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Radiation tests ASTRO-H reference samples at ESA

Purpose of the study.

The purpose of this study is to check the radiation resistance of a set of 10x10x40 mm BGO reference crystals used for cutting Astro-H crystals on their radiation resistance against Co-60 gamma rays. These samples were tested at NICC on their resistance against hard UV light.

Experimental

The samples were packed in aluminized plastic and heat sealed after which they were delivered to ESA on April 4,2012. The test report at the ESA radiation facility is attached to this report. In addition to the 10 reference crystals from NICC, two other standard BGO crystals were irradiated and tested : A 35 mm diameter, 38 mm high BGO crystal from NICC and an 51x51 mm crystal from Chinese supplier.

The reference crystals serial numbers and NICC code are as follows :

Sample Code	Serial	UV testresult NICC
1	GA8-204-2	3.2 %
2	GA8-206-2	2.8 %
3	GAL10-338-2	3.5 %
4	GAAL10-331-2	2.1 %
5	GAL10-341-2	2.1 %
6	GAL10-344-2	3.4 %
7	GAL14-131-2	3.0 %
8	GAL15-161-2	2.0 %
9	GAL16-98-2	1.6 %
10	GAL16-104-2	4.3 %
11	51x51 mm Test	n.a.
12	35x38 mmtest NICC	n.a.

Before irradiation all crystals were tested on light output by wrapping them with reflective teflon tape and mounting them with optical grease on the phase plate of a Hamamatsu R1307 PMT. A 662 keV 137 source was mounted on the far end and the peak location of the 662 keV peak was recorded for each crystal. As a reference the BGO crystal with code 9 which was not irradiated was selected and every time the peak was adjusted to the same channel. As a comparison, sample code 10 (also not irradiated) was tested just all the irradiated crystals.

Irradiation Scheme

All crystals EXCEPT sample 9 and 10 were irradiated at the ESA 60-Co facility in the Netherlands between April 5 and April 11. The crystals were subjected to the following doses :

To achieve this the crystals were mounted at different distances from the Source

	Total Dose	**Distance from source**
Crystals 1,2,3	10 kRad	556 cm
Crystals 4.5,6	23 kRad	393 cm
Crystals 7,8	50 krad	250 cm
Crystal 9,10	NONE	n.a.
Crystals 11,12	20,4 kRad	392 cm

The irradiation took place over a period of approx. 5 days

RESULTS

We have tested the Light output of the crystals at two four different times after Irradiation : 2 days, 7 days, 14 days, 21 days.

Crystals 4,5,6 and 6 were per mistake not shipped to SCIONIX and received 3 kRad more than intended and then crystals 11 and 12 received. These crystals were only received on 17-4.

In the table below the peak locations of the crystals are shown. One can see that there is a spread in the peak location of the 10 reference crystals between channel 696 and channel 747 which is between -3.4-+3.7 % from the average of 720. This is typical for the material. It should be noted that The estimated measurement error is +-2 %.

20 kRad Irradiated samples 12,4 and 11 (from left to right)

Sample	Dose	Before	13-4	18-4	25-4	2-5
1.	10 kRad	725	695	728	729	721
2.	10 kRad	712	662	682	704	717
3.	10 kRad	747	706	738	725	727
4.	23 kRad	732	---	639	647	696
5.	23 kRad	730	---	663	702	705
6.	23 kRad	739	---	661	681	721
7.	50 kRad	696	598	656	665	666
8.	50 kRad	704	606	635	713	656
9.	0 kRad	712	711	712	713	713
10.	0 kRad	701	685	714	723	705
11.	20 kRad	716	266	288	284	276
12.	20 kRad	819	747	782	808	810

Note the very strong decrease in light output of the **Chinese crystal sample 11** which turned brown/pink after 20 kRad

Below the absolute percentage of light output for each crystal relative to that before its irradiation and the relative degradation after three weeks is shown for all crystals

Sample	Dose	Before	13-4	18-4	25-4	2-5	Recovery
1.	10 kRad	100	95.8	100.4	100.6	99.5	(-0.5 %)
2.	10 kRad	100	93.0	95.8	98.9	100.7	(+0.7 %)
3.	10 kRad	100	94.5	98.9	97.0	97.3	(-2.7 %)
4.	23 kRad	100	---	87.2	88.9	95.2	(-4.8 %)
5.	23 kRad	100	---	87.3	96.1	96.5	(-3.5 %)
6.	23 kRad	100	---	89.4	92.1	97.6	(-2.4 %)
7.	50 kRad	100	85.9	94.3	95.5	95.7	(-4.3 %)
8.	50 kRad	100	86.0	90.2	101.3	93.1	(-6.9 %)
9.	**0 kRad**	**100**	**100**	**100**	**100**	**100**	**Reference**
10.	0 kRad	100	97.7	101.8	103.1	100.6	(+0.6 %)
11.	50 kRad	100	37.0	40.0	40.2	39.7	(-60 %)
12.	50 kRad	819	91.2	95.5	98.7	98.8	(-1.2 %)

CONCLUSION.

We can conclude that the with 10 krad irradiated samples at the lowest dose rate show 100 % recovery within the error after three weeks. The 20 krad irradiated samples recover within 2.4 and 4.8 % after three weeks and the 50 krad irradiated samples show between 4.3 and 6.9 % damage which is expected to recover after some more time.

The reference crystal from NICC behaves the same as the 23 kRad Astro-H samples And the Chines crystal shows a very large damage and almost no recovery.

The samples comply with the Astro-H requirement where a maximum dose of 20 kRad is expected over the 5 year life time of the instrument.

It has been demonstrated that all samples that show UV damage less than 5 % show also less than 5 % Co-60 damage assuming a receioer time of 3 weeks.

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