Characterising a Papillon 50 electronic brachytherapy source using a plastic scintillation detector

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Electronic Brachytherapy: Physics - Dosimetry

Purpose
To characterise a Papillon 50 (P50) electronic brachytherapy (eBT) source using a small plastic scintillation detector (PSD).

Methods
The P50 delivers 50 kVp X-rays (half value layer ~ 0.7mmAl) via collimating steel applicators (Ø22-30 mm). The delivered dose from the P50 source was measured using a PSD system and an internal ion chamber in the P50. The P50 output is given in monitor units (MU), where 100 MU ~ 1 Gy. The PSD system is based on a cylindrical BCF-12 plastic scintillator (Ø1 mm, L=0.5 mm) coupled to an optical fiber, which transmits the scintillation light to a photo multiplier tube (PMT) (H5783 SEL3, Hamamatsu). The PMT is coupled to an electrometer (unidos webline, PTW). The PSD was placed in a block of solid water and the P50 applicator was placed on top of the block pointing towards the PSD, corresponding to a 5 mm solid water depth. The following quantities were determined.
MU precision: Irradiation was done for ten different MU-values and repeated ten times for each. The total dose of each irradiation was measured with the PSD, and the mean and SD determined.
Temporal stability: Irradiations for a long period of time were performed to investigate the P50s temporal stability. The P50 was set to irradiate for 200-600 s and the accumulated dose over 10 s was measured repeatedly throughout each irradiation.
Depth-dose curves: The distance between the PSD and P50 was varied by inserting plates of solid water in between. The dose was measured at each depth during a 10 s irradiation. The results were compared to published results with an ionization chamber and Monte Carlo simulations[1].

Results
MU precision: Fig. 1a shows the measured mean signals for the 10 MU values. The SD was 5.2% for 50 MU and up to 1.1% for the remaining MU values. The dashed line is a fit to the mean measured signal as a function of MU, only including MU ≥ 400. The mean signal show a strong linear relation. Fig. 1b shows the residuals between the fit and measurements on fig. 1a. The fit overestimates the signal at MU

below 400, likely due to the PSD measuring the decaying irradiation when the P50 is turned off unlike the intrinsic ion chamber.
P50 stability: Fig. 1c shows the measured signal as function of time from irradiation start. The signal decreases exponentially over time by up to 3%. Fig. 1d shows the signals after an exponential time correction. The SD then becomes 0.18% on average.
Depth-dose curves: Fig. 2 shows the relative dose of the P50 source measured at depths ranging between 7 mm to 49 mm in solid water. The results agree within the uncertainty of MC and ion chamber results.

Conclusion

The dose from a P50 can be measured with good accuracy using a PSD system. The PSD could therefore potentially be used to characterise P50 and other eBT sources in terms of both temporal and positional dose distribution.

