Simulation of Temporal Dosimetry Methods using LiF: Mg, Ti as a Chain-of-Custody Detector

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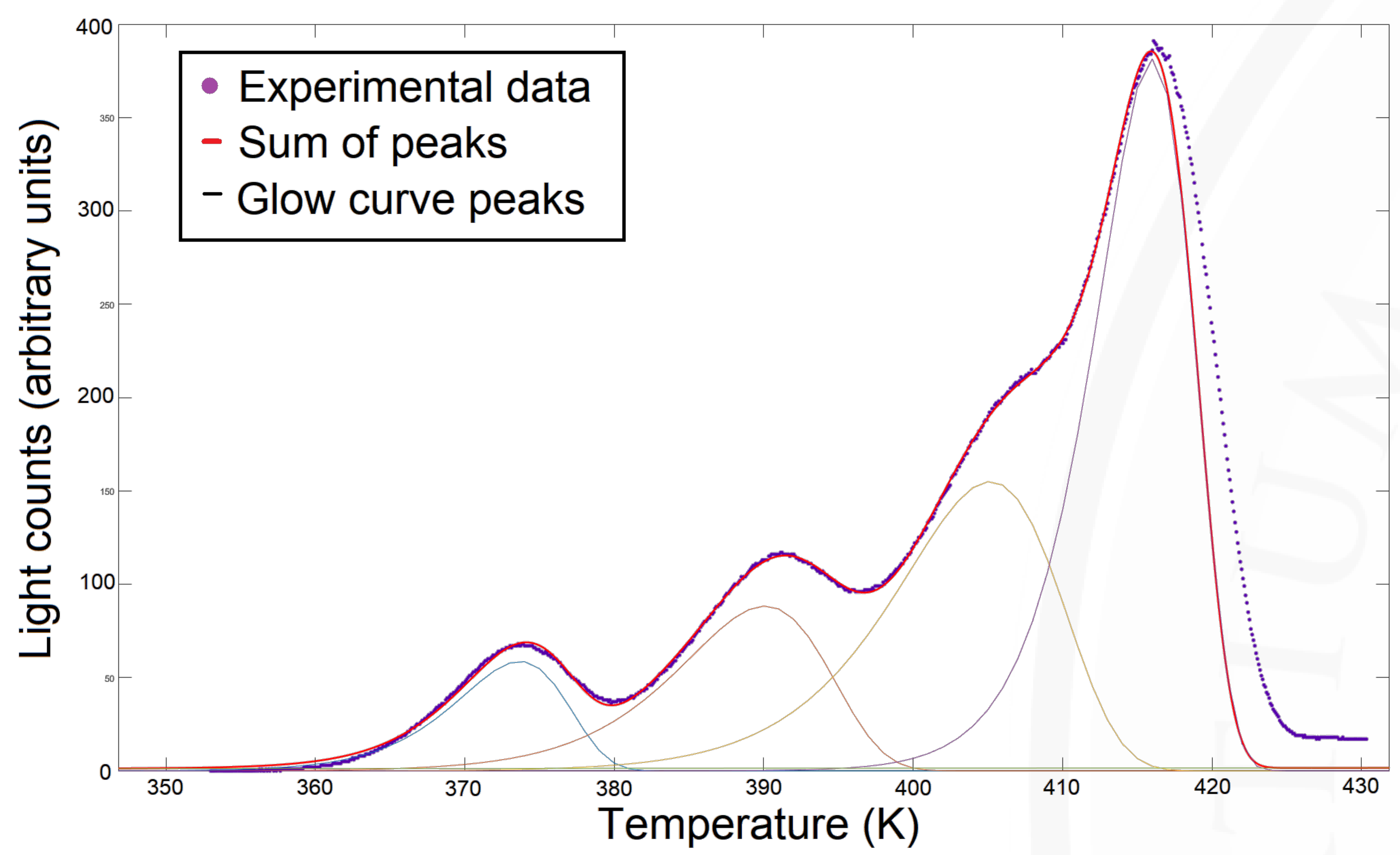
Introduction and Motivation

Dosimeters are devices used to monitor environmental and personnel radiation dose. Passive dosimeters such as thermoluminescent dosimeters (TLDs) capture ionizing radiation. The energy from the ionizing radiation is converted into electron-hole pairs. Electron-hole pairs resultant from the radiation exist in different energy (trap) states. In TLDs, heating causes the recombination of electron hole pairs which induces a release of visible light proportional to the dose received. Traps are liberated at different threshold temperatures corresponding to their respective energies.



