Dose-Rate and "SSD" Dependence of Commercially Available Diamond and Diode Detectors

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Purpose

Diode and diamond detectors are solid-state detectors with a myriad of applications including small field dosimetry, intensity-modulated radiation therapy (IMRT) QA and *in vivo* dosimetry.[1,2] This work aims to investigate the magnitude of the instantaneous dose-rate dependence of various commercially available diamond and diode detectors by varying the nominal repetition rate (NRR) and source-to-surface distance (SSD).

Background

Most medical linear accelerators generate a pulsed-beam with the instantaneous dose-rate being much higher than the average dose-rate. Solid-state detectors such as diodes and diamonds generally have a high charge carrier mobility, which allows them to be used in a variety of dose-rates. However, doping the sensitive volume with impurities can lead to a significant dose-rate dependence.[3] Previous studies have shown that diamond and diode detectors exhibit some dose-rate dependence in megavoltage photon beams.[3,4]

Dose-rate dependence of a detector can be characterized by investigating the change in detector response by varying source-to-surface distance (SSD) or linac nominal repetition rate (NRR). For a typical radiation beam, dose-rate follows the inverse-square law and an ideal detector follows this relationship when the SSD is varied. When delivering a set amount of monitor units (MU), the ideal detector's response remains unchanged regardless of the NRR used.

Results

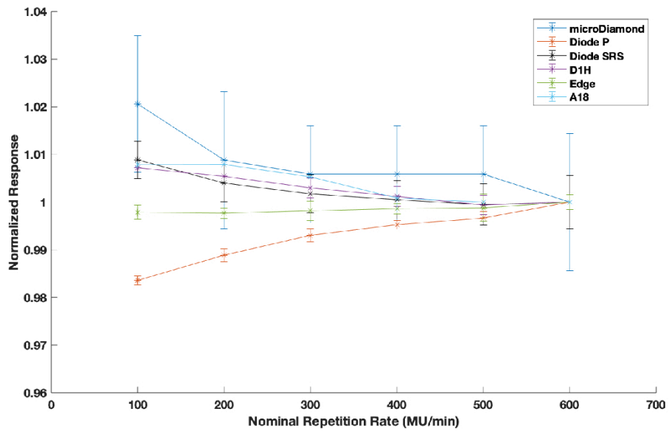

Fig. 1: Dose-rate dependence as a function of NRR of the microDiamond detector, A18 ionization chamber, and various diode detectors. The combined uncertainty at k=2 is shown.

• The normalized detector response was found to decrease with increasing NRR for all of the studied dosimeters except Diode P and EDGE detector. Within the investigated NRR range, the Diode SRS, A18, D1H, and EDGE detectors were found to be dose-rate independent up to 1% and the microDiamond and Diode P detectors were found to be dose-rate independent up to 2%.

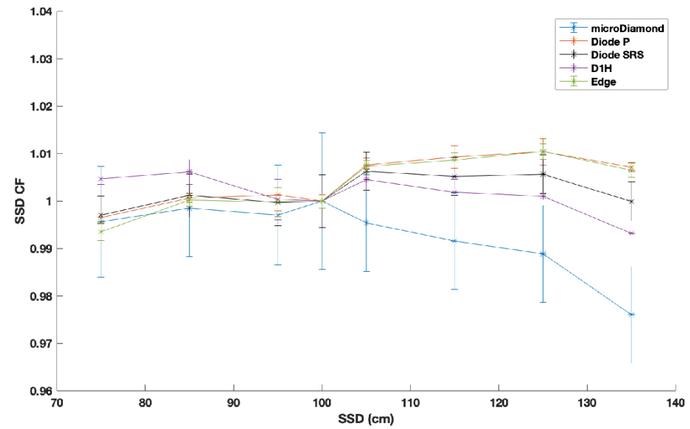

Fig. 2: Dose-rate dependence as a function of SSD of the microDiamond detector and various diode detectors. The combined uncertainty at k=2 is shown.

• The microDiamond detector was found to have the smallest signal-to-noise ratio relative to the other detectors used in this study. Within the SSD range of 75 cm to 135 cm, all detectors, except microDiamond, were found to be "SSD" independent up to 1%. The microDiamond detector was found to over-respond up to 2% at extended SSDs compared to the ion chamber response.

Methods

One commercially available diamond detector (PTW 60019 microDiamond) and four diode detectors (PTW Diode P, PTW Diode SRS, Exradin D1H, and Sun Nuclear EDGE) were compared with an ionization chamber (Exradin A18) in this study. A 6 MV photon beam from a Varian 21EX linear accelerator (Varian Medical System, Palo Alto, CA) was utilized for all measurements. All of the detectors were placed at a depth of 1.5 cm inside a 1D water tank (Sun Nuclear, Melbourne, FL) with the field size set to 10x10 cm^2 and SSD of 100 cm.

The dose-rate dependence was studied by varying both NRR and SSD. 100 MUs were delivered during each irradiation and the generated charge was collected using a MAX4000 electrometer (Standard Imaging, Middleton, WI). For all of the diodes and diamond detectors, a pre-irradiation dose was given until a stable current reading of within 0.5% was observed. The SSD was set to 100 cm for the NRR dependence study and the NRR was set at 600 MU/min for the "SSD" dependence study. The dose-rate dependence as a function of NRR of the linac was studied by varying the NRR from 100 MU/min to 600 MU/min settings. All of the readings were normalized to the reading acquired at 600 MU/min.

The dose-rate dependence as a function of SSD was investigated by varying the SSD from 75 cm to 135 cm. An SSD correction factor was calculated by normalizing the diode and diamond readings by the Exradin A18 ionization chamber readings:

$$\text{SSD CF} = \frac{(M_{\text{diode}}/M_{\text{ic}})_{100cm}}{(M_{\text{diode}}/M_{\text{ic}})_{SSD}}$$

where M_{diode} and M_{ic} are diode/diamond and ionization chamber readings, respectively.

Conclusions

- The microDiamond and Diode P detectors showed the largest dependence on the NRR with a variation of up to 2%. All of the other detectors displayed no NRR dependence within the 1% limit.
- The microDiamond detector was found to have the largest SSD correction factor at extended SSDs among all detectors. All investigated diode detectors demonstrated minimal SSD dependence with $< 1\%$ correction factors.
- All of the studied detectors were found to have a dose-rate dependence of up to 2%. Therefore, these detectors are suitable for use within this limit.

References

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