Aluminization of Scintillating Fibers for the Luminosity Detector of ATLAS

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Abstract

We report on tests on 25 cm long squared, $0.5\times0.5\ \text{mm}^2$ SCF-3HF optical scintillating fibers, which have been aluminized by the magnetron sputtering technique in Lisbon during 2005. Two groups of fibers were used: 9 isolated fibers (**Set I**) and 20 stacked inside an acrylic piece (**Set II**). Fibers in **Set I** were used to measure the attenuation length of the fibers and were processed in Lisbon but not aluminized. Fibers in **Set II** were polished in a milling machine with a diamond blade and aluminium coated at one end. The other end was polished at CERN. From this set 10 were cut and polished at 90º with the axis of the fiber and the other 10 the end to be aluminized has been cut at 45º. The reflectivity of the aluminium mirror has been measured in a dedicated test bench. Preliminary results give a value of reflectivity of 51% for the fibers with a 90º cut.

1. Material

A sample of squared 25 cm long, $0.5\times0.5\ \text{mm}^2$, SCF-3HF, optical scintillating fibers from Kuraray. The fibers were stacked inside a trapezoidal acrylic piece in order to be cut at 90º or 45º with the axis of the fibers. Several transparent polystyrene plates have been also used for the aluminization tests.

2. Polishing

The tests have started with dedicated polishing and aluminization by magnetron sputtering machine [1, 2]. Because of the special shape of the fiber support it was necessary to adapt the table of polishing. A direct visual examination of polishing was considered quite satisfactory and, for the moment, no measurement of the quality of the polished surface was done.

3. Aluminization

A dedicated machine for aluminization by magnetron sputtering was used for the TileCal WLS fibers and will be used in future work for this task. This machine has not been used for more than one year and when starting up the operations the cathode was not working properly. So, while we wait for a new cathode, and due to the urgency of the request, another aluminization by magnetron sputtering machine was used. However, the aluminium target in this machine was standard aluminium and not 99.999% pure aluminium as used for the WLS fibers for TileCal. The operation conditions (pressure, discharge time, distance target-fiber) were not optimised. A direct visual examination of aluminization has shown a reasonable quality of the aluminium mirror. Two transparent polystyrene plates from commercial CD boxes without any special polishing were aluminized.

4. Measurement of fiber light output and reflectivity

4.1. Testbench

A dedicated test bench for the measurement of the optical characteristics of optical WLS and scintillating fibers was used [4-7]. The main components of this test bench are: a black box with a precision x-y table (about 25μm transversal and about 1mm longitudinal), an EMI 9813B PMT with a Plexiglas light guide, read by a Keithley 480 Picoameter and a UV light source peaking at 375 nm. The scan of the fibers with the light source was made in both transversal and longitudinal directions.

4.2. Preliminary results

4.2.1. Squared scintillating fibers

Set I (9 Isolated fibers)

A set of 9 single fibers was measured in steps of 2 cm in order to extract an attenuation length and determine the reflectivity of the aluminized fibers. Experimental data were fitted to an exponential as:

$$I = I_0 e^{-\frac{x}{L_{at}}} \qquad (1)$$

where **I(x)** is the light output when the fiber is excited by the light source at the distance **x** from the photomultiplier and **Lat** is the attenuation length. The results are shown in Fig. 1 and an attenuation length of (73.0 ± 6.2 cm) is obtained.

