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Characterization of the Hyperscint™ Dosimetry System for Real-Time Dosimetry Measurements with the Varian TrueBeam™ Linac

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INTRODUCTION

Plastic scintillator/optical fibre systems offer advantages in dosimetry due to their near water equivalence, waterproof construction, linear dose response and possible millimeter size enabling high spatial resolution. Potential exists for these sensors in traditional radiotherapy[1] as well as small-field[2] and cutting-edge radiotherapy dosimetry[2-4]. The nanosecond decay times of plastic scintillators enable the possibility of real-time dosimetry. We had the opportunity to test the new Hyperscint™ system, which incorporates a specialized spectrometer optimized for radiation dosimetry coupled to PMMA and plastic scintillator fibres. These initial tests were carried out to determine if, as with similar sensors, dose and dose rate responses are linear. We also tested field size response and the whether the detector can provide real-time dose information.

AIM

To test the novel plastic Hyperscint™ scintillator detector system for relative dose measurement performance in dose (10-2500 cGy), dose rate (5-600 MU/minute), field size (9-625 cm^2), and timing resolution (5 down to 0.1 s).

METHODS

The Hyperscint™ system must undergo a calibration to enable the removal of spurious Čerenkov signal created in the plastics from which the sensor is made. To do this, a calibration step using an orthovoltage unit (in our case an XRAD 320) is done to identify the scintillation only spectrum; this was achieved as follows:

- Unit set at 100 kVp with current 10 mA and 2 mm Al filtration
- Scintillator placed in centre of field in the unit jig at 36 cm SSD
- Hyperscint™ integration time set to 5 s integration
- 10 Gy total dose delivered to Hyperscint™

Measurements were then taken on Varian TrueBeam™ with 6 MV photons at Dmax: one with high (long length of fibre) and one with moderate (short length of fibre) Čerenkov induced. The Hyperscint™ uses the established scintillation and Čerenkov spectra to create a calibration which us then used to isolate the scintillation spectra both during and after irradiations.

Tests of 3 mm long plastic scintillating fibre in reference dose conditions: centre of fibre at 100 cm SAD, 20 cm of solid water backscatter and 1.5 cm of buildup. Unless otherwise stated: field size of 10 cm x 10 cm, dose rate 600 MU/minute, dose delivered 200 cGy and a 5 s integration time were applied.

- **Dose linearity**: 10, 20, 50, 100, 500, 500, 2500 MU delivered at 600 MU/min
- **Dose rate**: 5, 20, 50, 100, 200, 600 MU/min. 10 MU delivered
- **Field Size**: (square) side lengths 3, 7, 10, 15, 20, 25 cm. 200 MU delivered
- **Timing studies**: decrease integration times from 5 s down to 0.1 s; delivered 200 MU

RESULTS

First tests of Hyperscint™ scintillator indicate the system to be capable of measuring relative doses of 10 cGy up to 2500 cGy within 1.2% of the expected dose, see Figure 1. The system showed dose linearity with a slope of 0.98 and R^2 of 1. Tests where dose rate was increased from 5 MU/minute to 600 MU/minute showed the Hyperscint™ to measure relative dose to within 4% of expected, see Figure 2. As field size was increased from 3 cm x 3 cm to 25 cm x 25 cm, relative dose measurements were accurate to within 2.5% of expected; discrepancies decreased to 1% as field size increased, see Figure 3.

The Hyperscint™ was also tested for its ability to deliver real-time (or near real-time) dosimetric information. For this, integration times were decreased from 5 s down to 0.1 s and doses of 200 cGy were delivered. Down to integration time of 0.3 s the system measured relative dose to within 1% of expected, but at 0.1 s the discrepancy rose to 3%, see Figure 4.

The highest variation was seen in dose rate measurements and could be due to the integration time of 5 s being too long or the delivered dose (10 MU) being too fine for resolution by the system. Field size variations showing overresponse in small fields to underresponse in large could be a result of the proprietary calibration algorithm overcorrecting for Čerenkov contributions.

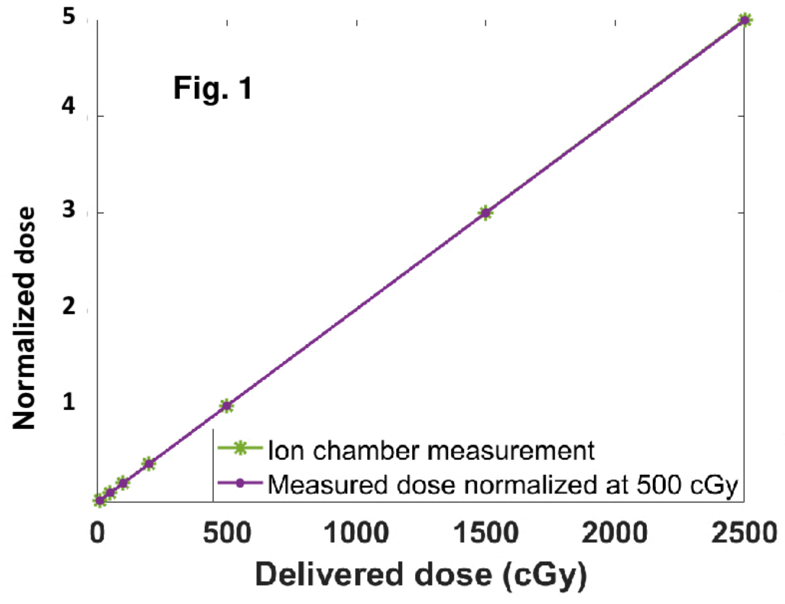

Fig. 1 - Dose response: Linear with R^2 1 from 10 up to 2500 cGy. All measurments under 1.2% deviation from expected

