Thermo-Acoustic Simulation of a Piezoelectric Transducer for Interstitial Thermal Ablation with MRTI Based Validation

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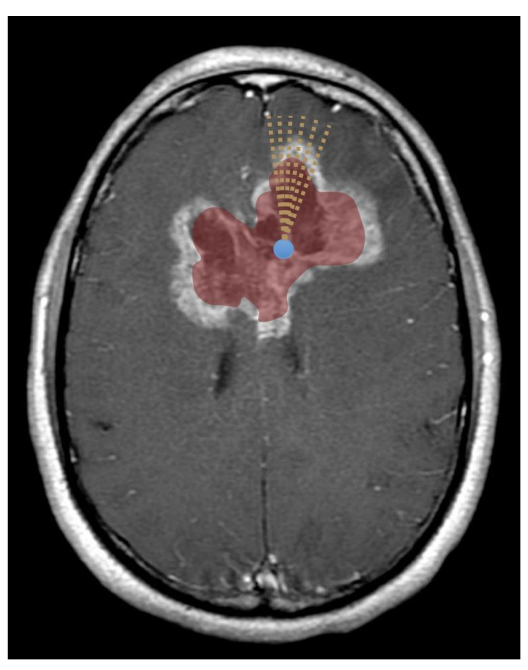
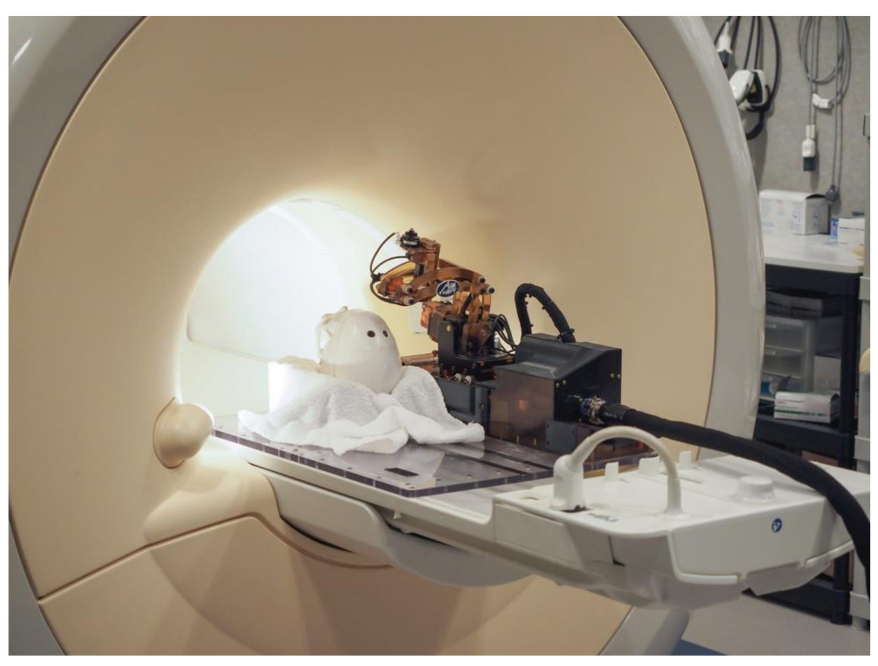
INTRODUCTION: Achieving appropriate margins when surgically treating complex shaped tumors is vital for reducing remission [1]. This can be particularly challenging in delicate tissues such as the brain. Treatment options that closely trace asymmetric tumor boundaries can conserve healthy tissue while removing cancerous cells.





NEEDLE BASED THERAPEUTIC ULTRASOUND (NBTU): Heating produced by directed ultrasound waves created by a piezoelectric transducer can be used to ablate a desired shape.

