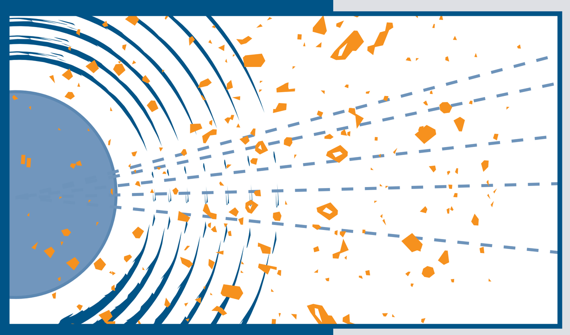
Development of a multi-sensitive element passive dosemeter based on OSL technology for IEC 62387 compliance



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CONTEXT

Why a new dosemeter?

- Evolution of standard for passive dosemetry
  Transcription: IEC 62387-1:2007 → EN 62387-1:2012

norme européenne NF EN 62387-1 Mai 2012

norme française Indice de classement : C 19-113

ICS : 13.280

- Will to improve range of compliance
- Standard evolution anticipated: start of the new dosemeter development in 2011

Requirements

Metrological requirements

- A least: compliant with the EN 62387-1:2012 standard
- At best: better metrological performances than those required

Design requirements

- Technology: Optically Stimulated Luminescence (OSL) with aluminum oxide (Al_2O_3:C)
- Number of sensitive elements: 4
- Dosemeter readable on existing readers
- No modification of the external appearance

Dose range	Mandatory dose range	Dose range expected
$H_p(10)$	0.1 mSv to 1 Sv	0.05 mSv to 10 Sv
$H_p(0.07)$	1 mSv to 3 Sv	0.05 mSv to 10 Sv

Energy Range	Mandatory energy range (average energies)	Energy range expected (average energies)
Beta		
$H_p(0.07)$	0.8 MeV	0.2 MeV to 0.8 MeV
Photons		
$H_p(10)$	80 keV to 1.25 MeV	16 keV to 6 MeV
$H_p(0.07)$	30 keV to 250 keV	16 keV to 1.25 MeV

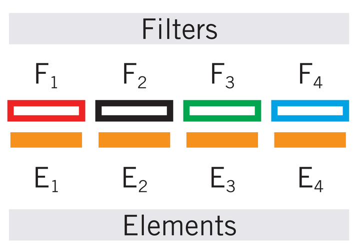
DEVELOPMENT

Dosemeter developed by using Monte-Carlo technique

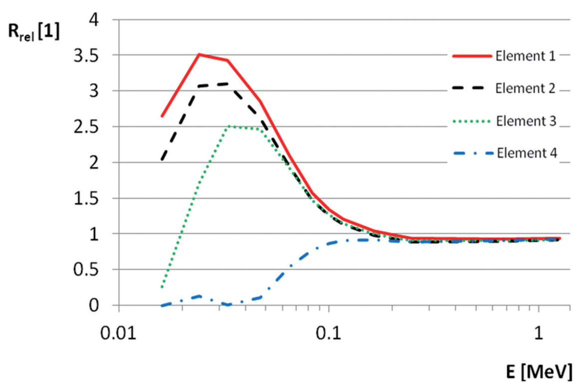
Basic principle of a multi-sensitive element passive dosemeter

- Sensitive material response modulation by using filters

Theoretical dosemeter



Sensitive element response normalized to $H_p(0.07)$ (R_{rel}) for the theoretical dosemeter as a function of photon energy



- Incident beam quality reconstruction by using pattern recognition
- Dose equivalent estimation

Numerous optimization and testing parameters

- Filter material
- Filter geometry
- Filter positionning
- Beam quality

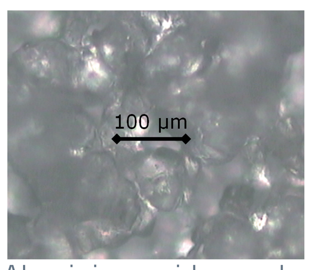
→ Monte-Carlo development

Steps

1st Sensitive elements modelling
2nd Geometrical modelling of the dosemeter and validation of the modelling on the InLight dosemeter with XA case
3rd Optimization of the new GN case

