Simulation of Radiation Dose Response in Phantom for CT

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Introduction: X-ray CT is widely used in diagnostic medical imaging. The radiation dose produced by the scanner to the patient is conventionally determined by an ionization chamber in a phantom of tissue equivalent characteristics. On a fundamental level, the radiation absorbed dose, J/kg, can also be determined directly by the temperature rise in the absorbing material.

We simulate the temperature response in a high density polyethylene (HDPE) phantom and compare with measured data.

Computational Methods: Study using "Heat transfer in solids" gives a transient temperature response for a polyethylene phantom with axial symmetry under the excitation of a spatially restricted heat source simulating a time averaged rotating CT beam with 20 periodic cycles ($\tau = 2.8$ s per rotation), with a decaying intensity toward the center of the cylinder. The outer boundaries are held at room temperature.

$$\rho C_p \frac{\partial T}{\partial t} - \nabla \cdot (k \nabla T) = Q$$

$$Q = Q_0 e^{-ar+b} \left(1 + \sin 2\pi t/\tau\right) \ (z_{min} < z < z_{max})$$

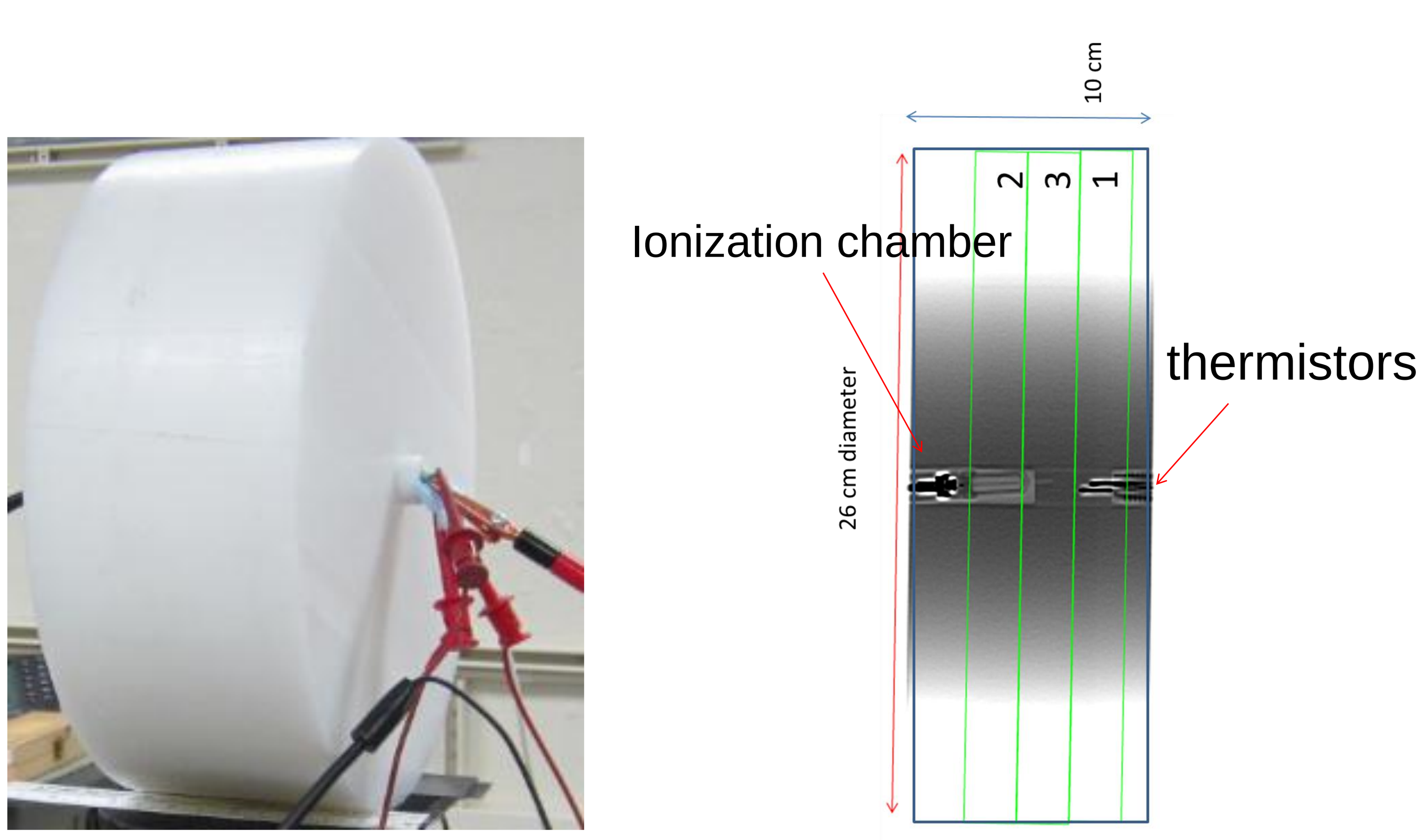


Figure 1. Left: Photo of PE phantom with electrical wiring for thermistors. Right: CT projection image showing on axis arrangement of an ionization chamber and the pair of thermistors.

Results: Fig. 2 shows the model and the accumulative temperature variation at a point in the tip of the thermistor following the oscillatory heat source. The output in Fig. 3, from the model adding glass and wire materials, better resembles the experimental data.

