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Simulation of the contribution of PMMA support scattering in the response of TLDs irradiated in Air KERMA.

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1. Introduction

TLD (*Thermoluminescent Dosimeters*) are widely used on personal dose evaluation. It's physics and technology is well know and can be found worldwide. Assays for its calibration, however, is a problem that involves a few laboratories and have some important particularities. The calibration or the research irradiation of this type of dosimeter depends of a well know irradiation field and the physical quantity related to the use of the TLD. This physical quantity will define the setup in which the TLD will be exposed to the radiation beam and the use of a phantom or not. In calibrations or research irradiations that uses air kerma quantity, is very important minimize the influence of radiation scattering on TLD response and even when using operational quantities as equivalent dose Hp, environmental equivalent dose H* and directional dose equivalent H', although the TLD is positioned in phantoms and scattering radiation is a undesired condition, only the radiation scattering caused by phantom should contribute to the response of the TLD.

Air kerma irradiation of TLD chips ou pellets is a critical condition because is almost impractical to irradiate something so small without a support structure in the setup, what implies in scattering radiation generated by this adjacent support structures. Most of assays are realized using PMMA supports, because of its small contribution to scattering, and this work intends to evaluate the influence of the scattering produced by the support and quantify it by Monte Carlo simulation [1][2][3] using the freeware CERN toolkit – Geant4 [4]. An idealized condition was programmed to compare a dose on a TLD arrangement on a ionizing radiation field of photons of 661.7 keV, simulating a ^{137}Cs gamma source. A physical support of PMMA was actually build in a CNC milling machine and used in the modeling. Four conditions of irradiation were simulated using the dose on a central TLD, chosen as a scoring volume, and compared using the rms calculated value as a standard deviation.

2. Methodology

A Geant4.10.07-p01 [5] version was used to simulate all experiment conditions. The physical structures that would be irradiated were programmed using the dimensions of the PMMA support actually constructed and standard NIST materials were used in the programming of Geant4 files: G4_AIR as the medium around structures, G4_PLEXIGLASS as PMMA support structure and G4_LITHIUM_FLUORIDE as TLD. The primary generator was programmed to generate photons with randomic uniform distribution on the xy plane with direction over z axis. The energy of photons was 661.7 keV to simulate a ^{137}Cs gamma source used in the laboratory and these photons irradiate the "volume world" that was a cube with 40 mm of edge. To reach the rms value up to 1 % of the dose value on the score volume, each simulation generates 5.10^8

photons. The dose was calculated on a score volume that was represented by a disc of lithium fluoride with 5 mm of diameter and 1 mm height. This disc was placed at the central TLD arrangement in a square array of 9 elements, separated with 9 mm – a central volume and its eight first neighbors. The average time of simulations was about 10^4 seconds in a notebook with an eight cores Ryzen 5 3500 AMD©processor, 8 MB of RAM and processor clock on simulation of 3 GHz. Four simulation conditions were programmed: a single central TLD, a square array of nine TLDs separated by 9 mm, a central TLD in a support and nine TLDs with support. The simulations have used the low-energy electromagnetic (LowE_Livermore) extensions of the Geant4 toolkit.

The Fig. 1 shows the physical PMMA support used on the TLD irradiations on the Metrology Laboratory of Centro Regional de Ciências Nucleares do Nordeste - CRCN-NE. It was intended to produce the less possible scattering radiation. The support have been designed using 2 mm of a PMMA sheet having leaked spaces between the TLD positions and was milling in a CNC machine. This support was used as reference to the simulated designed one. The support structure has walls with minimum possible width to avoid cracks or breaks but providing sufficient resistance to be useful on daily use. Every TLD spot has a diameter of 5.2 mm sufficiently large to almost all TLDs chips commercially distributed. This support dimensions and design were used in the programming of files.