[1] O. Croce, S. et al. Radiation Physics and Chemistry 81 (2012) 609-617

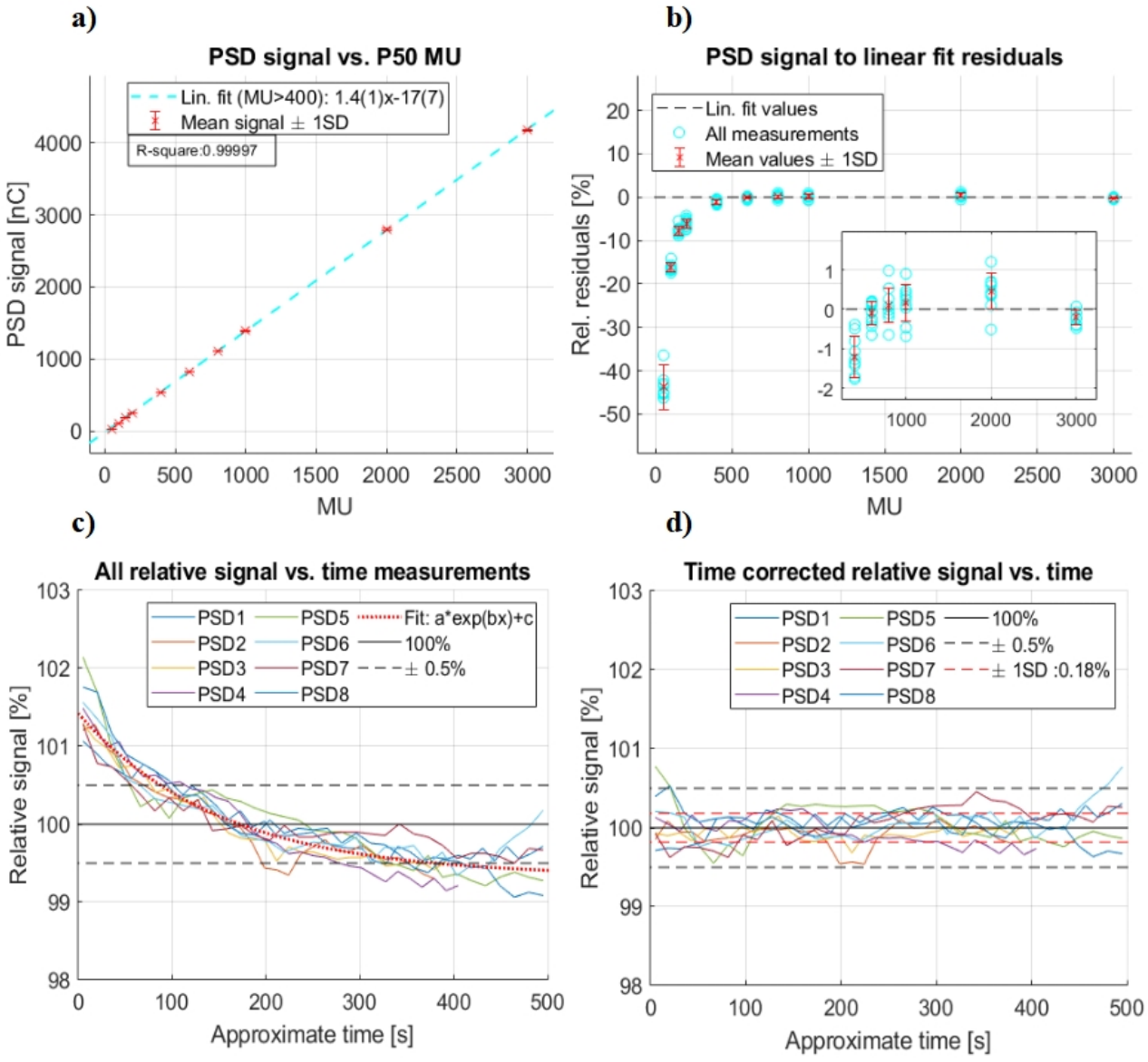

Figure 1: a) Measured signal for different MUs. The dashed line is a linear fit to the mean values for MU above 400. b) Relative residuals between linear fit and measurements. The insert is a zoom in of MU above 400. c) The P50s dose rate as function of irradiation duration. The red dashed line is an exponential function fitted to the mean of all measurements at each measured time. d) The measured signals from figure 1c corrected using the exponential function. The dashed lines indicate 0.5% deviations from the signal mean values (black) and ± 1 of the average SD (red).

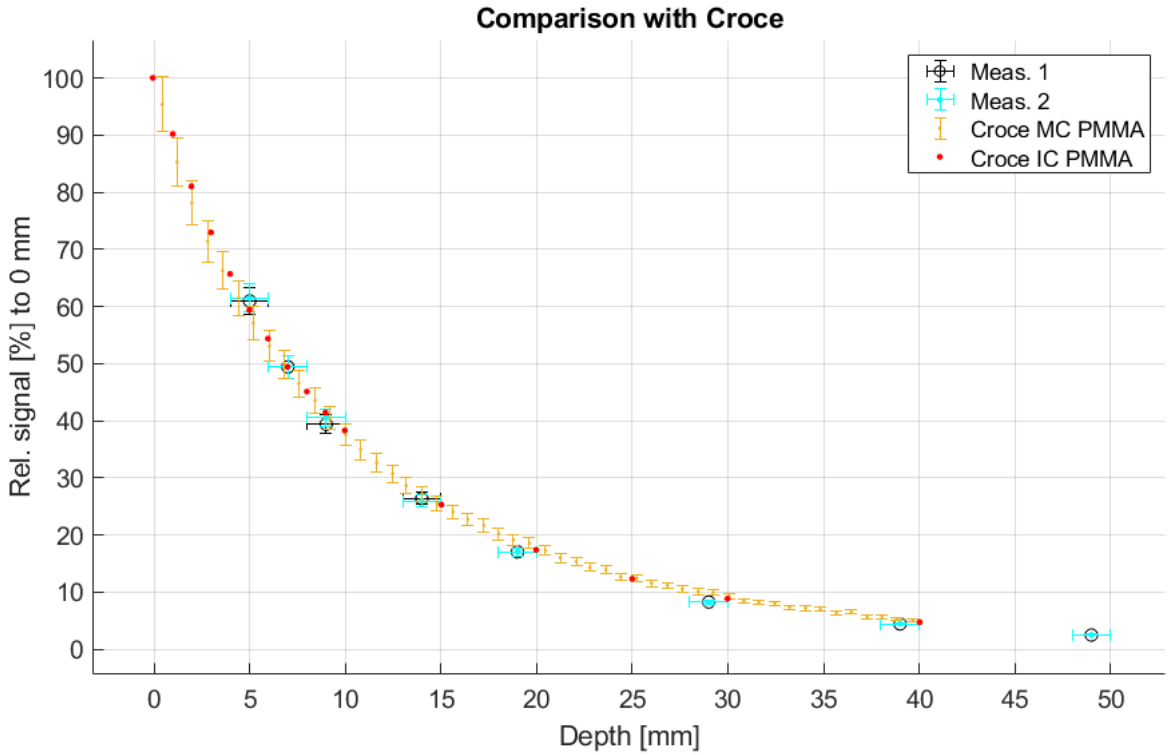

Figure 2: Relative depth dose (normalised at 0 mm distance from applicator tip) of the P50 source with a 25 mm diameter applicator measured with the PSD (black circles and cyan dots), an ion chamber (red dots), and MC simulations (yellow dots). Ionisation and MC results are taken from Croce et. al. (2012)[1]. Vertical errorbars indicate ±1 SD on measurements while horizontal bars indicate ± 1 positional uncertainty.