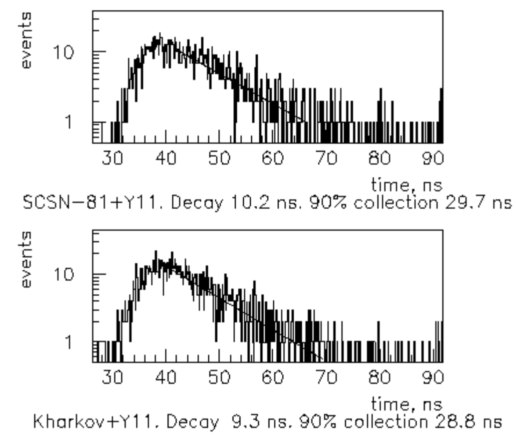

Fig. 6. *An example of time spectra for tile/fiber from SCSN-81 and Kharkov injection molded scintillators. WLS fiber Y11.*

The right part of the spectrum was fitted by exp(-t/τ) to obtain the decay time τ. The results for the tile/fiber systems are close to the decay time of Y11 fibers. Our results differ from τ values in [2] (5.7±0.1 ns) and are in agreement with [3] (10.9 ns).

The experimental setup is shown in Fig. 2. For time measurements we have used the TDC in the CAMAC crate connected with an IBM PC computer. The coincidence signal of two trigger counters was used as the start of TDC. The signal of the PMT3 stopped the TDC. The space between the fiber end and the PMT3 was adjusted to get the single photon regime. The time resolution of these measurements was about 0.7 ns. The typical time spectra are shown in Fig. 6.

On using the mask on one side of the tile it appears possible to improve the uniformity by a factor of 2 at the expense of 20-30% reduction in the light yield.

RADIATION HARDNESS OF TILE/FIBER SYSTEMS

Sets with tile/fiber systems from Kharkov and Kuraray scintillators were irradiated up to 3.0, 4.0 and 5.3 Mrad by a bremsstrahlung photon beam from the 10 MeV electron linac in air at room temperature. The dose rate was about 1 Mrad/hour. The space uniformity of dose was about 15%. The integral dose was measured with a CO PD 5/150 film and a calibrated densitometer to an accuracy of about 12%.

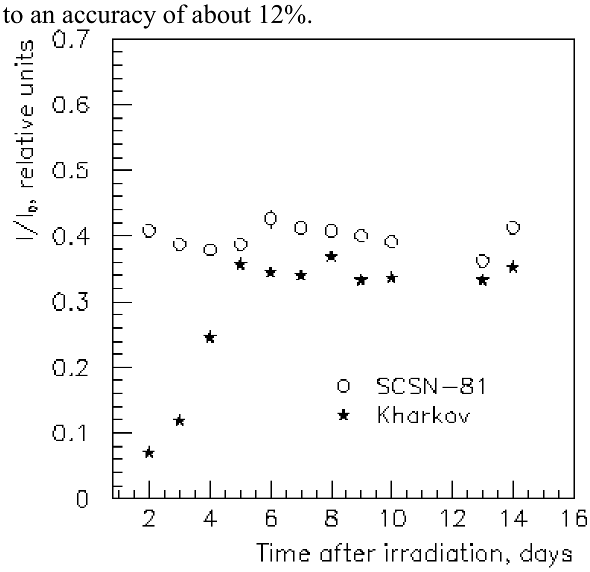

Fig. 7. *Recovering of light yield from SCSN-81 and Kharkov scintillators after dose 4.0 Mrad.*

The light yield and light yield uniformity of the tile/fiber systems were measured at different irradiation doses and recovery times as described above (Fig. 6,7 and. Tab. 2.).

The light yield uniformity (RMS) increases by a factor of 3 and becomes 15.7% for Kharkov and 9.0% for Kuraray scintillators with a non-irradiated fiber. The use of irradiated fibers does not change the uniformity. The light yield of tile/fiber systems made from scintillators of both types is nearly the same, about 5.5 photoelectrons per minimum ionizing particle.

These results may be attributed to the fact that the light attenuation length of the Kharkov scintillator is smaller than that of the SCSN-81 scintillator.

