COMSOL CONFERENCE BOSTON 2012

COMSOL Thermal Model for a Heated Neural Micro-Probe

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Excerpt from the Proceedings of the 2012 COMSOL Conference in Boston

Neural Probes

Limitations

- Simultaneous stimulation and sensing
- Spatial resolution
- Specificity

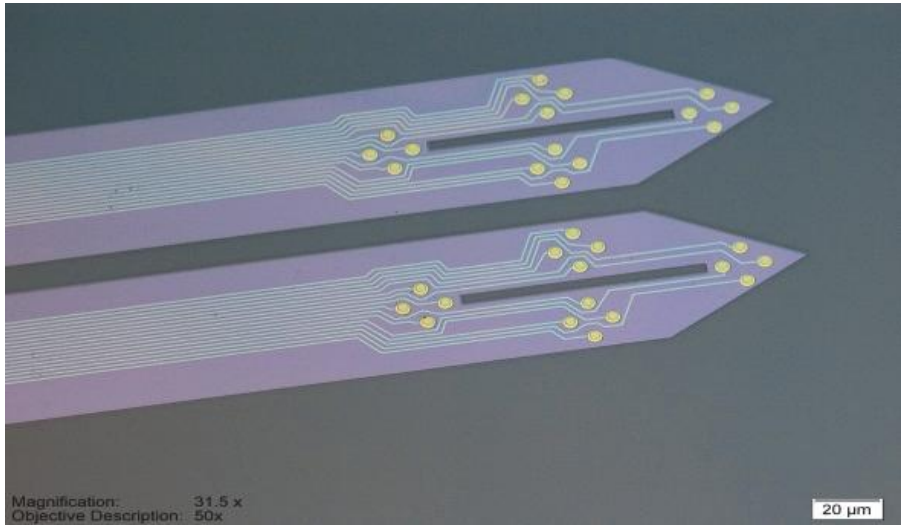
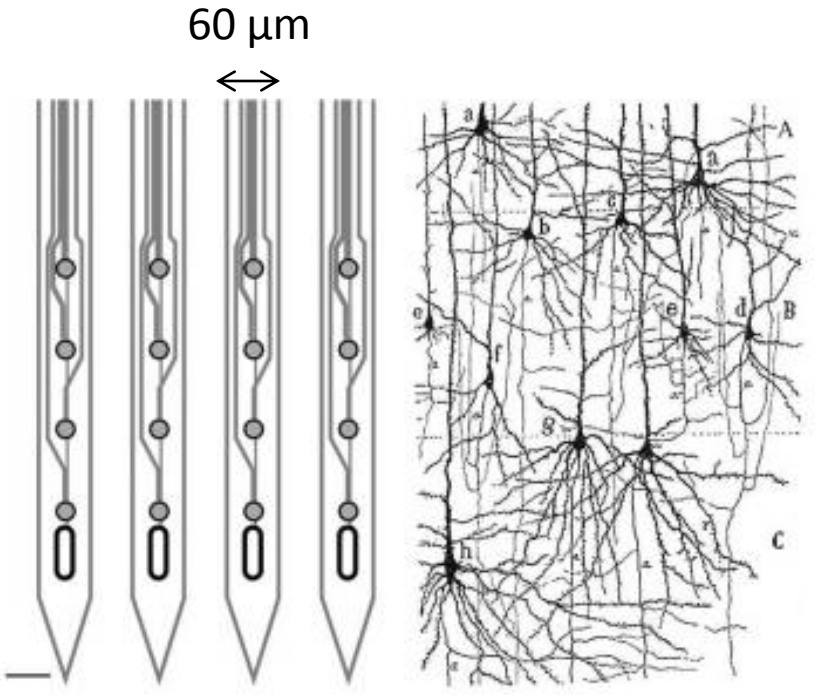


Figure provided by SB Microsystems and reproduced with permission.

