

X- Beam Test

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Requirements for the use in CMS

optical effectiveness as coupling medium

critical angle

absorption

1) $n_{\text{glue}} \geq n_{\text{epoxy}} = 1.57$ (APD_window)

2) absorption length $\gg 0.3$ mm

3) Good mechanical adhesion with PWO, APD and capsule.

4) Chemical compatibility with APD

5) No degradation of light collection and mechanical adhesion along 10 years of CMS running:

- radiation hard
- negligible ageing
- no disjunction or air bubbles formation

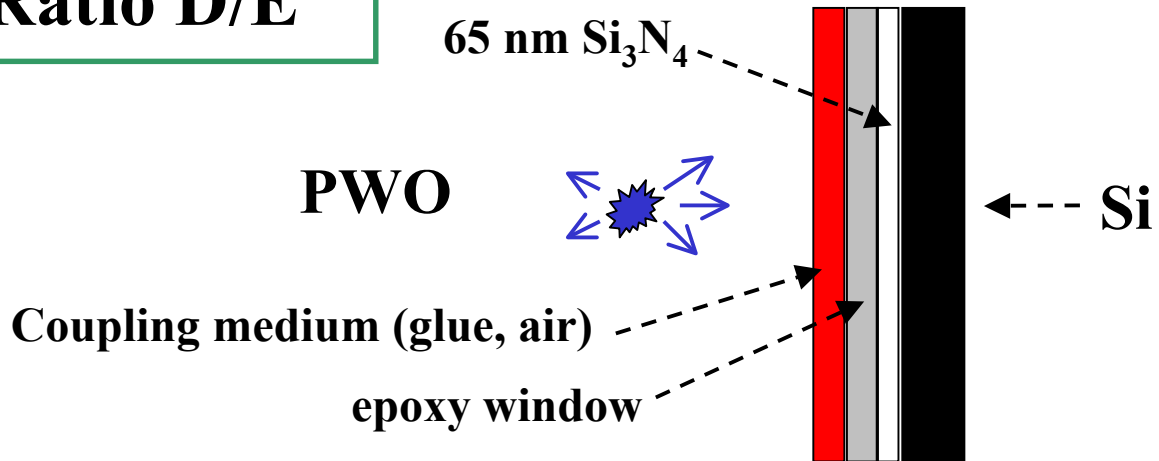
Considered glues for CMS (January 01)

product	$n @ 430 \text{ nm}$ ± 0.01	$\langle \Lambda \rangle$ (cm)	D/E (0.3 mm) (%)	D/E (1 mm) (%)	D/E (0.3 mm) epoxy window (%)
Histomount	1.63	> 10	12.0	12.0	11.2
3145	1.49	1.44 ± 0.06	9.4	9.1	9.4
NOA 61	1.59	0.55 ± 0.01	11.3	10.9	10.9
UV6114	1.60	0.371 ± 0.009	11.0	10.4	10.7
Melmount 1.582	1.60	6.8 ± 1.5	11.4	11.4	11.1
Melmount 1.704	1.73	0.10 ± 0.01	12.8	11.6	10.3
Naphrax	1.80	0.086 ± 0.003	13.8	11.1	9.7
TSE 3250	1.47	> 30	9.4	9.4	9.4
615	1.47	> 15	9.4	9.4	9.4
301	1.57	2.8 ± 0.3	10.9	10.7	10.9
301-2	1.60	> 10	11.5	11.5	11.1
302	1.62	0.466 ± 0.009	11.5	10.6	10.8
X-38-406	1.53	> 25	10.3	10.3	10.3
Epoxy	1.57	12 ± 6	10.9	10.9	10.9

~~not suitable~~

~~not rad hard~~

Ratio D/E



$$\frac{D}{E} = \frac{1}{2} \frac{\int_0^{\pi/2} d\theta \int_{330}^{615} d\lambda \frac{1}{2} [T_p(\lambda, \theta) + T_s(\lambda, \theta)] \text{IQE}(\lambda) S(\lambda)}{\int_{330}^{615} d\lambda S(\lambda)}$$

where

λ wavelength, θ incidence angle

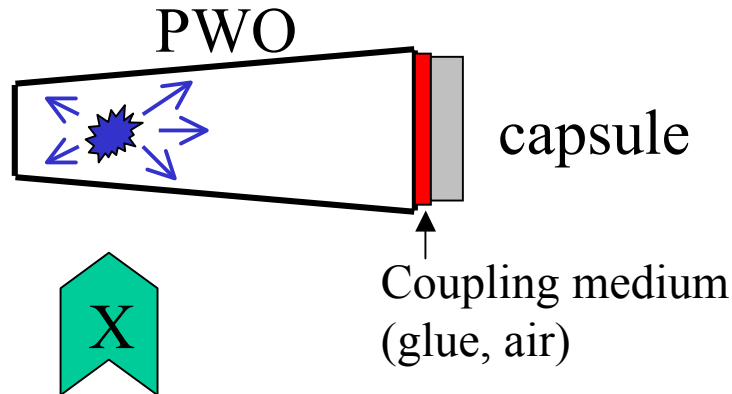
$\text{IQE}(\lambda)$ internal quantum efficiency of the APD