▲ Fig. 1: Typical experimentally measured glow curve for LiF: Mg,Ti (TLD100) emitted light as a function of temperature

Each trap state will decay under environmental conditions at a different rate according to its energy state or "trap depth". These decays can be represented as fading functions shown empirically to follow the equation:

$$G(t) = Ae^{-k_1 t} + Be^{-k_2 t}$$

Thus the signal read out from the TLD becomes:

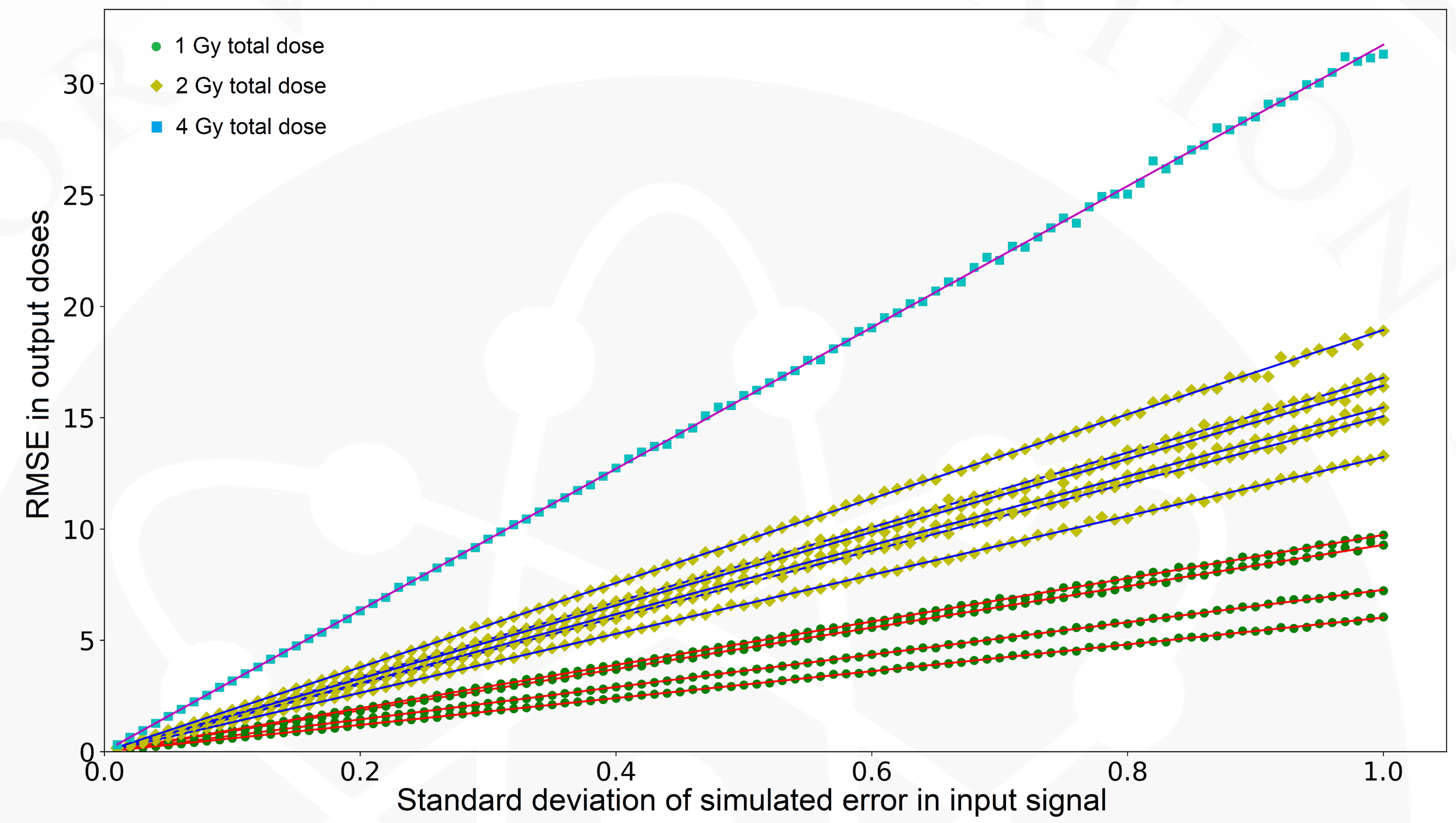
$$\bar{S} = \bar{D} \cdot \bar{G}$$

where S is the signal (1 x n), D is the dose (n x 1), G is the decay matrix (n x n), and n is the number of peaks. Each element in the signal and dose matrices will intrinsically correspond to different time intervals in the usage period of the dosimeter. These will be called "dose reconstruction time intervals" when calculated from the signal and decay matrices. For ease of use and cost efficiency, a Monte Carlo method simulation has been written to preliminarily evaluate the merit of this method, that is the topic of this poster.