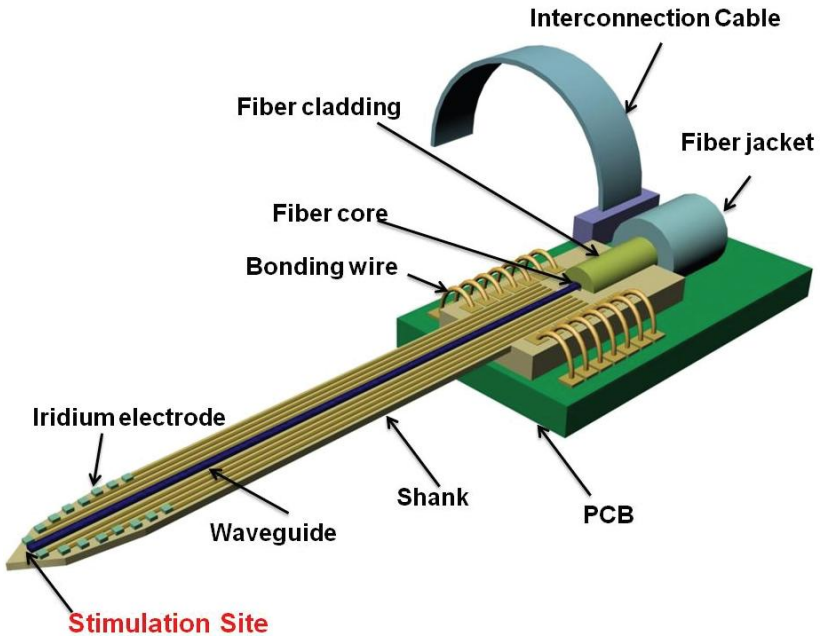


WISE et al, Proceedings of IEEE, VOL. 92, NO. 1, JANUARY 2004, pp 76-97

Optical Neuroprobe Technology

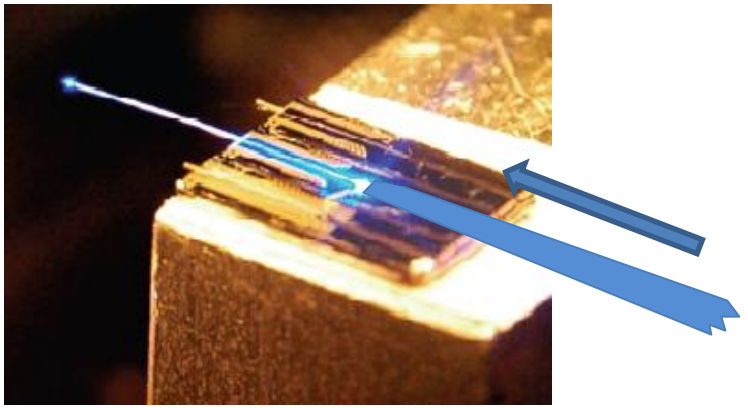
- Large coupling losses
- Too bulky for large networks

http://www.technologyreview.com/files/34054/mouse_x220.jpg
In “Decoding the Brain with Light”



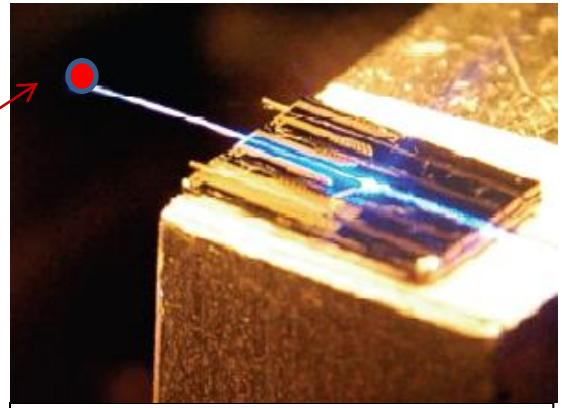
Cho, H.W. Baac, and E. Yoon, “A 16-site neural probe integrated with a waveguide for optical stimulation,” in *Center for Wireless Integrated Microsystems,* Ann Arbor, MI, pp. 995-998.

Localized Light Generation



Fiber Tail from source where light is generated. Majority of heat is generated at the light source

Light source on tip. All inefficiencies generate heat.



