Identification of Dwell Times with *In Vivo* Scintillation Detectors in Brachytherapy

Audrey-Anne Piché[1,2], Chahrazed Ghannoudi[1,2], Raphael Larouche[3], Luc Beaulieu[1,2]

[1]*Département de Physique, de Génie Physique et d'Optique et Centre de Recherche sur le Cancer, Université Laval, Québec, QC, Canada*

[2] *Département de Radio-Oncologie et Axe Oncologie du CRCHU de Québec, CHU de Québec, Université Laval, Québec, QC, Canada*

[3] *Medscint, Québec, QC, Canada*

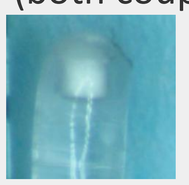
INTRODUCTION

- Brachytherapy: the source irradiates the tumor locally by stopping at specific positions for planned durations (dwell times), thus protecting nearby healthy tissues[1].
- Importance of *in vivo* dosimetry: detecting errors related to transfer tube inversion and uncertainty in catheter reconstruction that affect the treatment accuracy[2].
- **Objectives**: To **identify** and **validate** the dwell times of the source using an inorganic scintillation detector (ISD) and a plastic scintillation detector (PSD).

METHODS

Detectors used

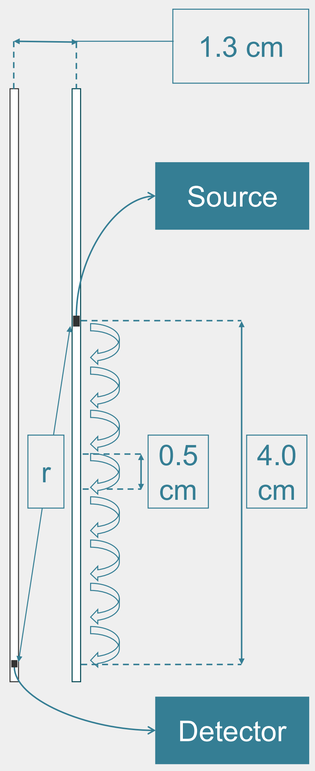
(both coupled to L8 m × Ø1 mm optical fiber)



PSD: L3.0 × Ø1 mm scintillating fiber (Medscint, QC, Canada)

ISD: L0.5 × Ø0.5 mm Gd_2O_2S:Pr,Ce,F

- Source to detector distances (SDD), *r*, varied between 1.3 and 4.2 cm according to the source's displacement of 4.0 cm with 0.5 cm intervals.
- Measurements were replicated 3 times for each dwell time (0.3, 0.5, 0.8 and 1 s) and for each detector in a $48 \times 48 \times 48$ cm^3 water tank.
- Iridium-192 Flexisource (Elekta, Netherlands) with S_K varying from 34069 to 34054 U.



- Dwell times were calculated from the integrated light spectra acquired at 20 Hz with Hyperscint-RP200 spectrometer (Medscint).

For the signal to noise ratio (SNR) measurements:

- ISD was moved by a robotic arm in a $48 \times 48 \times 48$ cm^3 water tank from 1.1 to 7.6 cm with the Iridium-192 Flexisource with 0.5 cm steps every 15 seconds along the source transverse plane ($\theta = 90°$).
- SNR was calculated at each position as the ratio of the mean to standard deviation of the signal, which was acquired at 200 kHz with the FastBox (Medscint) and numerically averaged to 493 Hz.

RESULTS & DISCUSSION

- Fig. 1 shows an example of the identification of dwell times from the integrated light-yield spectra.
- To consider transit dose, the planned dwell times include transition times[3]; therefore, intermediate dwell times are shorter than planned, while the first and last positions correspond to the planned times (Fig. 1, 2).

ISD (Fig. 2a):

- The maximal difference between measured and planned dwell times is 0.1 s with an average deviation of -0.045 ± 0.024 s.
- 93.5 % of the measurements have an absolute difference ≤ 0.05 s with planned dwell times.

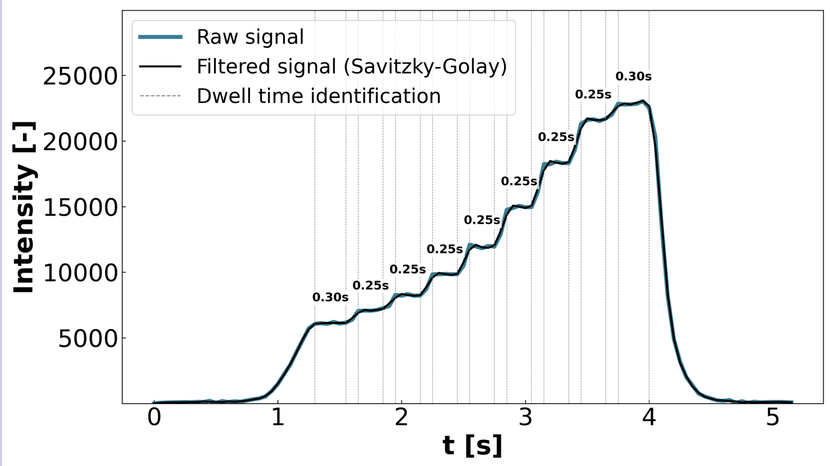


FIG. 1 – Integrated scintillation light signal as a function of time measured by ISD for 9 dwell times of 0.3 s in a needle.

