PhD Thesis Title: Development of an LED Array for Dosimetry in Diagnostic Radiology

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ABSTRACT:

The first goal of this research is to explore the dosimetric response of surface mount device (SMD) light-emitting diodes (LEDs) to diagnostic X-rays and radiotherapy beams. The response to the diagnostic X-rays was examined using five LED strip colors based on the variable diagnostic X-ray parameters, including kilovoltage peak (kVp), tube current-time product (mAs), dose, and source to detector distance. The response to the radiotherapeutic beams was preliminarily investigated with a cold white LED, while varying the irradiation angle, beam energy, source-surface distance, field size, and absorbed dose.

This work's second objective is to amplify the diagnostic X-ray radiation-induced signals by increasing the number of LED chips and using an amplifier board. Additionally, a detection capability comparison between the cold white LED and a bpw43 photodiode is presented.

Finally, this investigation aims at designing and fabricating an LED array prototype (LAP) dosimetric system. The LAP comprises a 20 × 20 cm^2 array of photovoltaic cold white LED chips sandwiched between two intensifying screens. The system was placed inside an air cavity shielded from optical noise using black vinyl tape. The screens converted the diagnostic X-ray beams to fluorescent blue light. The LEDs herein were executed in detector mode; thus, they converted the fluorescent light into radiation-induced currents. These analog currents were quantified and converted into digital voltage signals using a digital multimeter. The LAP characterization was implemented with (i) beam qualities established by the IEC 61267, i.e., RQR 7 (90 kVp) and RQR 8 (100 kVp), and (ii) low (25 mAs) and high (80 mAs) beam quantities defined herein. The cold white LED demonstrated a better dosimetric behavior. The LED chip number increment produced higher amplification coefficients than the amplifier board. Both the photodiode and LEDs demonstrated similar signal precision, linearity to mAs (dose), and dose and energy dependence. The minimum dose detected by the LAP was 0.1386 mGy, whereas the maximum dose implemented here was ~ 13 mGy. The LAP absorbed dose linearity was 99.18% and the mAs linearity was 98.64%. The sensitivity of the system fluctuated by ± 4.69%, ± 6.8%, and ± 7.7% during energy, dose, and dose rate variation, respectively. Two LAP data sets were 89.93% repeatable.

Thus, this study proposed an ultrathin (5 mm), lightweight (130 g), and relatively low cost (US $255) LED-based dosimetric prototype system. This prototype's dosimetric mechanism was simple, efficient, and accurate.

References to author publications that relate specifically to the dissertation:

1. **Edrine, Damulira**, et al. "Development and characterization of an LED-based

detector for dosimetry in diagnostic radiology" *Physics in Medicine & Biology* 66 (2021): 8. https://doi.org/10.1088/1361-6560/abef44

2. **Edrine, Damulira**, et al. "Application of Bpw34 photodiode and cold white LED as diagnostic X-ray detectors: A comparative analysis" *Applied Radiation and Isotopes* 170 (2021): 109622. https://doi.org/10.1016/j.apradiso.2021.109622

3. **Edrine, Damulira**, et al. "Amplification of Radiation-Induced Signal of LED Strip by Increasing Number of LED Chips and Using Amplifier Board." *Applied Sciences* 10 (2020): 651. http://doi.org/10.3390/app10020651

4. **Edrine, Damulira**, et al. "Comparison of Current–Voltage Response to Diagnostic X-rays of Five Light-Emitting Diode Strips" *Applied Sciences* 10 (2020): 200. https://doi.org/10.3390/app10010200

5. **Edrine, Damulira**, et al. "A Review: Photonic Devices Used for Dosimetry in Medical Radiation." *Sensors* 19 (2019): 2226. https://doi.org/10.3390/s19102226

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1. **Edrine, Damulira**, et al. "Current-Voltage Response of Cold White LED Strip to Radiotherapeutic Electron and Photon Beams: A Preliminary Study." *Journal of Physics: Conference Series* 1505 (2020): 1200. http://dx.doi.org/10.1088/1742-6596/1505/1/012008