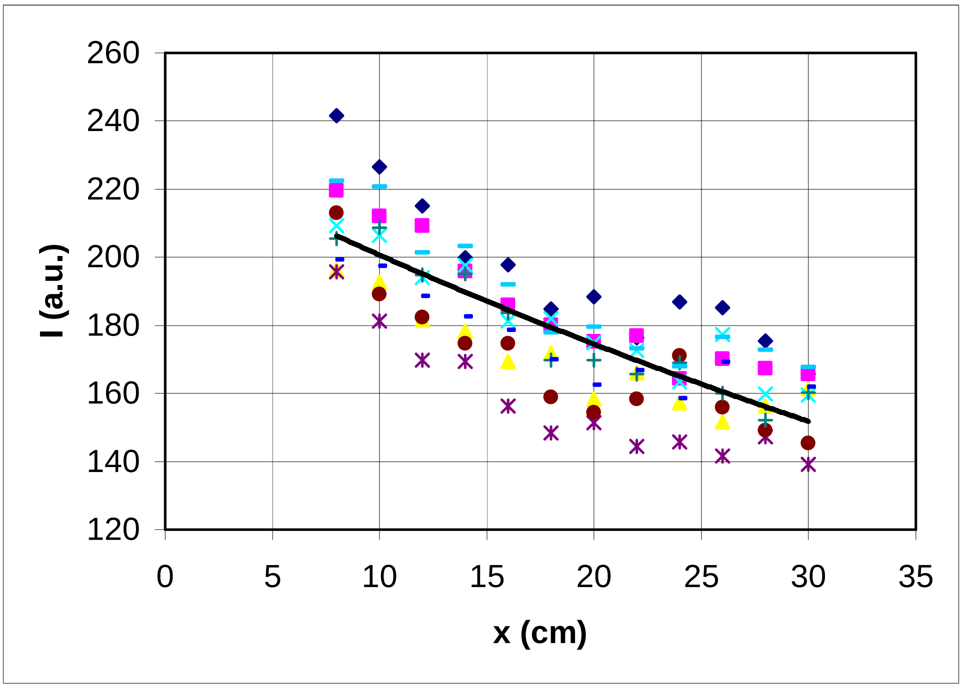

Figure 1: Fibers response to UV light source versus distance to the photomultiplier. The line represents the exponential function obtained with a fit to the points of a typical fiber.

Set II (20 fibers glued to acrylic piece)

The light output of the sets of the 10 stacked fibers was measured before and after the aluminization. The results are shown in figure 2. We should note that the fibers are glued at the aluminized end and so the measurement of the reflectivity of the mirror of the single fibers was not possible.

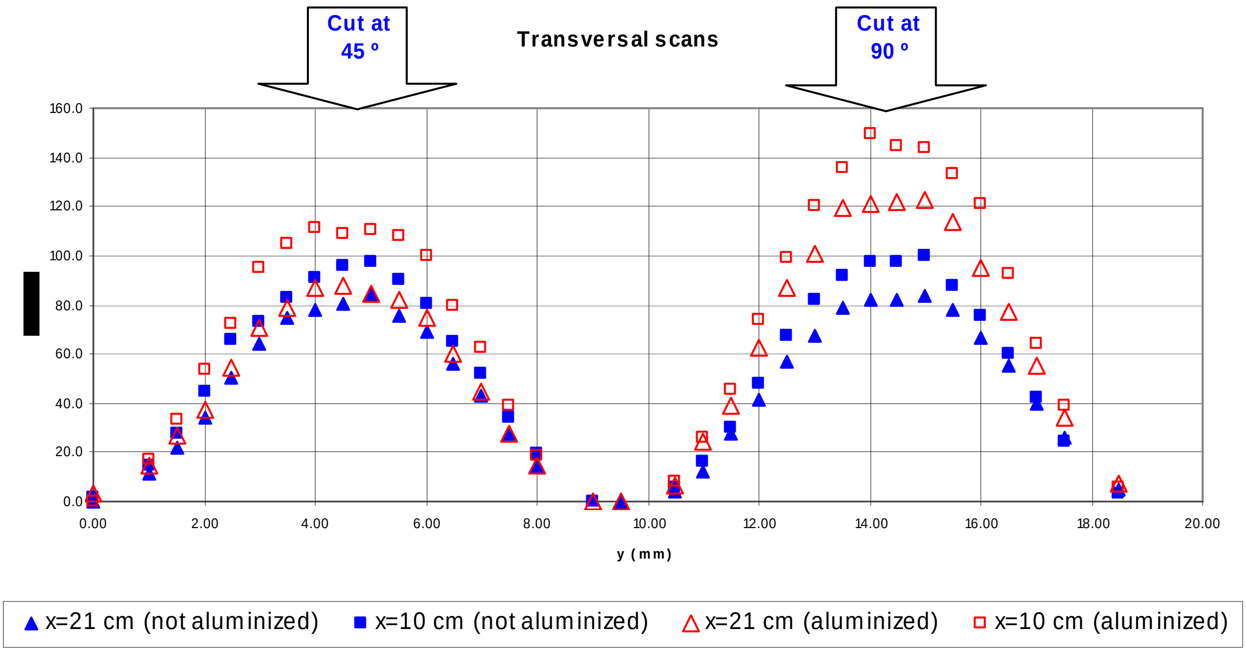

Figure 2: Response of fibers (Set II) to UV light before (*closed markers*) and after (*open markers*) the aluminization versus transversal position of the light source.

The results are presented in Table 1.