1ST STEP — Sensitive element modelling

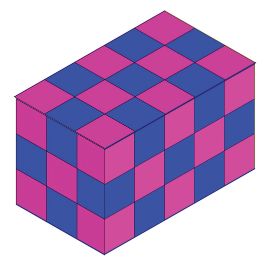
Material



Aluminium oxide powder embedded in plastic

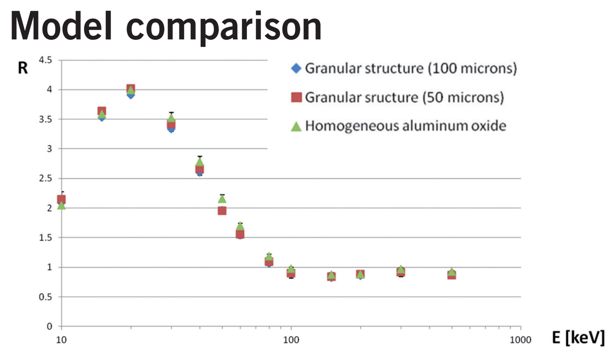
Numerical models

- Granular structure: cubic grains of the same dimensions for the binder and aluminum oxide



- Homogeneous structure: aluminum oxide with adapted density

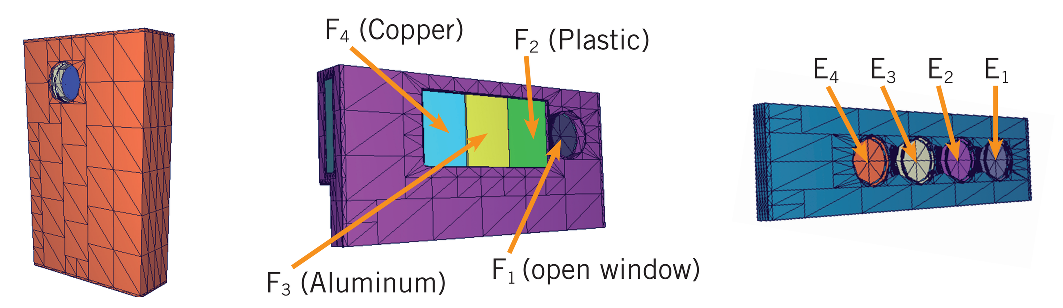
Model comparison

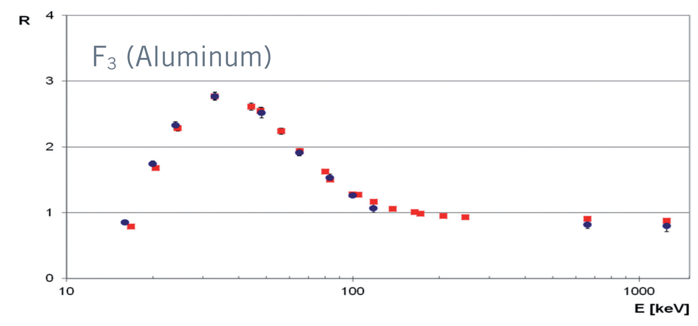


Energy dependency of the raw sensitive material and the different models for photons

→ No sizeable differences = Simplest model chosen

2ND STEP — Geometrical modelling and validation



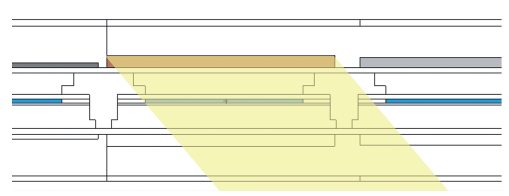


Energy reponse of E_3 for photons

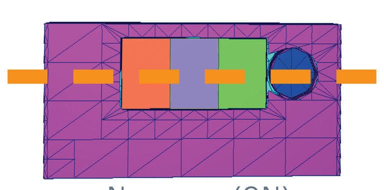
→ Acceptable agreement between MC and experimental data

3RD STEP — New design

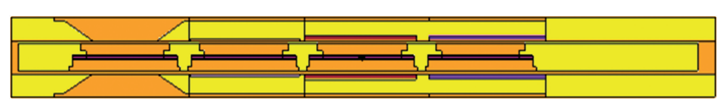
Material	Thickness [g/cm²]	Filter 1	Filter 2	Filter 3	Filter 4
Polyester	0.063	0.063			
Plastic (ABS)	1.325		1.325		
Plastic (ABS)	0.901			0.901	0.901
Aluminum	0.404		0.404	0.404	0.404
Titanium	1.804			1.804	
Tin	2.578				2.578
	Total thickness [g/cm²]	0.063	1.729	3.109	3.882



Filters closer to sensitive elements for better angular response



New case (GN)

