Literature study on the radiation damage on KURARAY SCSF-78M and SCSF-78MJ fibers

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1 Introduction

On the following pages a short summary of different publications concerning the radiation damage of Kuraray SCSF-78M and SCSF-78MJ fibers is given. The fibers that were interesting us are the SCSF-78MJ but most studies found have been done on SCSF-78M fibers, although it seems that the SCSF-78MJ has been developed to improve radiation hardness [1]. As it can be seen the results found on this subject are very diverse and no good conclusion can be drawn just from literature study. There are for example results showing that there is no radiation damage at all after 1Mrad of irradiation [2] and others saying that light output losses up more than 50% can be seen [3]. Some found that there is no influence of the surrounding material [4] and [5] and others detected a big dependance on the milieu the fiber is in during irradiation [6]. Some publications claim that the type of irradiation (proton, electron, γ...) has no influence on the damage observed [5]. As much as they seem to disagree on the irradiation damage, they almost all detect a strong recovery after a certain time [4], [5] and [7] no recovery within 40 days was only found in [6]. The attenuation length of the fiber SCSF-78MJ was found to be $150\text{cm}$ [1], $351\pm 17\text{cm}$ [8] or in [9] and [10] they find a two component attenuation length of $\lambda_0 = 126\pm 22\text{cm}$ and $\lambda_1 = 756\pm 194\text{cm}$. A very detailed study on the attenuation length is done in [11] and a average value of $\approx 400\text{cm}$ was found. On the next page the few characterizations of the fibers are given with the references. In order to highlight the basic information of each paper, some extracts are shown further down.
2 Characterization

- **No radiation damage (if no other notation, received dose: 1Mrad):** [3] (between 10 and 40 kGy), [7] ("SCSF-78M seems to be radiation hard up to 1Mrad")

- **Small radiation damage (less than 20% light loss):** [1] (only light emission tested not transparency, tested on SCSF-78MJ), [4], [12], [5] (for high rate irradiation)

- **High radiation damage (more than 20% light loss):** [6] (after 3Mrad), [3], [5] (for low rate irradiation)

- **Complete recovery:** [4], [5]

- **Partial recovery:** [6] (glued in white acrylic), [3], [7]

• Kuraray SCSF-78M after 1 Mrad of pions at 146 MeV → No damage within 10% error marge.

• Scintillating mechanism seems to be radiation hard.

• Aging of fibers see figure 1. One should cool the fibers.

• Strong annealing.

![Figure 1: Slide on aging of the fibers.](image)


• SCSF-78M
• Diameter of fiber: 740µm

• Experiment done with an electron gun (Sr source).

• Irradiated with a strong $^{60}\text{Co}$ source (measure of light yield taken 2h later).

• Tested fibers of Kuraray, Bicron and PolHiThech. Kuraray SCSF-78M turned out to have the best light yield and relatively radiation hard (not as radiation hard as 3HF fibers who have much lower light yield).

• SCSF-78M lose about 36% of their light yield after 3Mrad.

• No recovery was observed 40 days after fast irradiation. The fibers were partially glued and air was allowed to circulate.

• They observed a larger damage for fibers in white acrylic glue but those fibers recover partially within 60h.

• No irradiation rate dependency could be observed between 100Krad/day and 1Mrad/day.

• No difference in the damage due to proton, electron or $\gamma$ radiation was found.

• The experiments in the lab with a source overestimated the number of photoelectrons compared to testbeam.

Figure 2: Extract of some figures from the Dreiss-paper [6].

- Diameter of fiber: 500µm
- They used 70MeV protons to irradiate the fibers to 1Mrad.
- Damage of scintillation and of transmission was observed.
- They reported a recovery time of up to 600h.
Summary of literature study

Figure 3: Light output after irradiation as given in Aschenauer [3].


- SCSF-78M
- Diameter of fiber: 500µm

- States in his long introduction that all types of results have been measured, e.g. on the effect of different irradiation particles: some papers state that there is no difference in damage others found a dependence between damage and radiation type.

- Used 146MeV pions between 10 and 40 kGy.

- No irradiation damage found within 10% error.

- Mesures with SCSF-78MJ fibers of 1mm diameter.

- They have a measured attenuation length of about 150cm.

- At 10Mrad only a loss of 15% on the scintillating effect was measured.

- Fibers were irradiated at the Erlangen tandem accelerator.

- For clear fibers the attenuation length went from 400cm down to 120cm at the same conditions.

Figure 4: Irradiation effect on scintillating and clear fibers as given in Bisplinghoff [1].

- SCSF-78M
- Diameter of fiber: unknown.

- Tests done with 70MeV protons and 2MeV electrons with irradiations between 0.9 and 16.2Mrad.

- Separated measures of scintillator efficiency and optical absorption have been done.