The Yoon et al. Light Emission Neuroprobe

Research Objectives

- **1. Develop a Thermal Model**
- **2. Design a Mock Heated Probe**
- 3. Conduct Physical Experiments
  - Quantify heated region
  - Agar gel matrix
- 4. Investigate Active Thermal Management

❖This paper will describe the thermal model and the design of the heated probe

Thermal Model: Bioheat Equation

The Pennes Bioheat Equation

$$\rho C_p \frac{\partial T}{\partial t} = \nabla(k\nabla T) + \rho_b C_b \omega_b [T - T_{blood}] + \dot{q}$$

Energy Storage

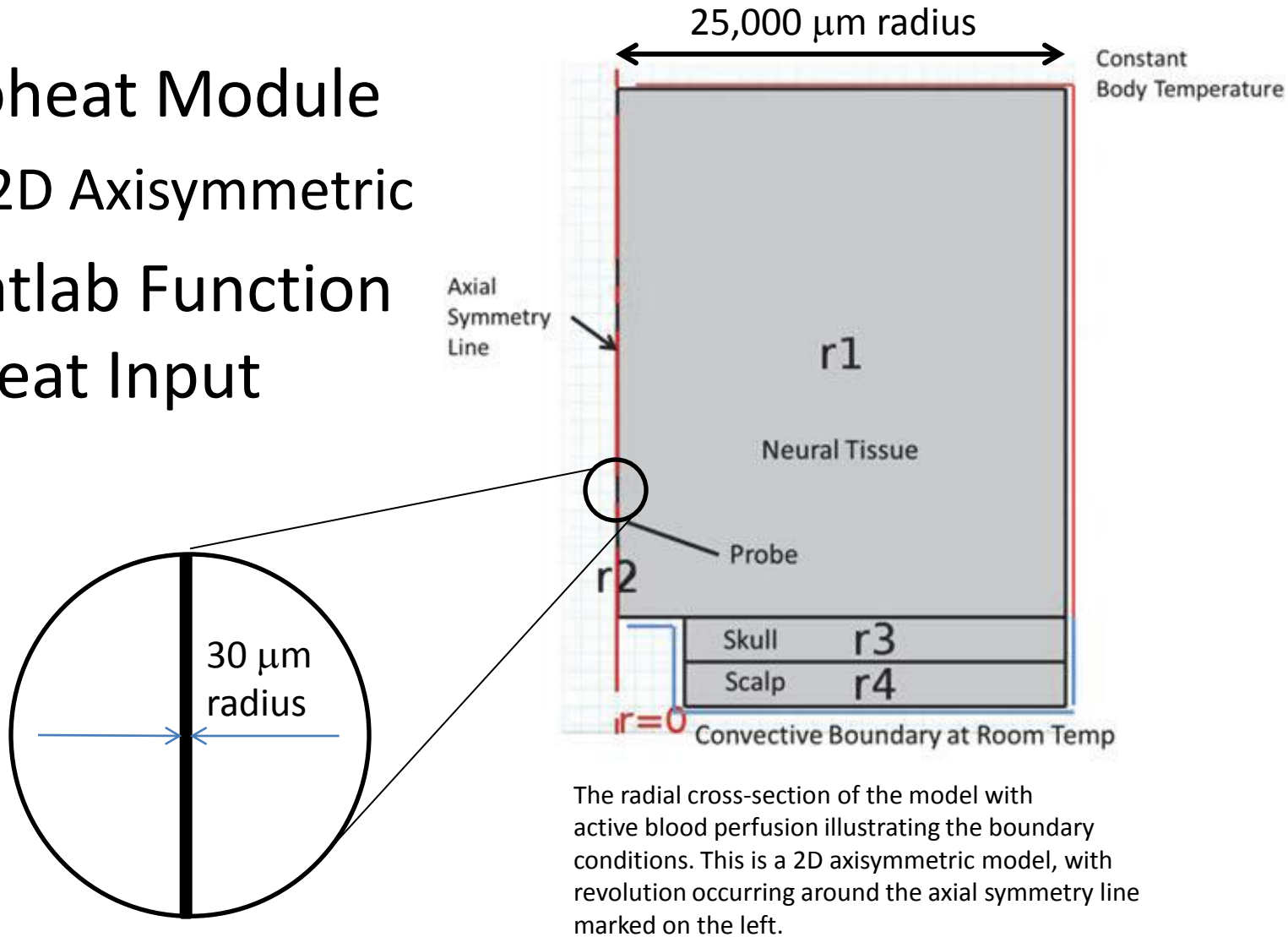
Thermal Diffusion

Blood Perfusion (convection)