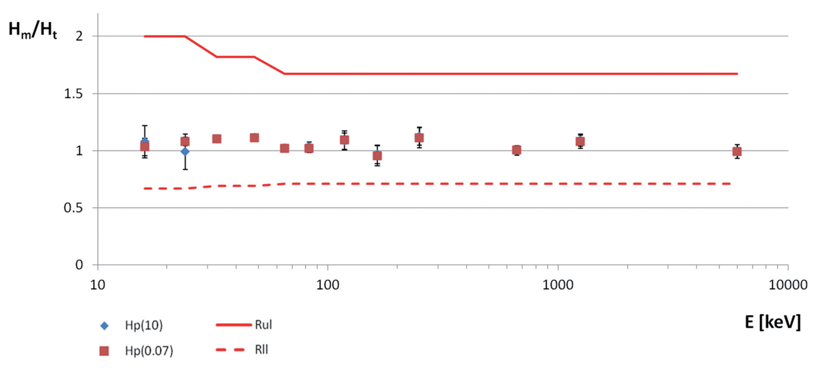


Enlargement of the open window for better energy-angle response at low energies and large angles

RESULTS

Dosemeter tested against European version of IEC 62387 by LNHB (the French national laboratory for ionising radiation).

Energy dependency for photons

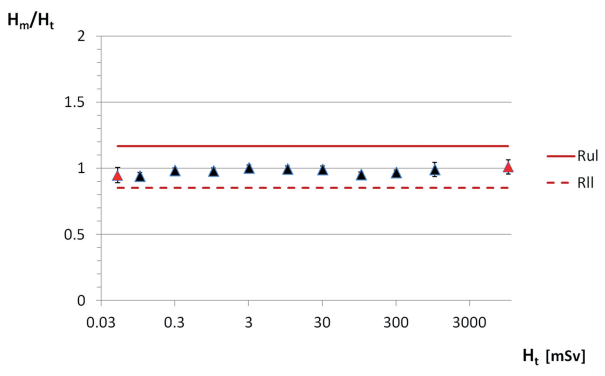


$$H_p(10):\quad 0.97 \le \frac{H_m}{H_t} \le 1.11$$
$$H_p(0.07):\quad 0.96 \le \frac{H_m}{H_t} \le 1.11$$
$$16\ keV \le \overline{E}_\gamma \le 6\ MeV$$

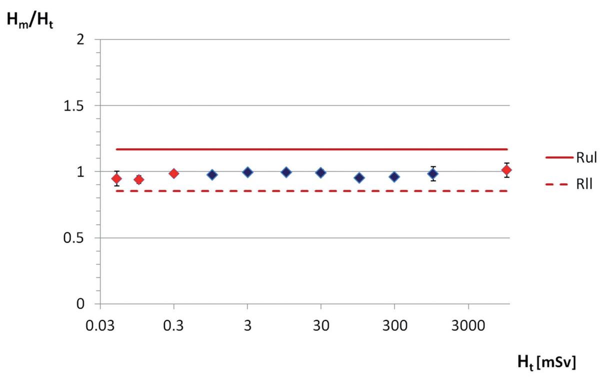
R_{ul} and R_{ll} are the upper and lower acceptable limits defined in the EN 62387-1:2012 standard. The limits vary with energy.

Linearity

$H_p(10)$



$H_p(0.07)$

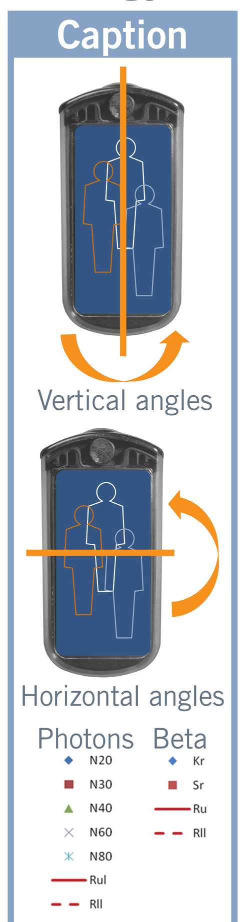


$$H_p(10):\quad [0.05\ \text{mSv}; 10\ \text{Sv}]$$
$$H_p(0{,}07):\quad [0.05\ \text{mSv}; 10\ \text{Sv}]$$

R_{ul} and R_{ll} are the upper and lower acceptable limits defined in the EN 62387-1:2012 standard. The limits vary with energy.