- Homogeneous energy deposition during irradiation was measured. (Range of 39mm for protons and 9mm for electrons)

- No difference between the damage of proton and electron irradiation was detected.

- The discovered the interesting fact that the output intensity decreases rapidly for higher irradiations (about 1-3Mrad). See figure 5.

- The fiber seems to be more damaged for the shorter wavelength part of the output.

- For short time irradiation with less than 1Mrad total recovery has been observed.

9  A. Mapelli "ALFA - Absolute Luminosity For ATLAS (a scintillating fiber tracker)" Poster 2009 [12]

- Kuraray SCSF-78, S-type, 0.5 × 0.5 mm2 square section, single cladded
Summary of literature study

Figure 5: The two step exponential decrease of the light emission measured by Klose [4].

- Diameter of fiber: unknown.

- Used 26GeV protons for irradiation and a $^{90}\text{Sr}$ source for measures.

- At 1Mrad he measures about 15% loss.


- SCSF-78M

- Diameter of the fiber: from 0.25 to 0.5mm.

- The fibers were exposed to a $^{106}\text{Ru}$ source ($e^{-}$ of 3.54MeV) or with 70MeV protons up to 1Mrad at high rate.

- Separate measure of scintillator and transparency damage was possible.
Summary of literature study

- scintillator efficiency loss of 20-80% and light transmission loss of 20-70%.

- Very good recovery was detected.

- The SCSF-78M fiber seems to be radiation hard up to 1Mrad.

<table>
<thead>
<tr>
<th>Material</th>
<th>λ(SF)</th>
<th>Specialties</th>
<th>Irradiation</th>
<th>Dose at 10 - 20 cm</th>
<th>Damage (%) at 10 - 20 - 25 cm</th>
<th>Recovery to 90 %</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>BCF-12</td>
<td>430</td>
<td>glue</td>
<td>spot</td>
<td>6.4 / 1.4 Mrad</td>
<td>72 - 82 - 60</td>
<td>600 h</td>
<td>T and S damaged</td>
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<td>no glue</td>
<td>spot</td>
<td>6.4 / 1.4 Mrad</td>
<td>62 - 62 - 68</td>
<td>600 h</td>
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<tr>
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<td>glue</td>
<td>spot</td>
<td>6.4 / 1.4 Mrad</td>
<td>78 - 76 - 60</td>
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<td>63 - 63 - 68</td>
<td>&gt; 600 h</td>
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<td>profile</td>
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<td>profile</td>
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<td>95 - 89 - 89</td>
<td>160 h</td>
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<tr>
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<td>spot</td>
<td>6.4 / 1.4 Mrad</td>
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<td>no glue</td>
<td>spot</td>
<td>6.4 / 1.4 Mrad</td>
<td>70 - 100 - 85</td>
<td>400 h</td>
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<tr>
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<td>spot</td>
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<tr>
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<td>spot</td>
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<td>100 - 99 - 94</td>
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<td>150 h</td>
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<td>spot</td>
<td>6.4 / 1.4 Mrad</td>
<td>80 - 78 - 100</td>
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<td>glue</td>
<td>profile</td>
<td>0.2 - 1.2 Mrad</td>
<td>100 - 100 - 100</td>
<td>0 h</td>
<td>no damage at all</td>
</tr>
</tbody>
</table>

Table 1: Results on the proton irradiation damage to the different scintillating fiber materials.

Figure 6: The irradiation damage as given by Aschenauer [7].


- SCSF-78M
- Diameter of the fiber: 0.48mm
Summary of literature study

- Experiments were done with 70MeV protons, 2MeV electrons and $^{60}$Co photons.

- Irradiated with more than 1Mrad at 20cm and with 0.1Mrad at 10cm at a rate of 30Mrad/h.

- Other irradiations were done with low rate electron irradiation up to 1Mrad (5 steps during 9 weeks).

- In high rate irradiation experiment a clear damage was detected (20%) but the fibers recovered.

- In lower rate irradiation experiment the light output of the scintillating fibers decreased for up to 30%.

- No influence of coverage (glue etc) or atmosphere during the irradiation was detected.

- No difference between proton and electron damage was detected.

- Strongest damage 30h after irradiation but complete recovery after 2 days.

- 1.4Mrad irradiation within 70 days caused up to 25% loss of light output. (30% error)

- When measured with a light guide, up to 60% loss of light output can be detected (maybe due to browning of optical glue?). (30% error)
Summary of literature study

Figure 7: The emission spectrum during electron irradiation as given by Aschenauer [5].

Fig. 5. In-situ measurement of the emission spectra of a scintillating fiber excited by high dose rate electron irradiation in dependence on the irradiation time in seconds.
Figure 8: The time dependence of the light output during and after irradiation as given by Aschenauer [5].
Summary of literature study

References