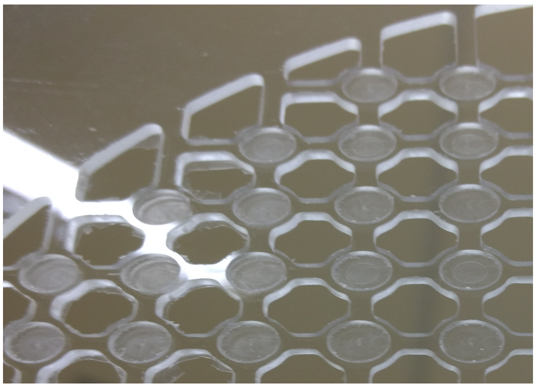
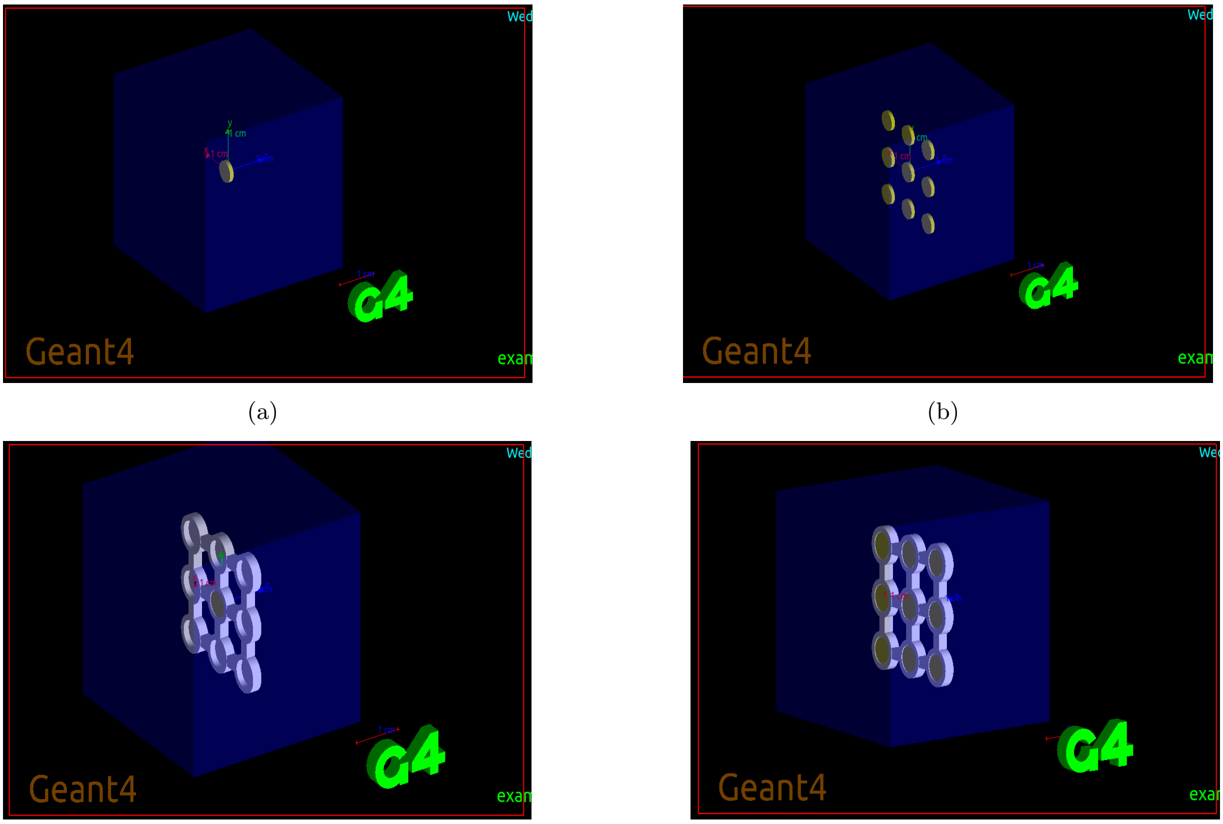


Figure 1: Detailed of PMMA support for TLD chips and pellets.

3. Results and Discussion

The results obtained from simulations have shown the contribution of scatter TLDs response, in the arrangements studied. The calculated scattering corroborates an intuitive thinking that the using the support, Fig. 2(d), the dose accumulated in the scoring volume is greater than with the score volume alone in space, Fig. 2(a). Table I presents the *dose* simulated in the score volume with the standard deviation represented by the *rms* value. It is possible to visualize that the PMMA support contributes with dose accumulated in less than 4% comparing with dose accumulated without the use of the support. There is no difference generated by the scattering between TLDs. It it can be observed by the fact that there is no statistical difference between the dose of the central TLD and TLDs array geometries and central TLD + support and TLD array + support geometries. It can be seen that the difference between mean values is almost 10 times bigger than *rms* values what sustain that this difference is statistically relevant. How the average uncertainty of a commercially TLD measurement system is about 20 % [6] – and for low doses can be reach 40 % – the contribution of this PMMA support is negligible or corrected by factor.



(a) (b) (c) (d)

Figure 2: Geometries programmed in simulation: (a) simple TLD (yellow) in center as score volume; (b) array of nine TLDs; (c) central TLD in the support of PMMA (light blue); (d) nine TLDs in PMMA support.

Table I: Simulated dose and rms values.

Geometries	Dose (μGy)	rms (μGy)
TLD central	73.21	0.27
TLDs array	73.35	0.27
TLD central + support	76.18	0.28
TLDs array + support	76.23	0.29

4. Conclusions

This work presents a simulated comparison among the dose accumulated on a score volume represented by a TLD chip on four conditions of irradiation in an ionizing radiation beam of 661.7 keV photon energy (^{137}Cs), with and without PMMA support and with and without other TLD chips in array. The PMMA support designed to stand the TLDs samples implies an addition of less than 4% in the accumulated dose in a score volume what, considering the uncertainties concerning the TLD dosimetry, is acceptable.

Acknowledgments

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