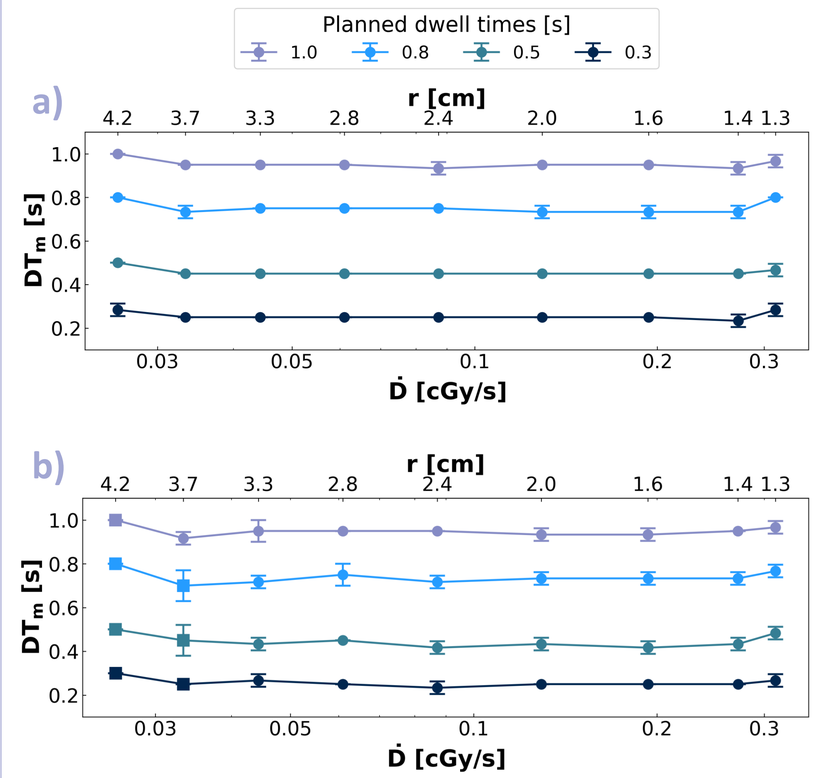


FIG. 2 – Averaged dwell times measured (DT_m) by a) ISD and b) PSD for three replicates with standard deviation represented with error bars as a function of SDD (*r*) and of the dose rate ($\dot{D}$) (S_K varying from 34069 to 34054 U). The square markers correspond to values with less than three measurements due to unidentified dwell times.

PSD (Fig. 2b):

- 33.3 % of dwell times measured at SDD of 3.7 and 4.2 cm were not distinguished due to lower light yield[4].
- The maximal difference between measured and planned dwell times is 0.15 s with an average deviation of -0.054 ± 0.032 s.
- 77 % of the measurements have an absolute difference ≤ 0.05 s with planned dwell times.

SNR results with the FastBox:

- Rose Criterion (SNR > 5) is respected up to a dose rate of 8.52×10^{-7} cGy/s (Fig. 3).
- The FastBox is an interesting option to identify sub-0.3 s dwell times since it offers about 49 points for detection of 0.1 s dwell times (compared to 2 points with the Hyperscint-RP200 at 20 Hz).

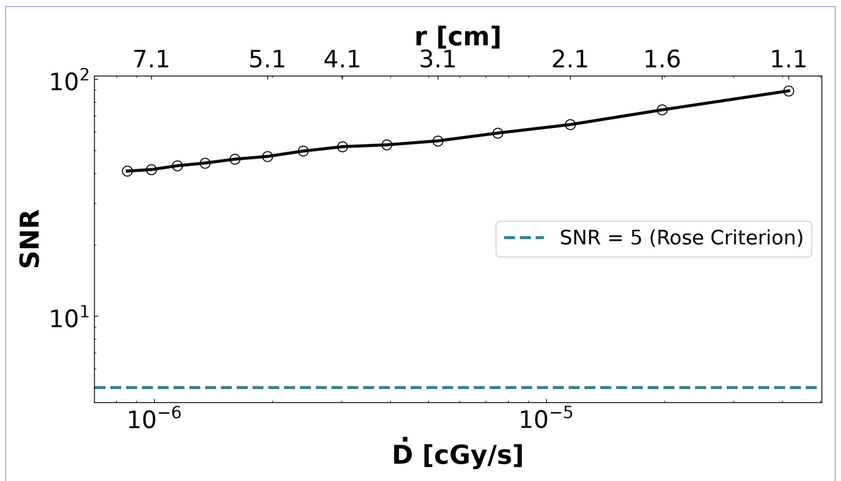


FIG. 3 – SNR of ISD as a function of the dose rates at 200 kHz (frequency was numerically averaged to 493 Hz). SDD vary between 1.1 to 7.6 cm from an Iridium-192 Flexisource with S_K = 32416 U.

CONCLUSIONS

- ISD provides a more precise detection of dwell times at further SDD than PSD because of its higher light-yield.
- The FastBox is a promising acquisition tool to detect short dwell times.

Following steps:

- Measurement of dwell times with the FastBox.
- Validation of in-phantom dwell times for a prostate cancer treatment plan paving the way toward precise time-resolved *in vivo* dosimetry.

REFERENCES

[1] Fonseca GP, Johansen JG, Smith RL, et al. Phys Imaging Radiat Oncol. 2020.

[2] Tanderup K, Beddar S, Andersen CE, et al. Med Phys. 2013.

[3] Fonseca GP, Viana RS, Podesta M, et al. Med Phys. 2015.

[4] Beddar S, Beaulieu L. Scintillation Dosimetry. 2016.