$S(\lambda)$ PWO scintillation spectrum

$T_p(\lambda, \theta), T_s(\lambda, \theta)$ p and s-polarised transmittance PWO $\rightarrow$ Si
calculated with the optical constants of the crossed materials

Coupling medium	$n @ 430 \text{ nm}$	$\langle \Lambda \rangle$ (cm)	D/E (%)	η
air	1	$\gg 10$	3.50	1
Histomount	1.63	>10	11.19	3.2
DC3145	1.49	1.44 ± 0.06	9.39	2.7

X-Beam Test



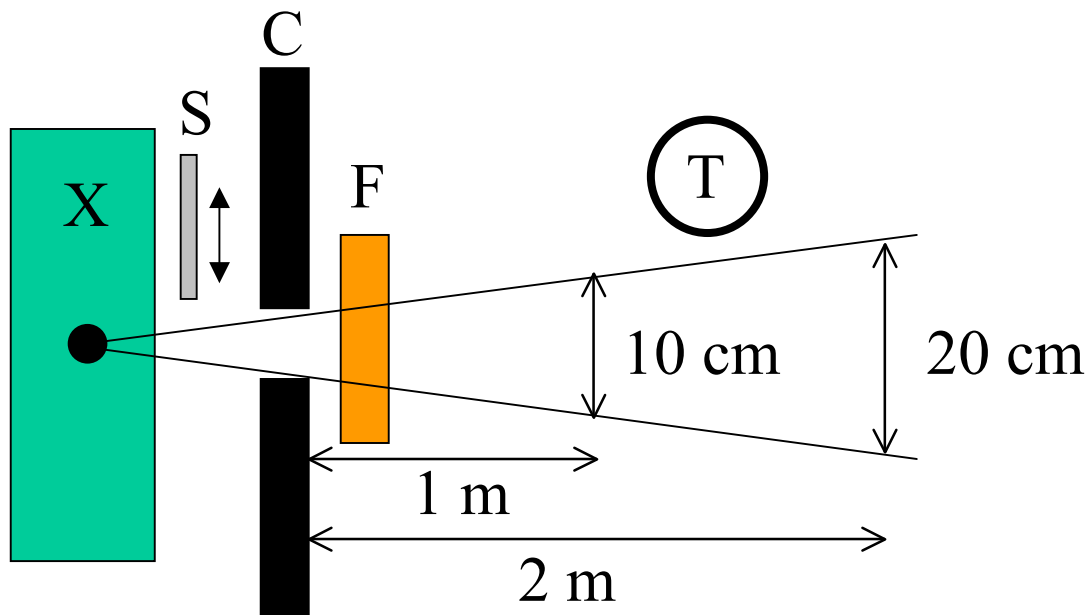
$$\eta = \frac{signal_{glue}}{signal_{air}} = \frac{(D/E)_{glue}}{(D/E)_{air}}$$

The “X-beam Test” allows the experimental validation of the prediction

$$\rho = \frac{\eta_{Histomount}}{\eta_{DC3145}} = \frac{(D/E)_{Histomount}}{(D/E)_{DC3145}} \sim \frac{11.19}{9.39} = 1.192$$

X ray source at ENEA-Casaccia

(National Institute of Metrology of Ionising Radiations)



C = collimator

F = Filter

T = thermocouple

S = shutter

X = X ray tube (CHF 320G Gilardoni)

- absolute measurement of dose and dose-rate
- energy spectrum
- beam qualification
- precise alignment of the sample (optical)

precise reproduction of the irradiation conditions

dose-rate < 1%

sample position < 0.1 mm

Operational conditions

APD voltage supply

30 V to avoid gain fluctuations (**$M \sim 1$**)

Readings:

- current by picoammeter (Kithley 485)
- output voltage by DAQ (NI 16XE50) and PC