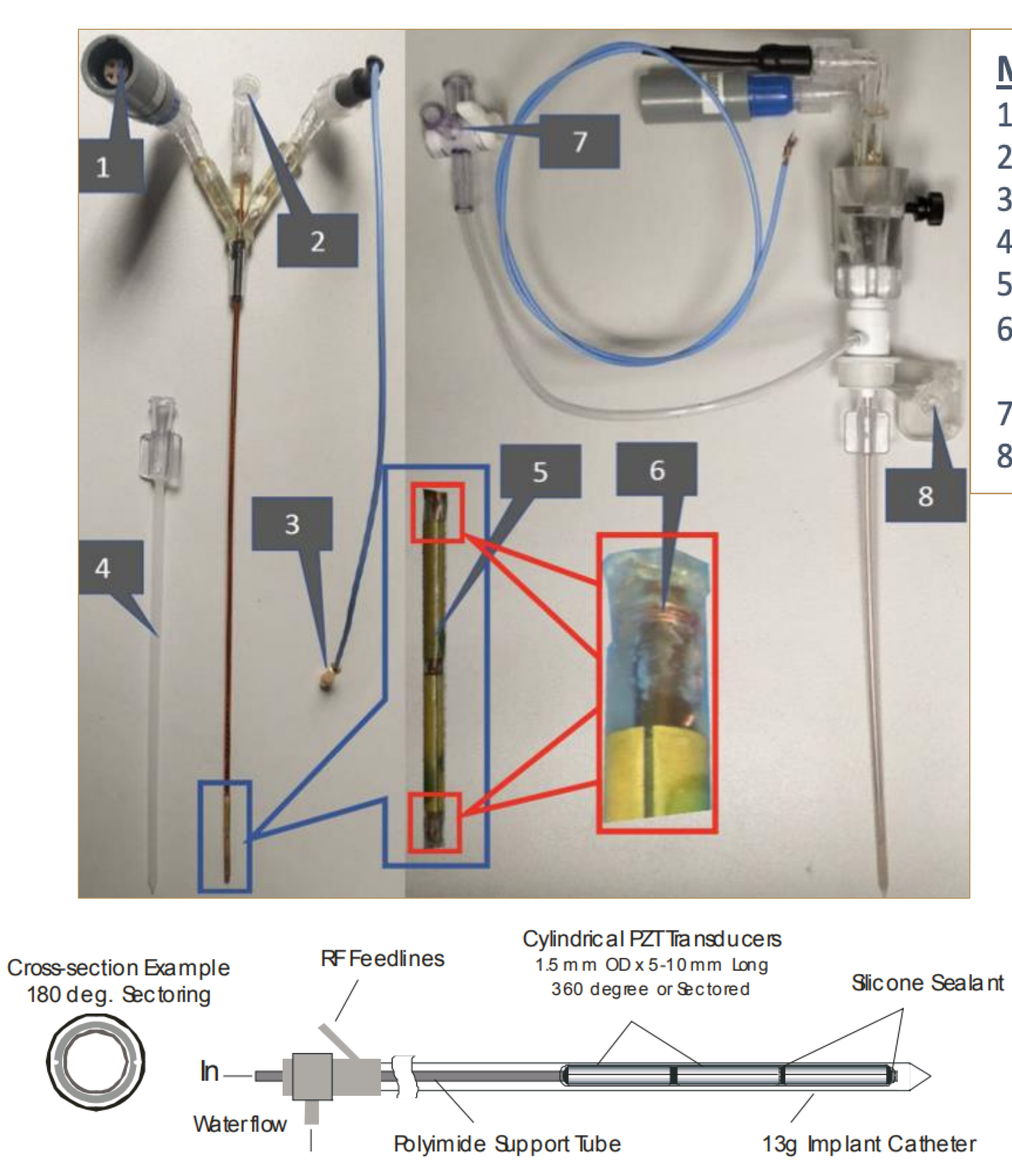


Figure 1. NBTU probe and schematic