Volumetric Heat Generation

Modeling Details

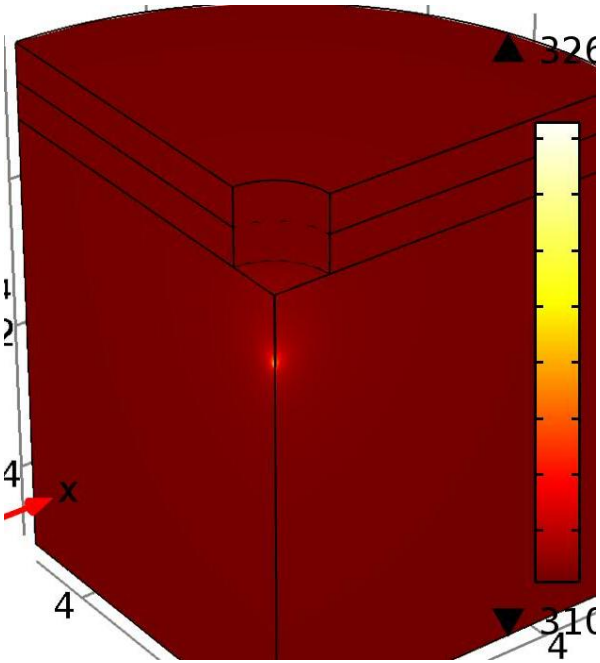
- Bioheat Module
  - 2D Axisymmetric
- Matlab Function
  - Heat Input



The radial cross-section of the model with active blood perfusion illustrating the boundary conditions. This is a 2D axisymmetric model, with revolution occurring around the axial symmetry line marked on the left.

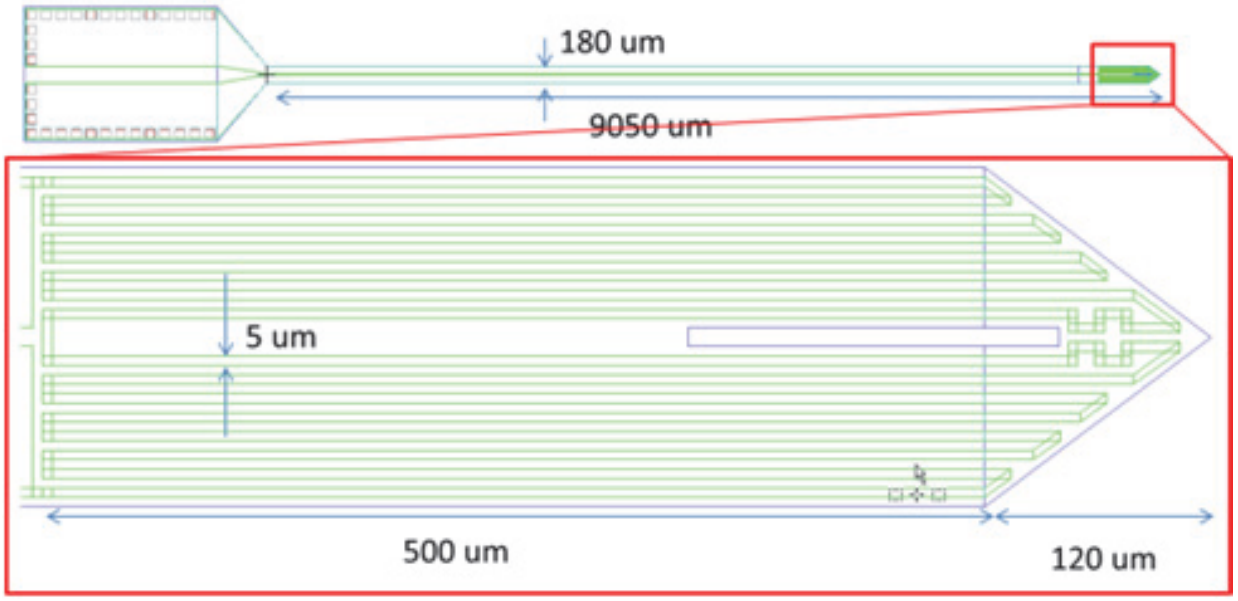
Quarter Model

- Same basic geometry as the 2D axisymmetric Models
- Uses same boundary conditions
- Assumes heat uniformly distributed within the probe.