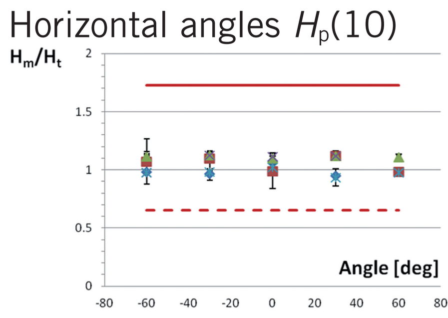
Energy-angle dependency

Caption

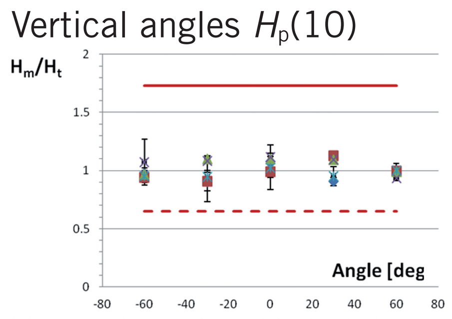


Photons

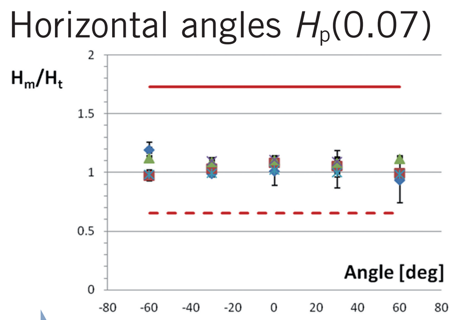
Horizontal angles $H_p(10)$



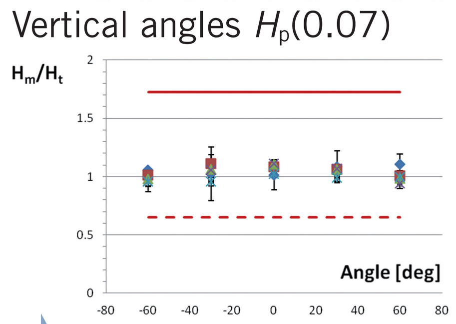
Vertical angles $H_p(10)$



Horizontal angles $H_p(0.07)$



Vertical angles $H_p(0.07)$

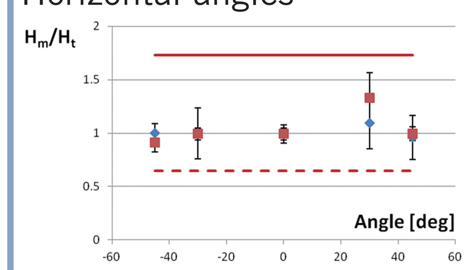


$$H_p(10):\quad 0{,}94 \le \frac{H_m}{H_t} \le 1{,}13$$
$$H_p(0{,}07):\quad 0{,}94 \le \frac{H_m}{H_t} \le 1{,}19$$
$$angle:\quad -60° \le \theta_H \le 60°$$

$$H_p(10):\quad 0.90 \le \frac{H_m}{H_t} \le 1.12$$
$$H_p(0{,}07):\quad 0.93 \le \frac{H_m}{H_t} \le 1.11$$
$$angle:\quad -60° \le \theta_V \le 60°$$

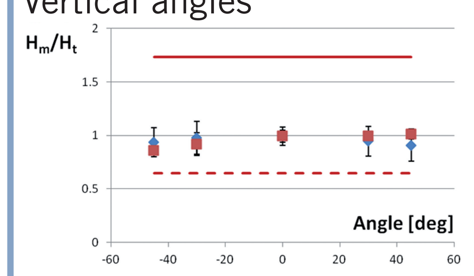
Beta

Horizontal angles



$$H_p(0.07):\quad 0.99 \le \frac{H_m}{H_t} \le 1.33$$
$$angle:\quad -45° \le \theta_H \le 45°$$

Vertical angles



$$H_p(0.07):\quad 0.86 \le \frac{H_m}{H_t} \le 1.01$$
$$angle:\quad -45° \le \theta_V \le 45°$$

R_{ul} and R_{ll} are the upper and lower acceptable limits defined in the EN 62387-1:2012 standard. The limits vary with energy. For readability purpose the values used correspond to the most restricting limits.

CONCLUSION

Dosemeter declared **compliant with EN 62387-1:2012** for **photon** and **beta** radiations on the following range by LNHB:

- Dose range: 0.05 mSv to 10 Sv for $H_p(10)$ and $H_p(0.07)$
- Photons: mean energies from 16 keV to 6 MeV; angle from -60° to 60° H/V
- Beta: mean energies 0.2 MeV to 0.8 MeV (^{85}Kr and $^{90}Sr/^{90}Y$); angle -45° to 45° H/V

Dosemeter with high metrological performances

- Non-linearity below 5% over 6 decades
- Photon energy dependency better than 11% over three decades
- Photon angle dependency better than 13% (except one point at 19%)
- Beta energy-angle dependency better than 14% (except one point at 33%)

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