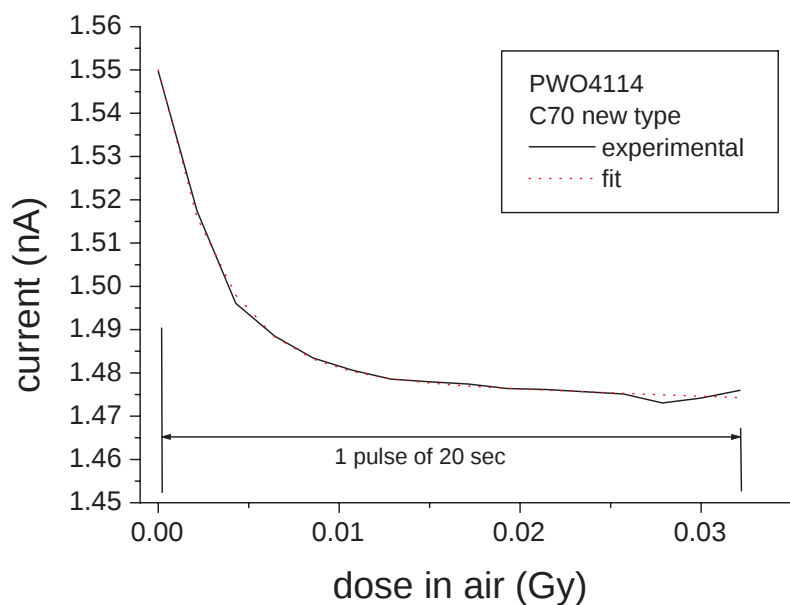
$\sigma \sim 0.02 \text{ nA}$

Signal $\sim \text{nA}$ with:

- X-tube alimentation: 250 kV, 10 mA
- filter P8, Be(3mm) + Al(4.06mm) + Cu(0.51mm)
- at 1m from the source ($\varnothing = 10 \text{ cm}$)

$\langle E \rangle \sim 100 \text{ keV}$ dose-rate (air) $\sim 1.5 \cdot 10^{-3} \text{ Gy/s}$

Damage & Systematic



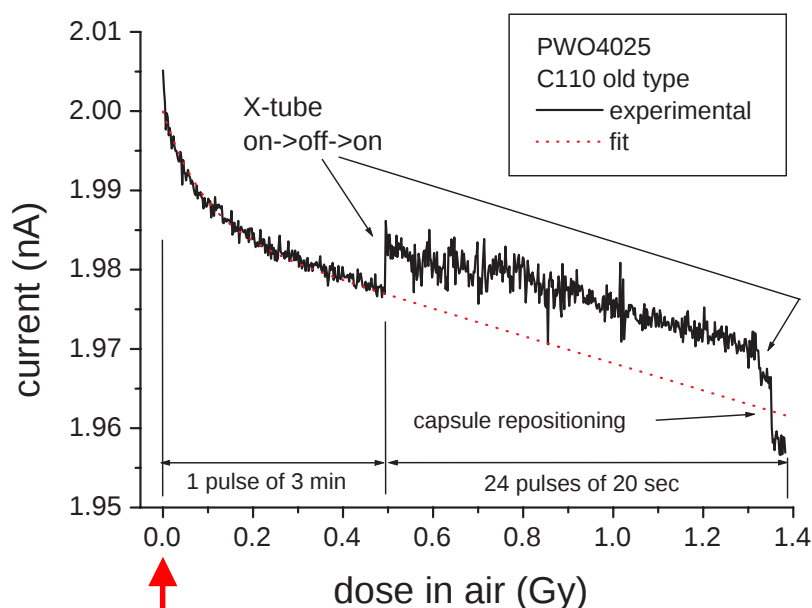
$$P1 = 1.479 \pm 0.001$$

$$P2 = 0.07 \pm 0.002$$

$$P3 = 0.0033 \pm 0.0001$$

$$P4 = 0.15 \pm 0.05$$

$\Delta = -4.9 \%$
(fast $\sim -4 \%$)



$$P1 = 1.9853 \pm 0.0002$$

$$P2 = 0.0145 \pm 0.0004$$

$$P3 = 0.095 \pm 0.005$$

$$P4 = 0.0171 \pm 0.0002$$

$\Delta = -2.2 \%$
(fast $\sim -0.5 \%$)

the exposure occurred during the very preliminary tests (filter, HV and i) is missing!!!

Damage & Systematic

- X-pulse of 20 sec: allows good signal precision, but causes damage
- **damage** $\sim 10^{-2} \ll \eta \sim 3 \Rightarrow$ does not wash out the gluing improvement but should be taken into account

1) fit with the function

$$y = P1 + P2 \exp\{-x / P3\} - P4x$$

2)
$$\eta = \frac{y_{\text{GLUE}}(x_{\text{START}})}{y_{\text{AIR}}(x_{\text{END}})}$$

- the signal reproducibility is better than **0.4%** for both X-source-switching and capsule-repositioning

Results

#	PWO	Capsule	glue	y_{END} (nA) @ 22 C	y_{START} (nA) @ 22 C	η
R	4025	110 old	/	1.975	2.025	1.025
A	4091	165	Histo	1.648	4.015	2.436
B	4113	100	Histo	1.643	4.050	2.465
C	4114	70	DC3145	1.476	3.040	2.060
D	4115	85	DC3145	1.827	3.758	2.057

- slight recovery (+2.5%) of the reference crystal
- $A \leftrightarrow B$, $C \leftrightarrow D$ good agreement !!!
- $\eta_{\text{EXP}} < \eta_{\text{CAL}}$: because of the depolished surface,

but

$$\frac{\eta_{\text{Histomount}}}{\eta_{\text{DC3145}}} = 1.190 \pm 0.008$$

- No bubbles observed with new capsules (flat APDs) during and after gluing procedure