	I (Arbitrary Units)			
	Fibers cut at 90º		Fibers cut at 45º	
x (cm)	Not Aluminized	Aluminized	Not Aluminized	Aluminized
10 cm	99	146	97	113
21 cm	85	124	82	90

Table 1: Light output I of fiber for an excitation source at distance *x* to the entrance of the PMT light guide

For non-aluminized fibers the light output response is nearly the same as for the cut at 90º and at 45º. For the ones with a cut at 90º a ratio between the light output for aluminized and non-aluminized fibers of 124/85 at x = 21 cm was obtained. Meanwhile, for the fibers cut at 45º this ratio is much lower: 90/82. From the results at 10 cm and at 21 cm for non-aluminized fibers, considering an exponential decreasing of the light with distance as in **Eq. 1** effective attenuation lengths of 72 cm, for the fibers cut at 90º, and 69 cm, for the fibers cut at 45º, were obtained. Note that these values are consistent with the value obtained for the set of single fibers scanned in the longitudinal direction. Using these values and the ratio of the light output of the aluminized fibers to the non-aluminized fibers near the aluminium mirror ($x = 21$ cm) a reflectivity of 51% was obtained for the fibers cut at 90º. For the fibers cut at 45º a reflectivity of 9.6% was obtained. We should emphasise that we are assuming the response of one individual fiber for extrapolating the response of a set of ten fibers glued near the mirrored end by about 2 cm.

4.2.2. Polystyrene plates

The reflectivity of the mirror was measured and a reflectivity of about 50% was obtained for a wavelength of 530 nm (the wavelength of maximum emission for the squared SCF-3HF fibers [3]. Future tests will be done with polished plates. The results are shown in Fig. 3.

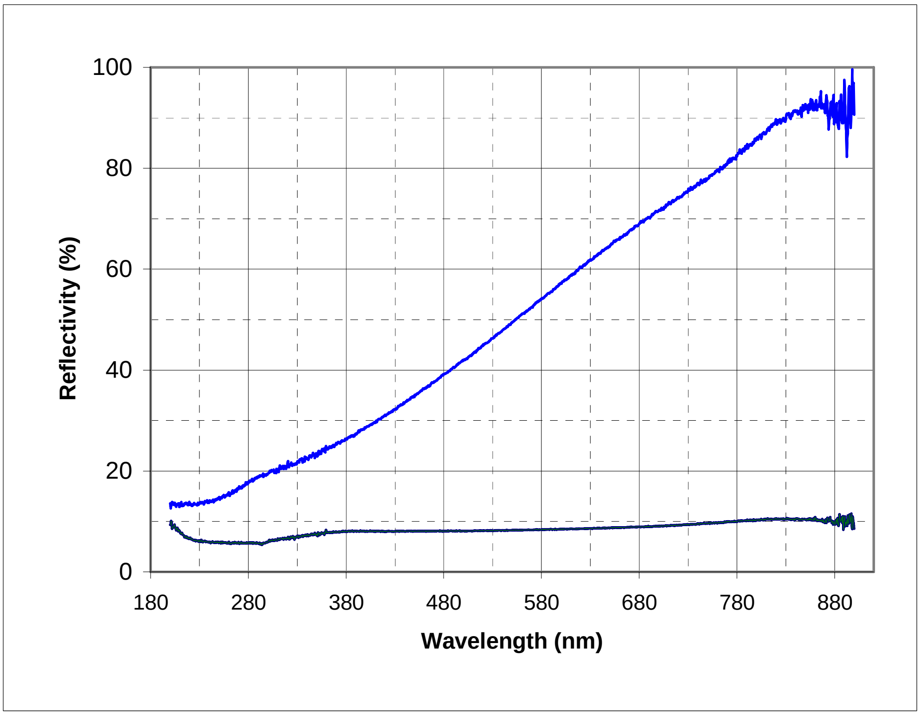

Figure 3: reflectivity of polystyrene plate before (green) and after (blue) the aluminization

5. Future work

The purchase of a new cathode is under way. The design of a new set-up for the support of the fibers that allows an adequate polishing started. In our understanding these preliminary results (reflectivity of 51%) are rather satisfactory for the conditions reported above. The factors that could contribute to this low value of the reflectivity might be the impurities of the aluminium target and the packing of the fibers. However, the results are far from a reflectivity of 75% obtained for the WLS fibers of TileCal. An R&D phase was necessary in order to optimize the polishing and aluminization of this special set of fibers.

6. Aknowledgements

To Andre Braem for the supply of fibers.

7. References

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