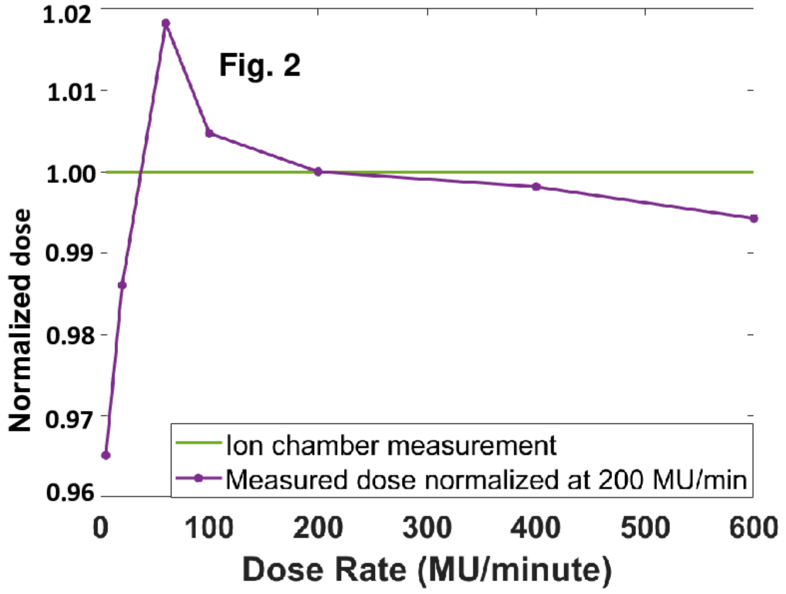

Fig. 2 - Dose rate response: Dose rates 5-600 MU/minute. Relative normalized response was between -4% and +2% from expected

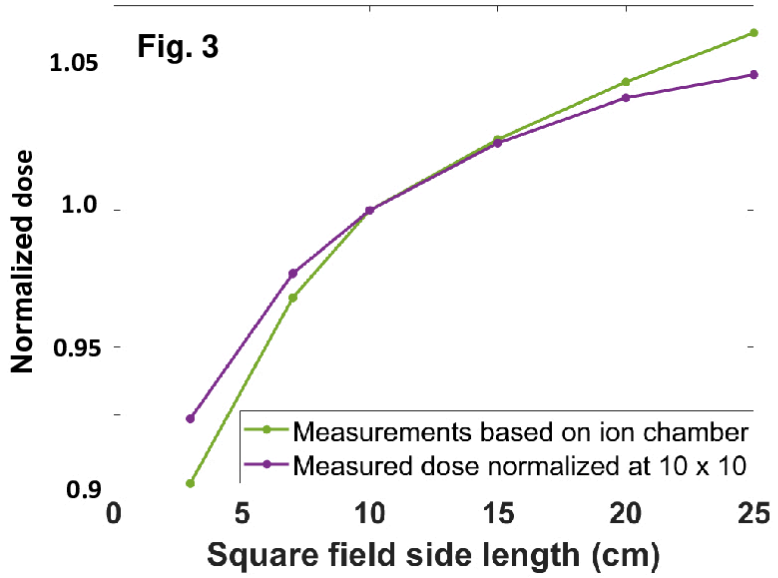

Fig. 3 - Field size response: 2.5 % deviation from expected at 9 cm^2 down to 1 % deviation at 625 cm^2. Green curve shows calculations based on ion chamber measurements taken at commissioning

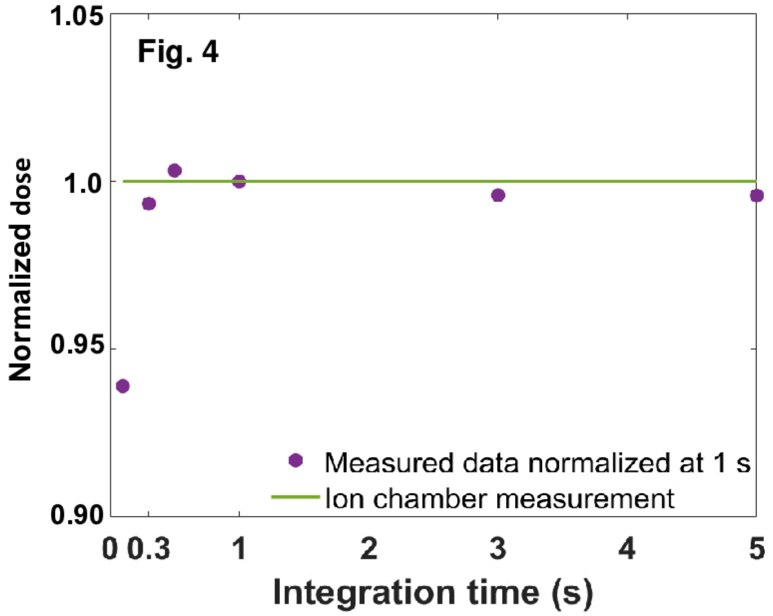

Fig. 4 - Timing resolution: spectrometer integration time reduced from 5 s to 0.1 s. Green line at 1.0 indicates expected measurement when 200 cGy delivered

CONCLUSIONS

The Hyperscint™ has shown encouraging preliminary results with mostly low deviations from those based on ion chamber measurements in dose and dose rate linearity, field size linearity and timing resolution. After appropriate calibration, the Hyperscint™ could be to be used to measure relative dose delivered in cGy as well as indicate changing dose conditions within 0.3 seconds. Investigations into reasons for and solutions to the variations observed in these results are being undertaken. Future tests will determine inherent system error and repeatability, angular dependence, and response in moving fields.

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CONTACT INFORMATION

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