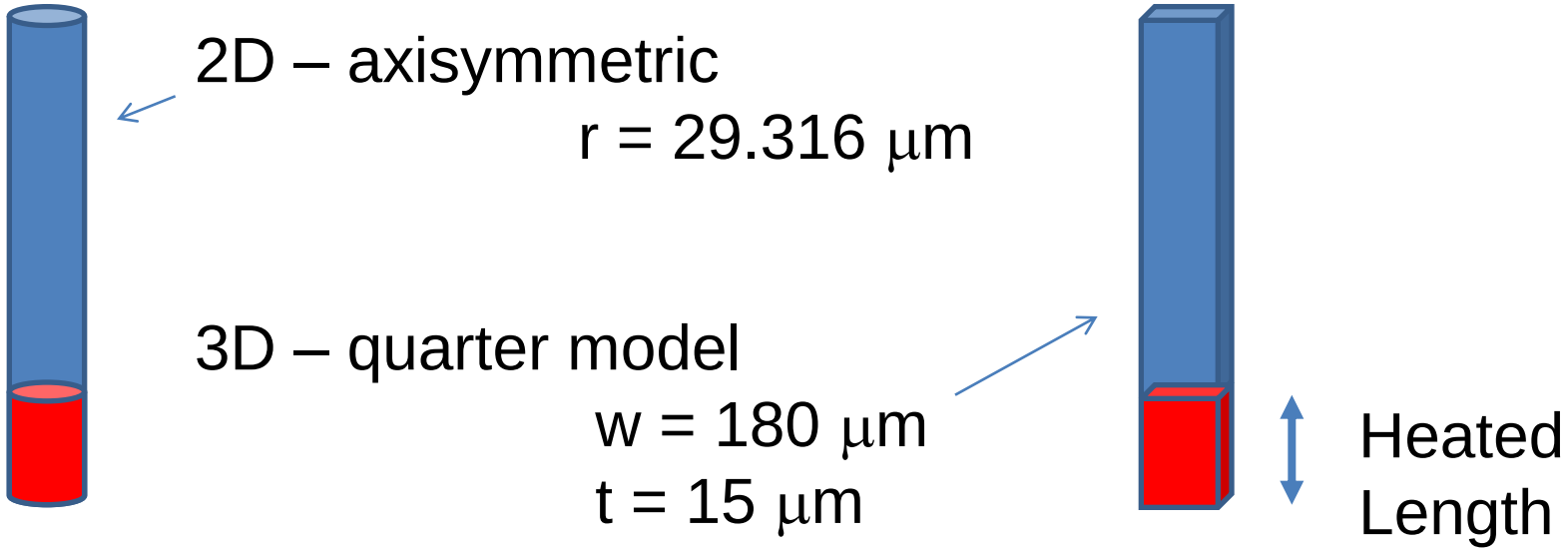
Mock Heated Probe

- An ohmic heated micro probe has been designed and fabricated
- Designed to induce temperature change > 10 degrees C.