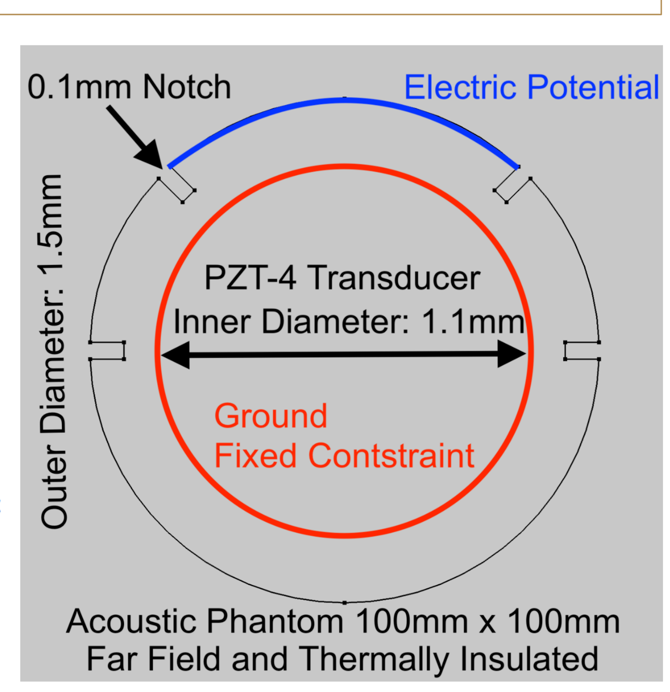
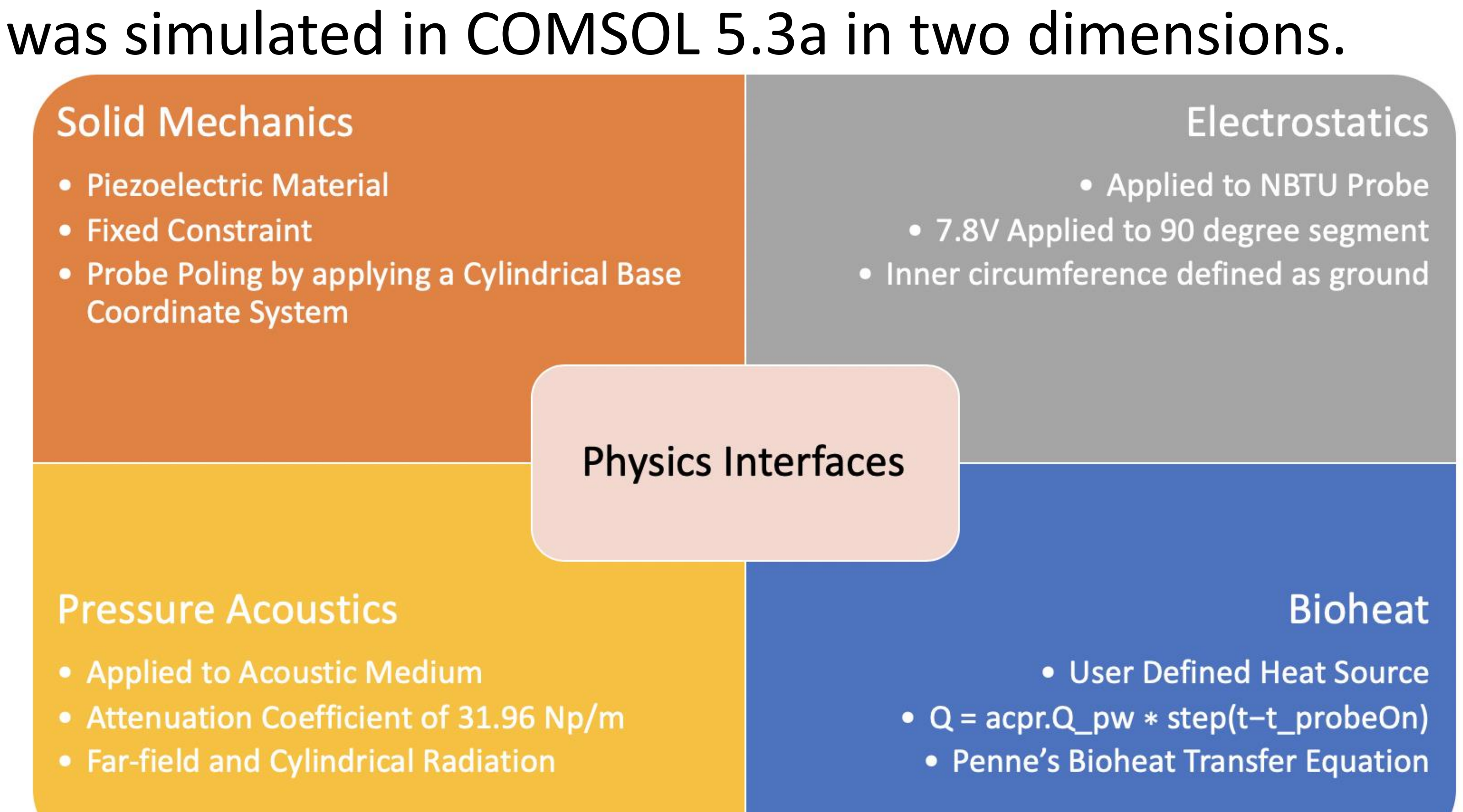