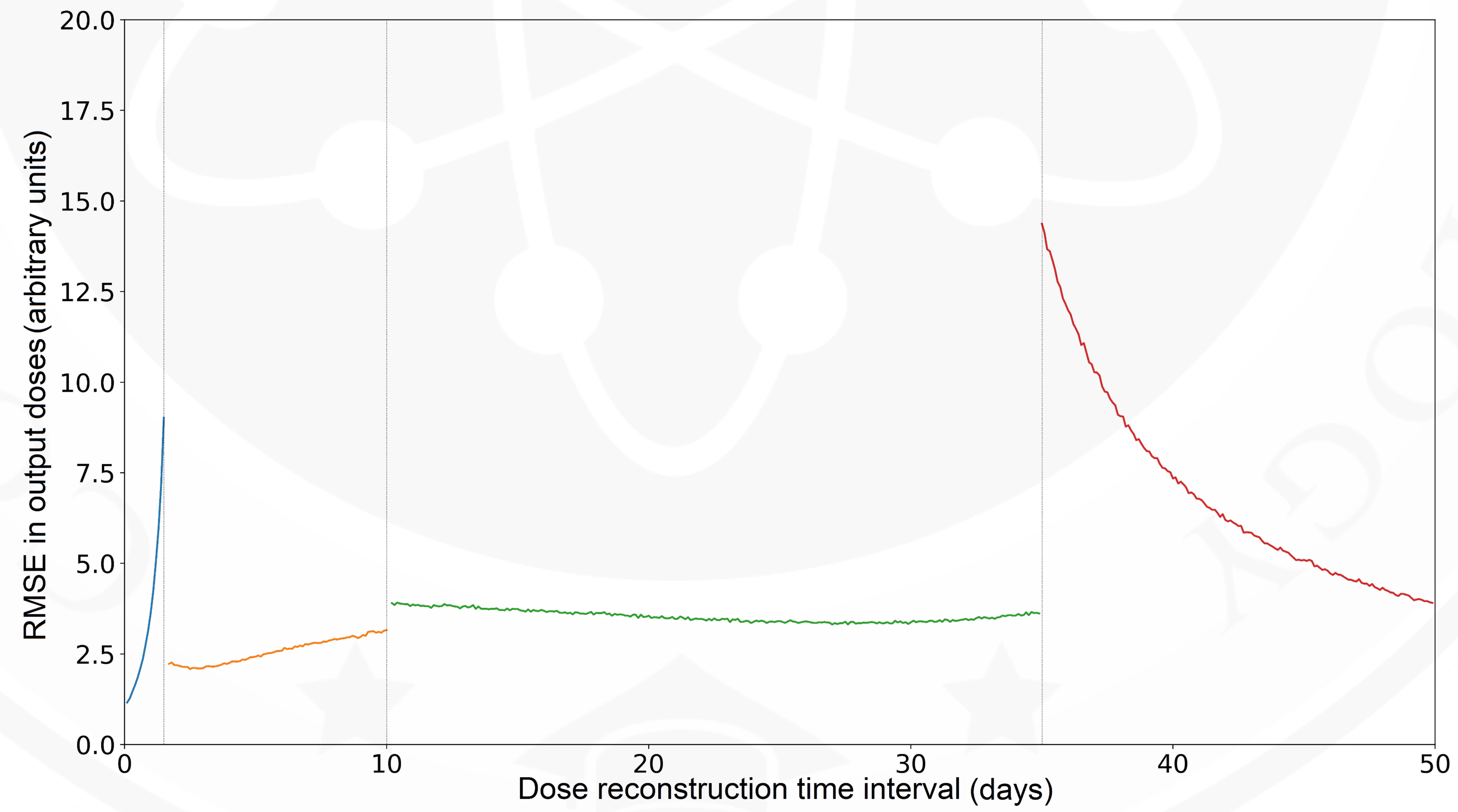
Mission Relevance

This project is focused on using Monte Carlo method simulation to evaluate passive integrating TLD materials as temporal chain-of-custody detectors.

