Master’s Thesis Engineering Technology

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Experimental Evaluation of the HS-RP200 Optical Fiber Scintillator for Dosimetry in Clinical and Preclinical Radiotherapy

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1 Background

Accurate dose delivery is essential in radiotherapy to ensure treatment effectiveness while minimizing damage to healthy tissues. Traditional **dosimetry systems**, such as **ionization chambers** and **film dosimetry**, offer high precision but often lack real-time capabilities, flexibility, or spatial resolution. **Optical fiber scintillators (OFSs)** have emerged as promising alternatives, offering high **sensitivity**, near **tissue equivalence**, and the potential for **real-time dose measurements** [1].

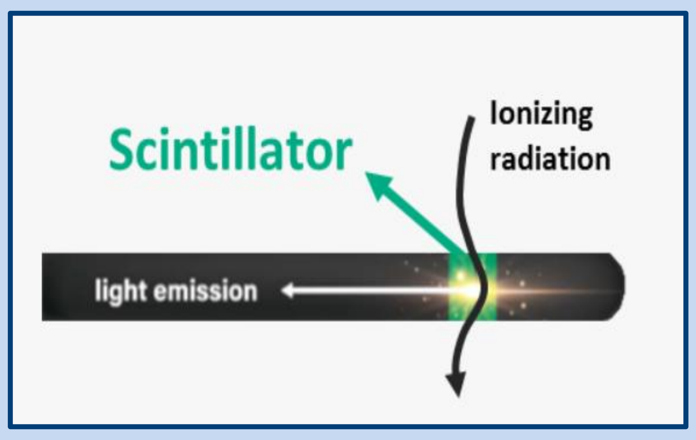

Figure 1: Working principle of OFS [4].

OFSs are promising alternatives to conventional dosimetry systems. They work by converting ionizing radiation into light via a scintillating material, which is transmitted through an optical fiber to a photodetector, as shown in Figure 1. OFSs offer advantages such as **compact size, real-time readout, Electromagnetic interference (EMI) immunity**, and suitability for **in vivo applications** and **high spatial resolution** [2], [3]. A comparison between the OFS and traditional dosimetry methods is presented in Table 1.

Table 1: Comparison between traditional dosimetry systems and OFS.

Feature	OFS	Ionization Chamber	Film dosimetry
Real-time readout	✓	X	X
Compact size	✓	X	✓
Tissue equivalence	✓	✓	✓
EMI immunity	✓	X	✓
High spatial resolution	✓	X	✓

2 Research Objectives

Recent advances in optical fiber scintillator technology, such as the **HYPERSCINT RP200 (HS-RP200)** (illustrated in Figure 2), offer new opportunities for precise, real-time dosimetry.

However, the reliability of OFS systems must be rigorously assessed across different radiotherapy modalities.

This study investigates the **HS-RP200**, following the workflow shown in Figure 3, by evaluating:

- **Reproducibility** under repeated measurements;
- **Linearity** across different dose levels;
- **Accuracy** compared to film and alanine dosimetry.

Figure 2: Hyperscint Research Platform 200 (HS-RP200), Medscint [2].

Main objective:

The main objective is to validate the dosimetric performance of the HS-RP200 optical fiber scintillator by systematically evaluating its reproducibility, linearity and accuracy under different radiation conditions, using alanine pellets and film dosimetry as reference standards.

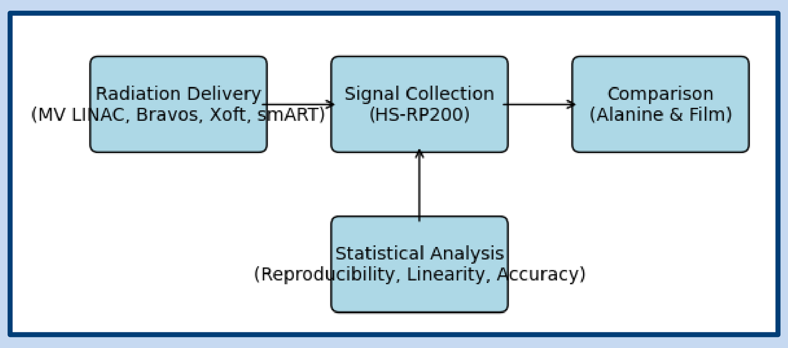

Figure 3: Schematic workflow, from radiation delivery to statistical evaluation of the HYPERSCINT RP200 performance.

3 Experimental Setup

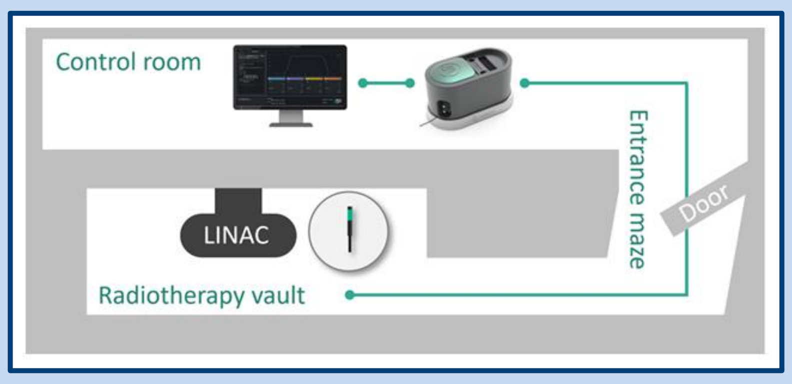

Figure 4: Recommended setup for conventional LINAC measurements [2].