Figure 2. COMSOL simulation setup

COMPUTATIONAL METHODS: Transducer geometry and material as well as medium properties determine thermal propagation characteristics. The NBTU probe was simulated in COMSOL 5.3a in two dimensions.



STUDY RESULTS: Frequency sweep from 1 MHz to 10 MHz at 0.1 kHz increments is shown in fig 3. Resonant frequency of 5.237 MHz was selected. An acoustic pressure field was computed at this frequency and is shown in fig 4. A time domain study using these results was conducted to simulate heating for 240 seconds with 240 seconds of cooling.

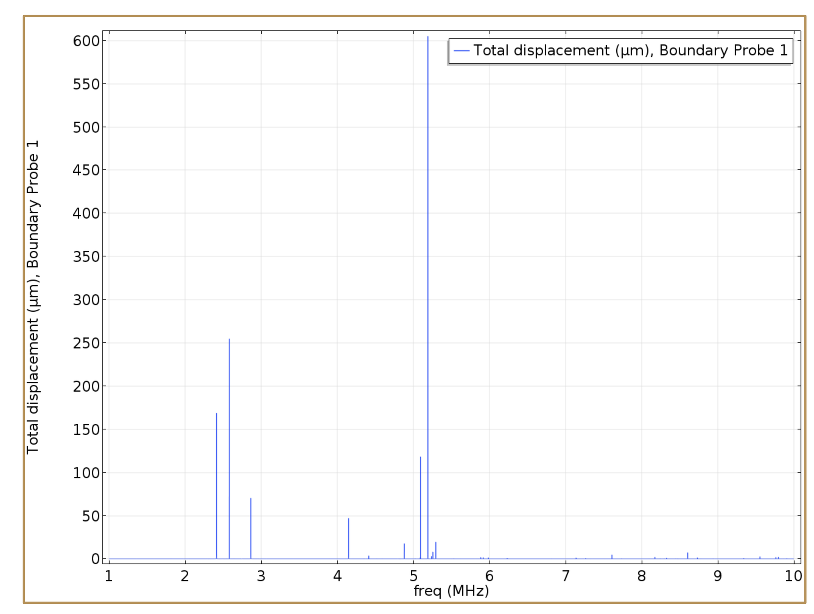


Figure 3. Frequency Sweep

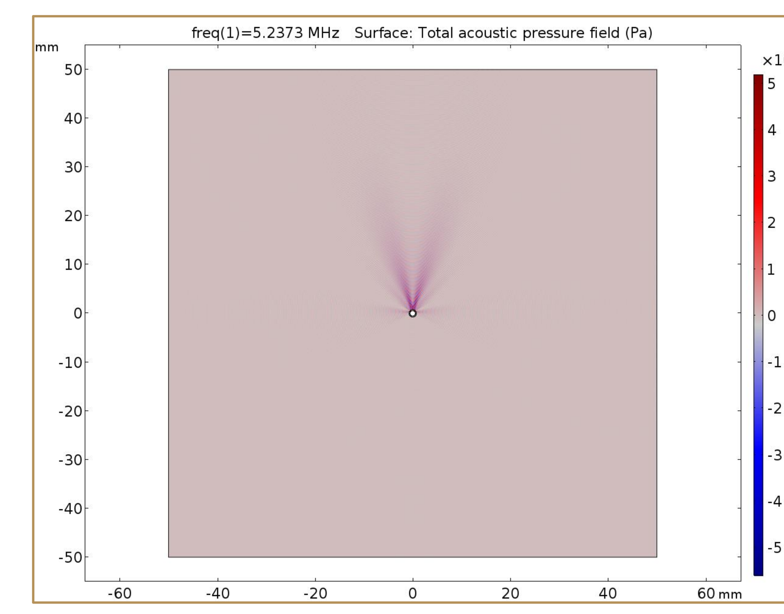


Figure 4. Acoustic Pressure Field

EXPERIMENT AND RESULTS: Model validated experimentally under MRTI. A phantom built using [2] and whose acoustic properties were modeled in simulation was used, see fig 5. A vertical line crossing through x=0 for the simulated and measured temperature maps at t=240s is shown in fig 6. The computed RMS error through this vertical line was 0.53 °C with a maximum computed difference of 1.54 °C

