Study of signal filtering of a dosimetry system with a luminescent plastic detector, designed for dosimetry in radiotherapy, by means spectral analysis

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INTRODUCTION

Radiation detectors used in direct-reading radiotherapy suffer from two main problems: their non-equivalence to human tissue (water) and their size, which makes them unsuitable for the small fields present in modern irradiation techniques (radiosurgery, IMRT, VMAT, etc.), problems that are avoided by scintillation plastics. The use of scintillation plastics, despite the good number of studies and works carried out on the subject that allow the development of systems based on them to be addressed, has not led to a sufficient development of systems based on these procedures that allow their introduction into current radiotherapy practice.

AIM

In the present work, the spectrophotometric behavior of a plastic detector assembly is studied, in order to exclude possible undesirable or unmanageable effects related to the radiation response of the studied materials. So that the characterization and calibration works of a dosimetric system based on these materials, can be well oriented, with the confidence that a greater understanding of physical phenomena offers. An additional objective is the evaluation of the suitability of the materials used and the potential real problems that may arise to try to optimize and adapt their choice to radiotherapy uses. Specifically, the measurements made were aimed at studying the difference in the response of the detector assembly subjected to different radiation conditions.

METHOD

The detector assembly consists of two parallel 20 m long PMMA optical fibers, with 1.0 mm core and 2.2 mm OD Polyethylene jacket (Fig. 1), only one fiber is optically coupled to a small cylindrical polymer scintillator detector (PSD) of 2.0 mm length and 1.0 mm diameter (BCF-10M, Saint Gobain) that presents a sensitivity curve characterized for an emission peak at 432 nm. The second fiber is used as reference for subtracting the undesirable signal generated by the irradiation process, where part of the transmission fiber is inevitably irradiated. Two, a VARIAN TrueBeam and a SIEMENS PRIMUS were used as LINACs, that provided us a variety of beams of different energies, XR radiation fluence rates, and electrons, as described in Table I.

The spectrophotometer used has been an StarLine AvaSpec-ULS4096CL-EVO (AVANTES). Measurements have always been carried out under the same conditions: integration time of 10 s and an average of 7 measurements per acquired spectrum. All the measurements of the study were always carried out with these parameters, always taking a previous measurement of the dark current, following the methodology recommended by Avantes. The experimental set up is shown in Fig. 1.

The spectra cover a wavelength range between 200 and 1150 nm with an resolution of 0.301 nm and have been acquired consecutively for each of the two fibers, with and without detector.

The data treatment procedure (Fig. 2) has been: 1) subtraction of the spectrum data from the fiber with sensor minus the fiber data without sensor. 2nd) Normalization to 100 at the respective maximum of each spectrum.

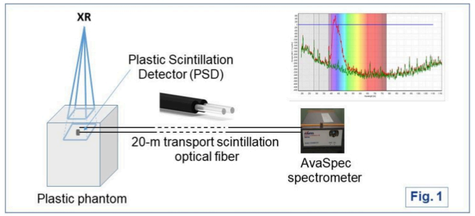


Fig. 1

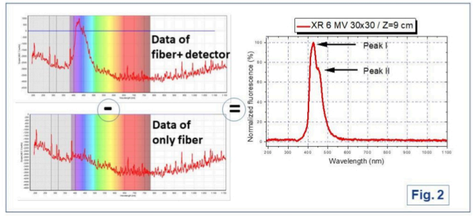


Fig. 2

RESULTS

The detector assembly used is quantitatively sensitive to the changes associated with the different dose rates and geometric conditions.

All spectra shape, after normalization, were practically identical for all irradiations performed, although with some specific differences outside the region of the central peaks of interest (400-500 nm). These variations are of small magnitude compared to the value of the maximum of the spectra (<0.05%), but they must be taken into account in terms of their contribution to the integral signal of the entire spectrum and that, when reaching the photodetector, it can give rise to undesirable deviations.

The spectrum is mainly characterized by three regions. The principal one, around 400-500 nm where two summed peaks appear (Fig.1, Peak I and II), and two others regions, one in the UV-blue and another in the visible-red area.

Additionally, in all the tests referenced in Table I, a peak at 670 nm appears very sharply (Fig. 6, Peak III) when the detector assembly is irradiated with electrons, and more so, when they are low energy (6 MeV) since depths greater than its therapeutic range Rp = 3 cm)

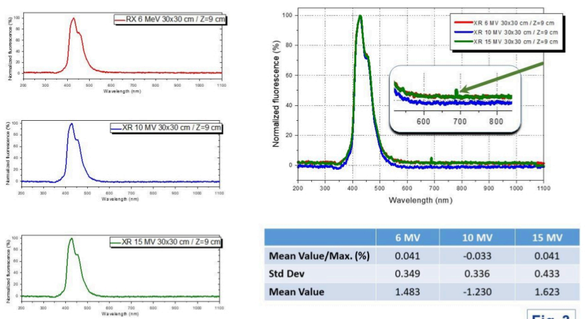
IRRADIATION CONDITIONS

TYPE OF RADIATION	COMPARISON STUDY	ENERGY	DOSE RATE MU/min	FIELD SIZE (cmxcm)	MEASUREMENT DEPTH (cm)
XR (VARIAN)	ENERGY	6 MV	600, 2400*	3X3, 20 X20, 30X30	Max, 2, 6, 9, 10 and 20
XR (VARIAN)	ENERGY DOSE RATE FIELD SIZE DEPTH	10 MV	600, 2400*	3X3, 20X20, 30X30	2, 6, 10
XR (VARIAN)	ENERGY	15 MV	600	10X10, 30X30	5, 9, 10 and 20
ELECTRONS (SIEMENS)	ENERGY FIELD SIZE	6 MeV	900	5X5, 20X20	1, 3
ELECTRONS (SIEMENS)	ENERGY FIELD SIZE	15 MeV	900	5X5, 20X20	1, 3

