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<u>Anthony J. MacKay Student Paper Contest Submission</u>

Paper Title: ***A novel method for resolving the energy spectrum of a radiation beam using doped plastic scintillators***

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Background

Knowledge regarding the *quality* of radiation in addition to absorbed dose can be very useful. The potential biological damage caused by low energy x-rays or heavy charged particles can be many times more severe relative to 1 MeV photons. In cancer radiotherapy, absorbed dose is used to optimize the amount of radiation delivered without accounting for energy variations of changes in radiation quality. Numerous studies have now shown that the impact of low energy scattered radiation on the radiation damage to the patient cannot be ignored and must be measured for optimal treatment. In the radiation protection industry, a radiation weighting factor (W_R) is used to account for this variation, however, these factors are often gross estimations. By measuring the energy spectrum, many characteristics of the radiation source/beam can be resolved. Using the NIST collisional stopping-power database, the linear energy transfer spectrum can be obtained if the energy spectrum is known. Similarly, the maximum relative biological effectiveness can be determined from the energy spectrum as shown by Nusrat et al (2018). This paper presents a novel technique for resolving the energy spectrum using doped plastic scintillators.

Methods

Plastic scintillators are organic materials which emit visible light upon interacting with radiation. Their response is intrinsically dependent on the stopping power of incoming radiation, as shown through Birks' Law (Birks, 1964). Through organometallic chemistry, various amounts of high-Z dopants can be incorporated into the scintillator volume. By adding high-Z elements, the radiation interaction cross sections of the scintillator can be tuned in order to change its sensitivity to certain energy ranges; an example of this is more high Z dopants inducing greater sensitivity to low energy x-rays.

In this work, 4 different scintillators were used. These included: 0%, 1.0%, 1.5%, and 5.0% Pb doped plastic scintillators (Eljen Technologies, Sweetwater TX). In order to resolve the energy spectrum, two main challenges needed to be overcome: 1) the design and fabrication of a detector apparatus, and 2) determining the responses of each type of scintillator to known photon energies. The detector apparatus was constructed allowing the scintillator light to be guided via an optical fiber to a Hamamatsu H17021 photosensor module. Measurements were conducted at Sunnybrook Health Sciences Center for high (6, 9, 12, 15 MeV e-) and low energy (100, 180, 250, 300 kV x-rays) radiation beams.

By knowing the response of each scintillator to various monoenergetic energy bins, the 'Response Matrix (**R**)' was created; this was done using Geant4.10.3 Monte Carlo simulations. The 'Signal Matrix (**S**)' was obtained through measurements. Using these two pieces of information, the energy spectrum (∅) can be resolved through: $\emptyset = \boldsymbol{S} \times \boldsymbol{R}^{-1}$.

Results

Each scintillator was modelled in Geant4.10.3 and the model was validated by comparing the light emitted by each scintillator in the simulated and measured case. Through this, an accurate scintillator model was established. The response matrix was created using energy bins of varying sizes; measurements were obtained using the detector apparatus. It was found that the doping with 5.0% Pb increased the sensitivity to low energy radiation (100 kV x-rays) by 474% (+/- 0.78%) relative to the highest energy used (15 MeV electron beam). As the doping concentration was decreased, the low energy sensitivity decreased significantly (141% +/- 0.22% for the 1.0% Pb doped scintillator). Using these measured and simulated results, the energy spectrum can be resolved.

Conclusion

In both radiotherapy and radiation protection, information regarding radiation quality is essential. Using differently high-Z doped plastic scintillators, the energy spectrum (and subsequently, the LET and maximum RBE) can be resolved using a simulated response matrix and the detector apparatus used in this study.

References

- Nusrat et al. 2018. Evaluating the biological impact of increased scattered radiation in single and composite field radiation beams. Biomedical Physics & Engineering Express (IOP). https://doi.org/10.1088/2057-1976/aab0db
- Birks, JB. 1964. The Theory and Practice of Scintillation Counting. Pergamon Publishing.