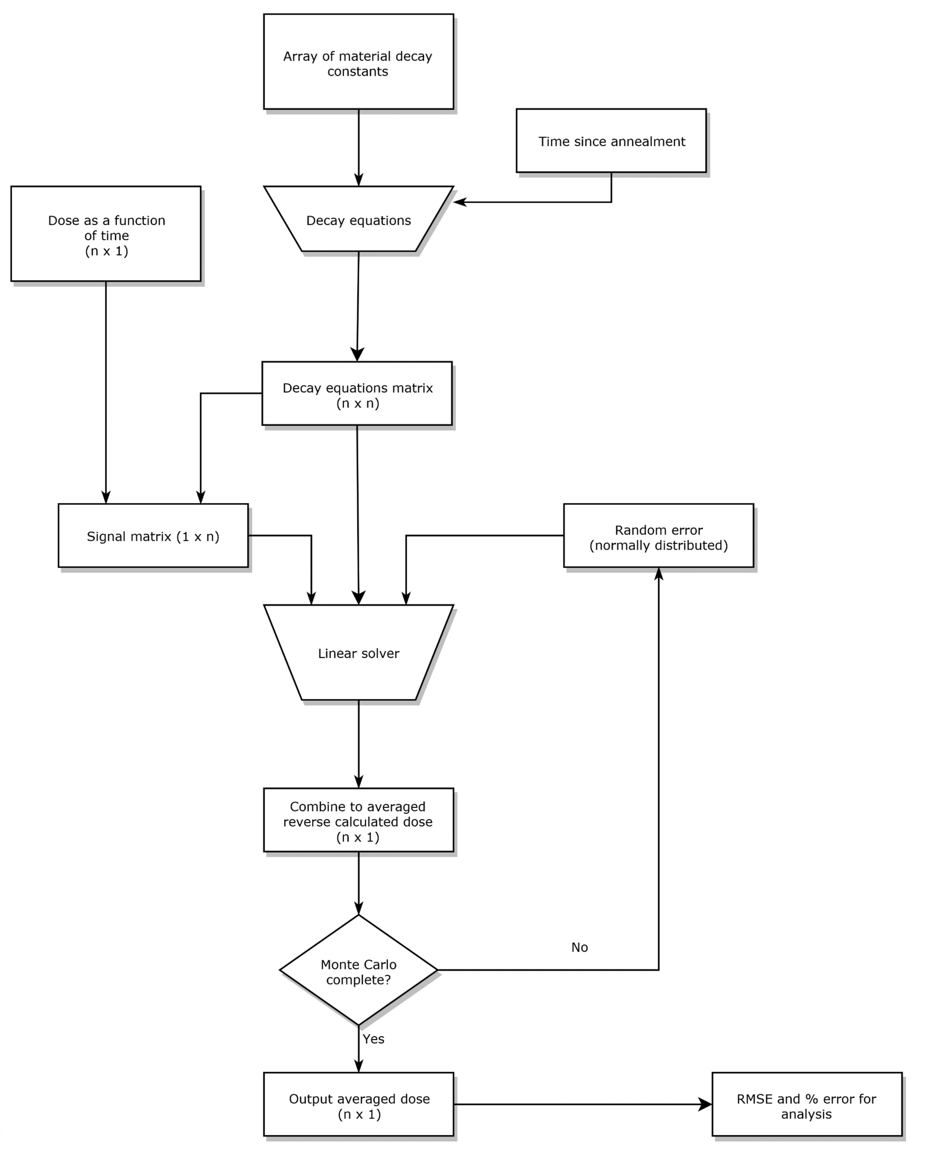
Technical Work and Results



▲ Fig. 2: Standard deviation of the simulated error in the integrated signal (normalized as a percentage vs RMSE of the output doses (not normalized)



▲ Fig. 3: RMSE of the output doses as a function of dose reconstruction time intervals chosen for each peak.



▲ Fig. 4: Flow diagram of python code created for this project

CVT Impact

Undergraduate Students

Jack H. Thiesen III (academic credit)

- Coauthor 2 planned journal articles, 1 Engineering Graduate Symposium poster, 1 CVT workshop poster

* Post NERS BSE plans: undecided

Conclusion

From this data it is reasonably clear that the simulation functions as expected and that it can find the time intervals of lowest error. Further experiments are required to better assess our objectives.

References

Kearfott, Kimberlee J. Integrative and Real-Time Radiation Measurement Methods and Systems. 25 Sept. 2012. (Patent)

Harvey, John A., et al. "Characterization of the Glow-Peak Fading Properties of Six Common Thermoluminescent Materials." Applied Radiation and Isotopes, vol. 68, no. 10, Oct. 2010, pp. 1988–2000

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