To validate the dosimetric performance of the **HS-RP200** optical fiber scintillator, measurements were conducted using four radiation platforms:

- **LINAC (6 MV, Varian TrueBeam):** various monitor unit settings were applied, while field size and SSD were kept constant to ensure consistent irradiation conditions.
- **Bravos afterloader (HDR brachytherapy):** reproducibility and linearity were evaluated using standardized dwell times and source positioning.
- **Xoft system (electronic brachytherapy):** dose measurements were performed at different depths.
- **MultiRad 225 (preclinical X-ray cabinet):** performance was tested for different tube potentials.

Figure 5: Setup for measurements Bravos afterloader.

Dedicated setups were developed for each modality, ensuring **controlled and reproducible irradiation conditions**. Examples of the LINAC and Bravos configurations are shown in Figures 4 and 5. Measurements were compared against **reference dosimetry systems**, including **alanine pellets and film**, to assess the accuracy of the scintillator under different radiation conditions.

4 Results

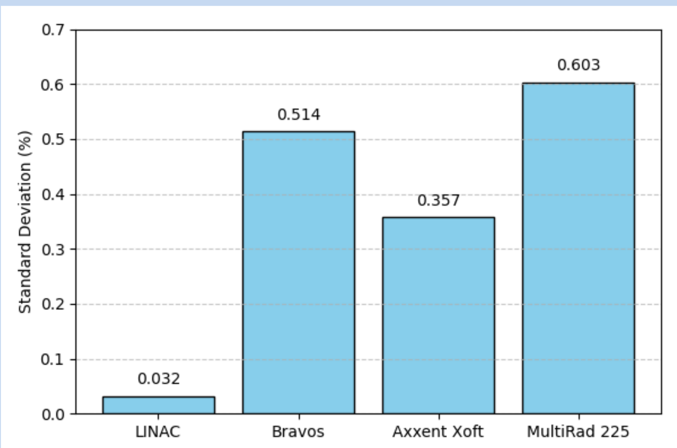

Figure 6: Results Reproducibility.

Several measurements were conducted to evaluate the **reproducibility, linearity,** and **accuracy** of the OFS across different radiation modalities.

Figure 6 presents the reproducibility results, showing a standard deviation below 1% for all four irradiation modalities, indicating excellent stability.

Figure 7 summarizes the **linearity results**. In the tested dose range, an **R^2 value of 1.00** was consistently achieved, demonstrating a highly linear response.

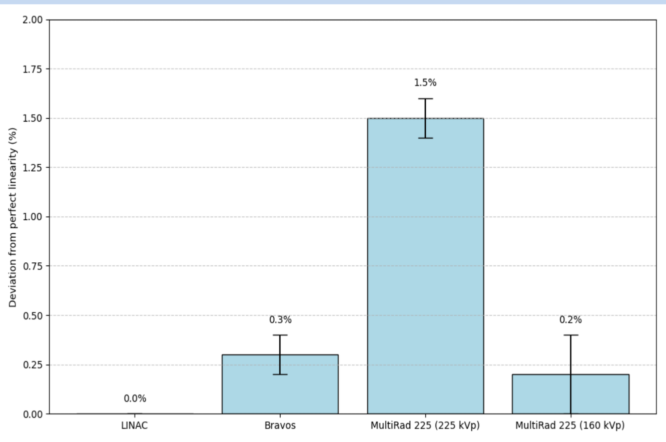

Figure 7: Results Linearity.

Table 2: Results Accuracy.

Modality	Reference Method	OFS - Reference Difference (%)	Combined Uncertainty (%)
LINAC	Alanine	0.987	0.763
LINAC	EBT3 Film	4.594	5.419
Bravos	TPS	0.583	/
Xoft	Calculated Dose	11.23	/
MultiRad 225	Alanine	2.53	1.04

OFS measurements were compared to **reference methods** across the four irradiation modalities. Differences ranged from **0.58% to 11.23%,** with **combined uncertainties** up to **5.42%**. Higher deviations for Xoft may be related to the use of **solid water slabs** instead of a **full water phantom**, introducing additional setup uncertainties.

5 Conclusion

Table 3: Summary OFS performance.

Modality	Reproducibility	Linearity	Accuracy vs Reference
LINAC 6 MV	Excellent	Excellent	< 1% deviation (Alanine)
Bravos	Good	Excellent	< 1% (TPS)
Axxent Xoft	Good	/	≈ 11% (Calculated Dose)
MultiRad 225	Good	Good	≈ 2.5%

The **HS-RP200** demonstrated **excellent reproducibility and linearity** for LINAC 6 MV and Bravos, with **deviations below 1%** compared to **alanine dosimetry** for LINAC. For Axxent Xoft and MultiRad 225, **good reproducibility and linearity** were observed. The slightly higher deviation observed for Xoft is likely related to the use of **solid water phantoms** instead of a full water phantom. For MultiRad 225, an **accuracy** deviation of approximately **2.5%** was found. Overall, these results indicate that the **HS-RP200** provides **reliable dosimetric performance** across a **wide range of irradiation modalities**, with minor modality-specific differences related to beam characteristics and measurement setup.

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[2] Medscint, *User Manual for HYPERSCINT Research Platform 200*, Québec, 2024.
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