



## Result of 18 2021 BTL LYSO Bars after Proton Irradiation at ITA

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## 36 BTL LYSO Bars

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ID	Dimension (mm <sup>3</sup> )	#	Polishing
BTL LYSO-907~1079	3.00×3.12×56.3	36	All faces

All samples received on April 6th, 2021 (Tuesday)

Sent to ITA: 4/30/20, 1.4/2.2×10<sup>13</sup> p/cm<sup>2</sup>: 6/16/21, back to Caltech: 7/22/21

#### **Experiments**

Longitudinal transmittance (LT), light output (LO) and decay time ( $\tau$ ) measured before and after 1.4/2.2×10<sup>13</sup> p/cm<sup>2</sup> for samples wo/w ESR

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# LYSO Bar Sample Cross Link



#### 18 each with odd/even ID: proton/neutron irradiation at ITA/Lowell

	Caltech ID	Barcode	Producer	Test		Caltech ID	Barcode	Producer	Test
	1	907	1	Proton		ESR 1	916	1	Proton
	2	908	1	Neutron		ESR 2	917	1	Neutron
	3	927	8	Proton		ESR 3	936	8	Proton
	4	928	8	Neutron		ESR 4	937	8	Neutron
	5	947	5	Proton		ESR 5	956	5	Proton
	6	948	5	Neutron		ESR 6	957	5	Neutron
	7	967	10	Proton		ESR 7	976	10	Proton
	8	968	10	Neutron		ESR 8	977	10	Neutron
	9	987	3	Proton		ESR 9	996	3	Proton
	10	988	3	Neutron		ESR 10	997	3	Neutron
	11	1007	9	Proton	i	ESR 11	1016	9	Proton
ſ	12	1008	9	Neutron	1	ESR 12	1017	9	Neutron
	13	1027	6	Proton		ESR 13	1036	6	Proton
	14	1028	6	Neutron		ESR 14	1037	6	Neutron
	15	1047	4	Proton		ESR 15	1056	4	Proton
	16	1048	4	Neutron		ESR 16	1057	4	Neutron
	17	1067	2	Proton		ESR 17	1078	2	Proton
	18	1068	2	Neutron		ESR 18	1079	2	Neutron

#### Sample 11 without ESR broken to two pieces after irradiation

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# **Error Weighted Average Fluence**



Fluence: error weighted average of Be-7 & Na-22 from activated Al foils 9 LYSO bars each with/without ESR were in G1/G2, Liyuan's 3/18/22 report

Group	Front EW Avg Fluence (cm <sup>-2</sup> )	± Error (cm <sup>-2</sup> )	Back EW Avg Fluence (cm <sup>-2</sup> )	± Error (cm <sup>-2</sup> )	Average Fluence (cm <sup>-2</sup> )	± Error (cm <sup>-2</sup> )
1	2.16E+13	7.2E+11	1.59E+13	6.9E+11	1.88E+13	5.0E+11
2	1.43E+13	6.8E+11	9.49E+12	7.1E+11	1.19E+13	4.9E+11
3	1.91E+13	7.6E+11	1.30E+13	7.5E+11	1.61E+13	5.3E+11

#### Fluence: 2.2, 1.4 and 1.9×10<sup>13</sup> respectively for G1, G2 and G3

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### EWLT & EWLT: 9 2021 Bars w/o ESR



#### Radio-luminescence weighted longitudinal transmittance (EWLT) Radiation induced absorption coefficient (EWRIAC)



Transmittance of Sample 11 was corrected by additional bouncings at the boundary

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### EWLT & EWLT: 9 2021 Bars with ESR



Radio-luminescence weighted longitudinal transmittance (EWLT) Radiation induced absorption coefficient (EWRIAC)



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# LO: Nine 2021 Bars w/o ESR



LYSO bars with Teflon block wrapping and an air gap coupling to an R1306 PMT triggered by a Na-22 source at the center



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# LO: Nine 2021 Samples with ESR



LYSO bars with ESR wrapping and an air gap coupling to an R1306 PMT triggered by a Na-22 source at the center



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# Light Output vs EWLT & EWRIAC



Good correlations between LO, EWLT and EWRIAC indicate that LO loss is due to radiation induced absorption with a mean light path of 9 cm



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### EWRIAC scaled to $2.5 \times 10^{13}$ p/cm<sup>2</sup> *RIAC* $\propto$ Fluence

1.6 m<sup>-1</sup> & 1.0 m<sup>-1</sup> for without & with ESR after  $2.5 \times 10^{13}$  p/cm<sup>2</sup> Average ESR effect is -0.6 m<sup>-1</sup>: ESR induced damage is negligible







# LO/ $\tau$ scaled to 2.5 $\times$ 10<sup>13</sup> p/cm<sup>2</sup>



-13.2% & -13.1% for bars without & with ESR after 2.5×10<sup>13</sup> p/cm<sup>2</sup> Average ESR effect is <1%: ESR induced damage is negligible



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### Summary



LT, EWRIAC, LO and  $\tau$  were measured for 18 BTL LYSO bars without and with ESR wrapping after 1.4 & 2.2×10<sup>13</sup> p/cm<sup>2</sup> at Fermilab ITA.

Proton induced LO loss is due to induced absorption with 9 cm path length, consistent with  $\gamma$ -ray & neutron induced damage.

LYSO bars from nine vendors show good consistency. The average variation of EWRIAC, LO and LO/ $\tau$  scaled to 2.5×10<sup>13</sup> p/cm<sup>2</sup> is 1.6/1.0 m<sup>-1</sup>, -13.6/-12.1 % and -13.2/-13.1 % respectively for 9 LYSO bars each without/with ESR with an overall consistency of 0.7/0.5 m<sup>-1</sup>, 11.9/17.6% and 9.4/18.3%.

Proton-induced damage in time resolution is ~7% for LYSO bars with and w/o ESR, indicating a negligible ESR effect. A larger divergence was observed for LYSO bars with ESR as compared to without ESR. A uniformized ESR wrapping would help.

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