Temperature effect on optical fibre sensors for HDR brachytherapy in-vivo dosimetry

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(1) Purpose/Objective

The optical fibre sensors will be used as part of an in-vivo dosimetry system developed by the EU funded H2020 program "Origin" for source localization and dose measurement during prostate and gynaecological brachytherapy procedures. It is essential to establish the effect of temperature on dose measurements owing to the temperature difference between calibration and use in a patient.

Figure 1. Optical Fibre Dosimeters comprising of a 1Y2O3:Eu+4YVO4:Eu and PMMA tip coupled to a polymer optical fibre

(2) Material/Methods

Measurements with a 5 cm source-sensor distance were taken using a custom perspex water tank adapted to hold 6F Elekta Proguide needles to house optical fibre dosimeters and deliver the Ir-192 source from an Elekta Flexitron afterloader.

16 optical fibres were placed in a water filled plastic vessel with a magnetic stirrer at an initial temperature of 39.6°C, and the outer water tank was filled with cold water and an icepack to induce cooling to room temperature at 26.7°C. Dosimeter temperature was monitored outside the treatment room using a DS18B20 temperature sensor connected to an Arduino Nano.

(3) Results

Applying a linear regression model and averaging the change in count magnitude across fourteen fibres between temperatures of 26.7°C and 39.6°C results in a total change in detector output of 0.43% with a standard error of 0.47% (k = 3). The combined uncertainty of the statistical noise in photon counting and the reproducibility for each detector is presented in table 1. Two fibres are excluded due to a sensor fault. Out of the 196 total measurements across all fibres, 47 exceeded the measurement uncertainty of their respective fibres.

Table 1. Percentage change in detector output of counts per second (Hz), with uncertainties for each fibre.

Fibre Number	$\Delta CPS_{\Delta T=12.9^\circ C}$ (%)	Reproducibility (%)	Statistical Uncertainty (%)	Combined Uncertainty (%)
1	0.56	0.80	0.27	0.84
2	0.17	0.26	0.32	0.42
3	0.22	0.95	0.26	0.98
5	1.59	0.14	0.31	0.34
6	-0.30	0.26	0.27	0.38
8	0.62	0.04	0.30	0.30
9	-0.16	0.87	0.35	0.94
10	1.08	0.57	0.30	0.65
11	-0.44	0.75	0.32	0.82
12	-0.28	0.90	0.33	0.96
13	0.88	0.74	0.33	0.82
14	0.49	0.18	0.31	0.36
15	0.84	0.43	0.31	0.53
16	0.72	0.39	0.28	0.48

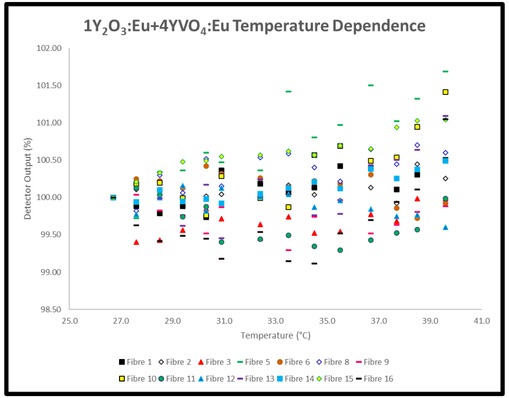

Figure 2. Change in optical fibre detector output of photon counts per second relative to the lowest temperature measurement (T = 26.7°C).

(4) Conclusion

The change in dosimeter output with temperature in the range of 26.7°C to 39.6°C was found to vary between fibres. A method of evaluating temperature dependence is outlined which minimises the influence of positional uncertainty on measurements, which is essential when using small volume detectors with a brachytherapy source.

(5) Funding statement

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