• WITHOUT FLATENING FILTER
(Not all of these results have been represented in this poster for reasons of space)

Table I

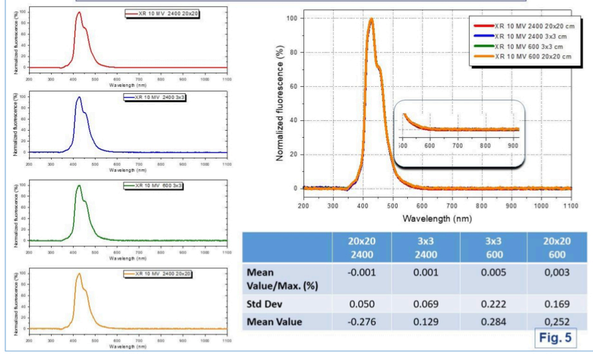
XR Energy spectra comparison: 6, 10 and 15 MV. Dose rate: 600 MU/min
Field size 30x30 cmxcm. Measurement depth: 9 cm



	6 MV	10 MV	15 MV
Mean Value/Max. (%)	0.041	-0.033	0.041
Std Dev	0.349	0.336	0.433
Mean Value	1.483	-1.230	1.623

Fig. 3

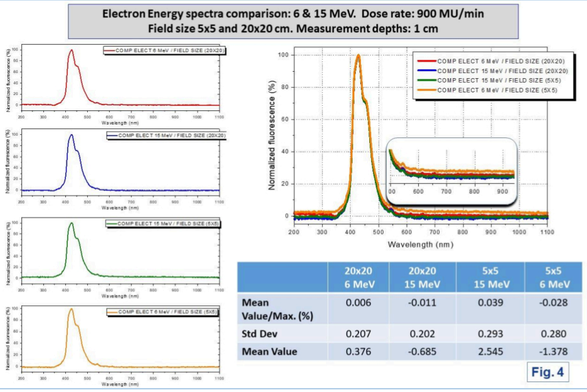
XR 10 MV Spectra comparison: Dose rate: 600, 2400 MU/min
& Field size: 3x3 and 20x20 cm. Measurement depth= 9 cm



	20x20 2400	3x3 2400	3x3 600	20x20 600
Mean Value/Max. (%)	-0.001	0.001	0.005	0,003
Std Dev	0.050	0.069	0.222	0.169
Mean Value	-0.276	0.129	0.284	0,252

Fig. 5

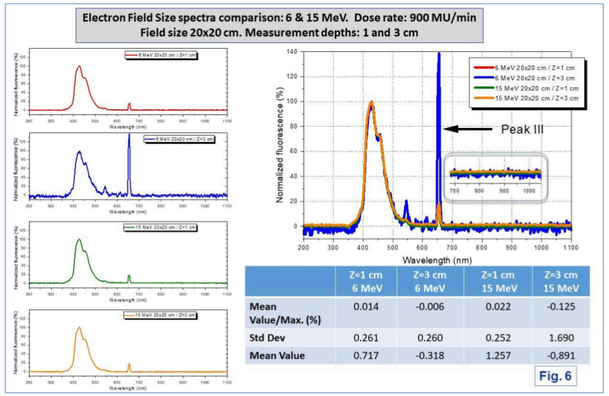
Electron Energy spectra comparison: 6 & 15 MeV. Dose rate: 900 MU/min
Field size 5x5 and 20x20 cm. Measurement depths: 1 cm



	20x20 6 MeV	20x20 15 MeV	5x5 15 MeV	5x5 6 MeV
Mean Value/Max. (%)	0.006	-0.011	0.039	-0.028
Std Dev	0.207	0.202	0.293	0.280
Mean Value	0.376	-0.685	2.545	-1.378

Fig. 4

Electron Field Size spectra comparison: 6 & 15 MeV. Dose rate: 900 MU/min
Field size 20x20 cm. Measurement depths: 1 and 3 cm



	Z=1 cm 6 MeV	Z=3 cm 6 MeV	Z=1 cm 15 MeV	Z=3 cm 15 MeV
Mean Value/Max. (%)	0.014	-0.006	0.022	-0.125
Std Dev	0.261	0.260	0.252	1.690
Mean Value	0.717	-0.318	1.257	-0,891

Fig. 6

CONCLUSIONS

According to the results, the selection of the last component of the dosimetric chain, the photodetector, must be carefully chosen so as to contribute to filtering these low-level signals mentioned.
Regarding the main region (Fig. 1, peaks I and II), the first corresponds to the maximum of the scintillator sensitivity curve (according to the manufacturer, 432 nm). The second appears at 450 nm, which can be attributed to Cerenkov radiation, although since the curve has been constructed as a difference between the two fibers, with and without detector, it could be thought that the Cerenkov should have been eliminated, so it could be considered another origin (in the hypothesis that the magnitude of the Cerenkov effect could be regarded negligible in the detector given its small size), such as that due to the attenuation function of the transport fiber or a combination of this with the sensitivity curve of the scintillator detector or that of the StarLine photodetector used (CMOS). Also for this reason, good care must be taken in choosing the scintillation material and the light signal transport fiber.
Regarding the presence of the peak around 670 nm, which can be observed very intensely in experiments with wide electron fields, but which also manifests itself to a lesser extent in smaller electron fields (Fig. 6) and even appears with XR (red arrow, Fig. 3), allows us to think that it is a Cerenkov contribution and that it manifests itself more intensely with electron beams, which XR. Again, this effect could be enhanced due to the attenuation function of the transport fiber and / or in combination with the sensitivity curve of the scintillator detector and the sensitivity curve StarLine photodetector (CMOS).

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