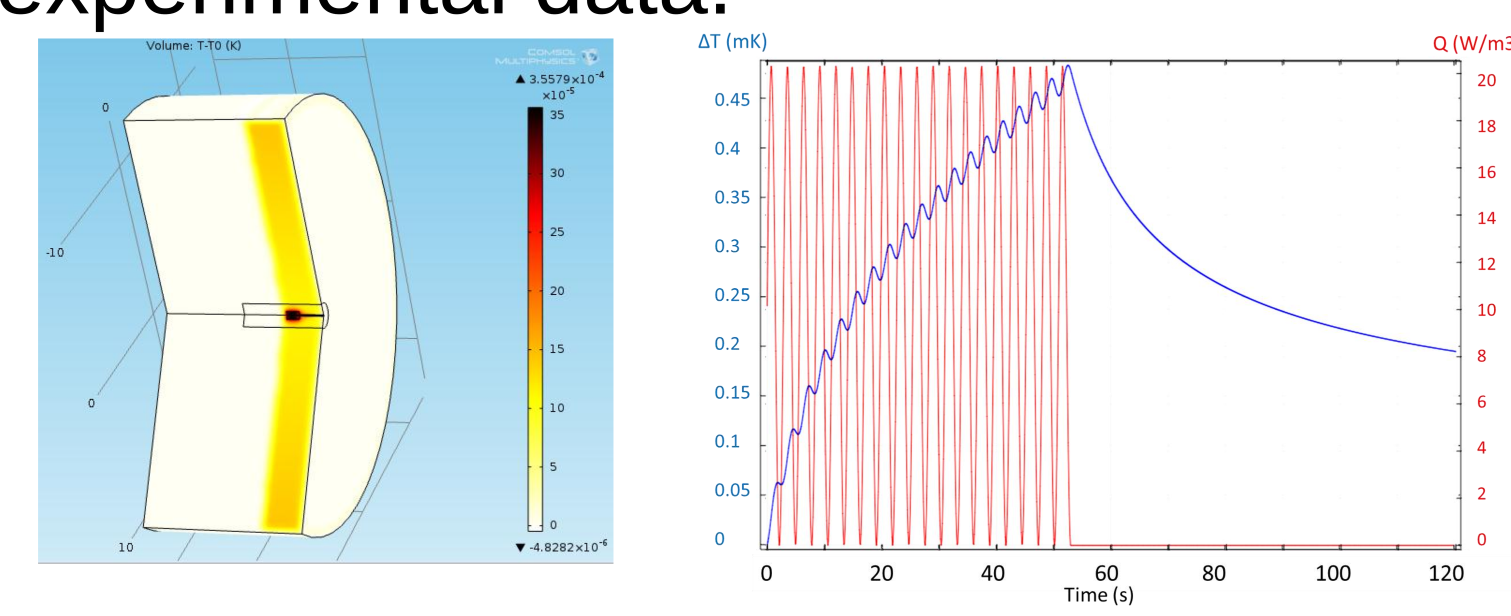
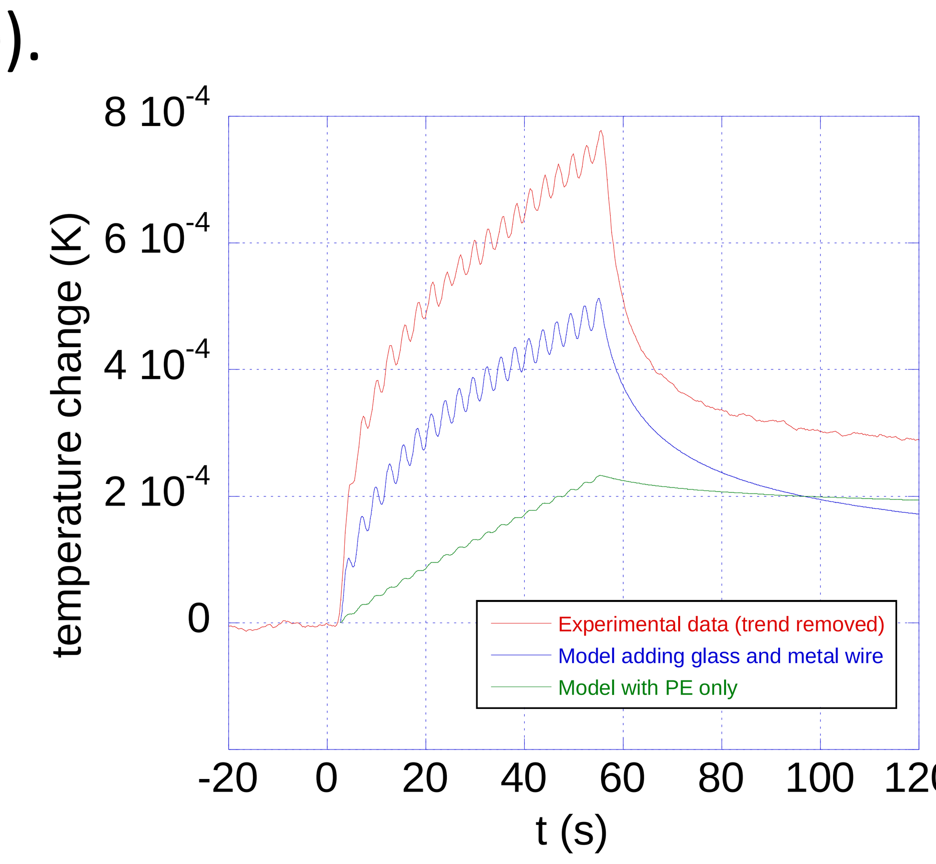


Figure 2. Model with 2D-axial symmetry of the PE phantom with inserts, a strip of which irradiated by a time varying heat source simulating the CT beam (red curve). The temperature change at 20 s after "CT beam on" is shown (blue curve).

Figure 3: Output of temperature waveform:
Green: PE only.
Blue: incorporating the sensing thermistors into the model.
Red: experimental data.



Conclusions: The ultimate goal of this work is to lead to a PE calorimeter for CT dosimetry. The simulation can provide an entire temperature distribution in the whole phantom, which essentially gives the dose map in 3D. Future work needs to address the excess heat and heat defects. Simulations with a more realistic 3D phantom model with rotating CT beam are also being undertaken.