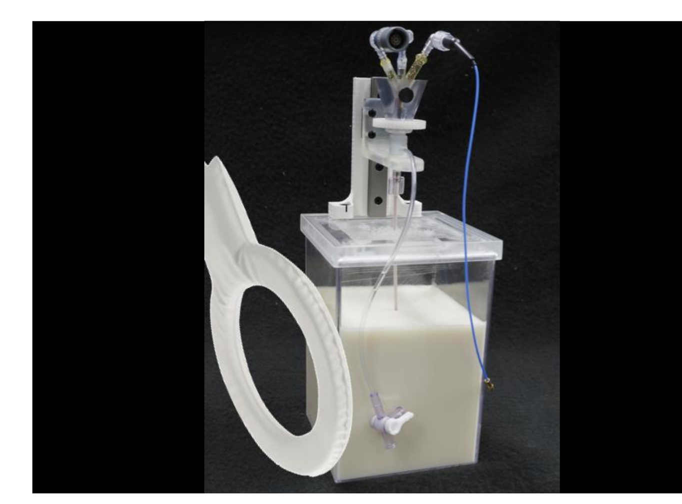


Figure 5. NBTU Experimental Setup

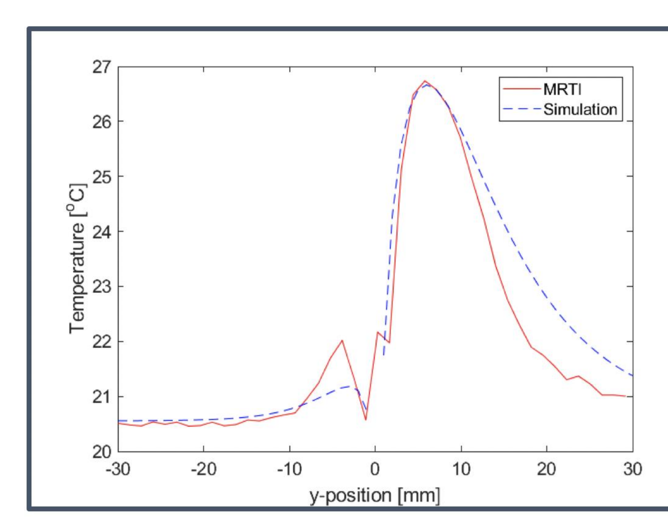


Figure 6. Plotted vertical readings through t = 240s

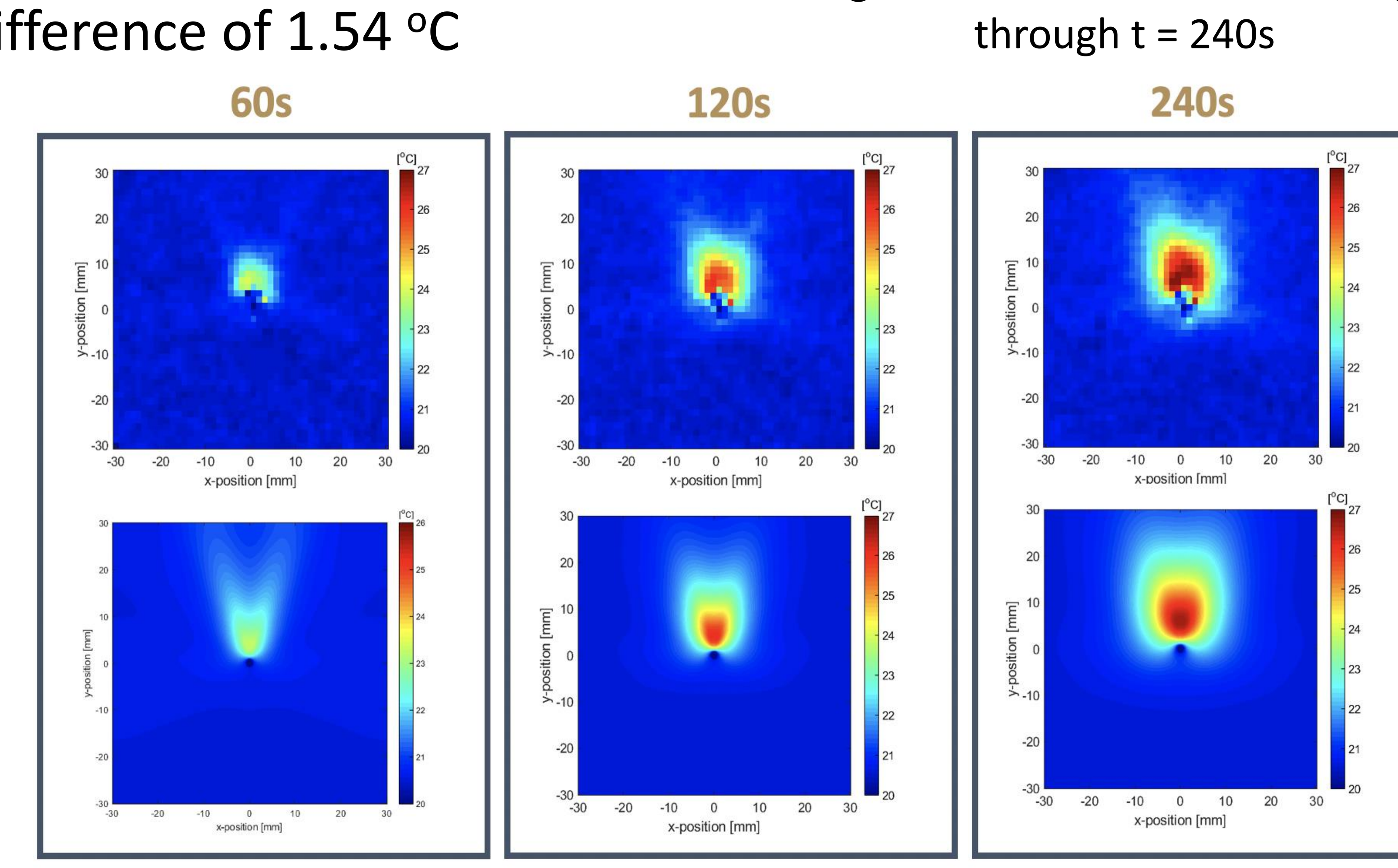


Figure 7.Comparison between MRTI readings (top) and model (bottom)

CONCLUSION: A Multiphysics simulation of a piezoelectric transducer for interstitial NBTU brain tumor ablation was presented. Future work:

- 3D modeling of ablation patterns
- Dynamic models of rotating probes for closed loop control
- Non-static material properties and blood perfusion

REFERENCES:

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