The decay time and the time needed to collect 90% of the signal are 10 ns and 29 ns, respectively, for all the tile/fiber systems under study; these values are mainly determined by the decay time of Y11 fibers.

The light yield degradation of the tile/fiber assembly with non-irradiated fiber is nearly the same (0.5-0.3 after/before irradiation) for Kharkov and SCSN-81

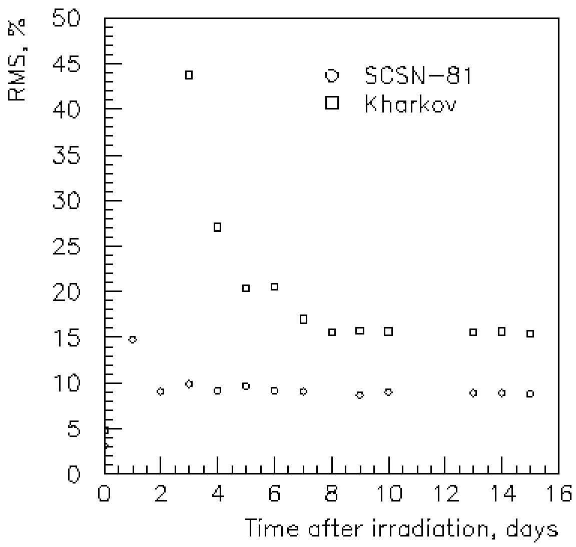

Fig. 8. *Recovering of light yield uniformity for tiles from SCSN-81 scintillators after dose 4.0 Mrad.*

Table 2

	Tile/fiber ligth yield ratio after/before irradiation		Tile/fiber uniformity [RMS, %]	
Dose [Mrad]	WLS fiber non-irrad.	WLS fiber irradiated	WLS fiber non-irrad.	WLS fiber Irrad.
Kharkov scintillator				
3.0	0.49 ± 0.04	0.31 ± 0.03	12.7 ± 1.0	13.3 ± 1.0
4.0	0.35 ± 0.03		15.7 ± 1.0	
5.3	0.31 ± 0.03	0.21 ± 0.02	17.7 ± 1.0	17.7 ± 1.0
Kuraray scintillator				
3.0	0.44 ± 0.04	0.32 ± 0.03	8.1 ± 0.5	7.1 ± 0.5
4.0	0.40 ± 0.04		9.0 ± 0.5	
5.3	0.37 ± 0.03	0.25 ± 0.02	9.9 ± 0.5	9.6 ± 0.5
Dose [Mrad]	WLS fiber light output ratio after/before irradiation			
3.0	0.73 ± 0.06			
5.3	0.70 ± 0.06			

SUMMARY

We have carried out comparative measurements for scintillating tile/fiber systems with Kharkov (10 tiles) injection molded scintillator and Kuraray (6 tiles) SCSN-81 scintillator, using Y11 fibers, 70 cm in length, 0.83 mm in diameter. The fiber end was non-mirrored. The tile size was 131x90x122 mm, where 122 mm is the trapezium height. All the tiles were wrapped with Tyvek.

The light yield of the Kharkov scintillator is 16% higher than that of SCSN-81 (taking into account the tile thickness difference).

The light yield degradation of the tile/fiber assembly with non-irradiated fiber is nearly the same (0.5-0.3 after/before irradiation) for Kharkov and SCSN-81 scintillators in the range of doses of 3-5 Mrad after two weeks of recovery. With irradiated fiber, it is about 0.2.

Measurements performed after 3.5 years on these systems have shown that the further recovering of characteristics in oscillators of both types for a long time practically was absent.

Painting, polishing of tile edges improve the light yield by about 10-15%. The mirroring of the fiber end slightly (10-20%) improves the uniformity but significantly (60-70%) increases the tile/fiber systems light yield. The light yield uniformity is at a level of 2-3 %.

The masking of the tile surface improves the light yield uniformity, but with some (about 20%) sacrifice in the light yield. So, the main characteristics of tile/fiber systems produced by the use of Kharkov injection molded scintillators are comparable to those of Kuraray SCSN-81, except the light yield uniformity.

The characteristics of the Kharkov scintillating tiles can still be improved, namely, by improving the quality of the polystyrene used.

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