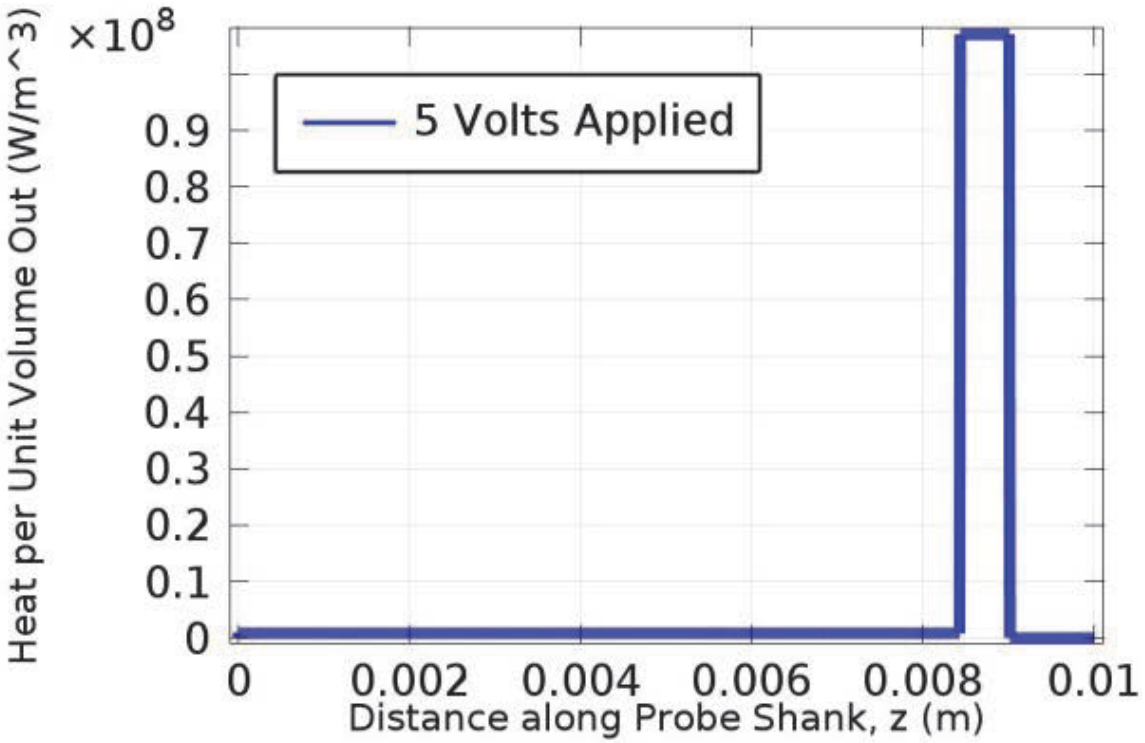
Modeling the Mock Probe

$$\dot{q} = \rho_{electrical} \left(\frac{I}{A_{element}} \right)^2 \left(\frac{N \cdot A_{element}}{A_{probe}} \right)$$

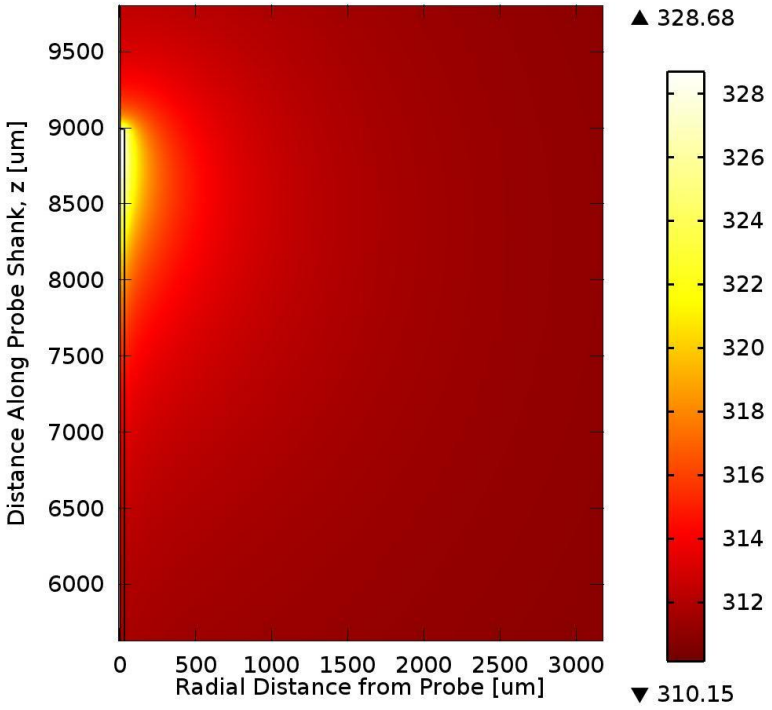


MATLAB Function Result

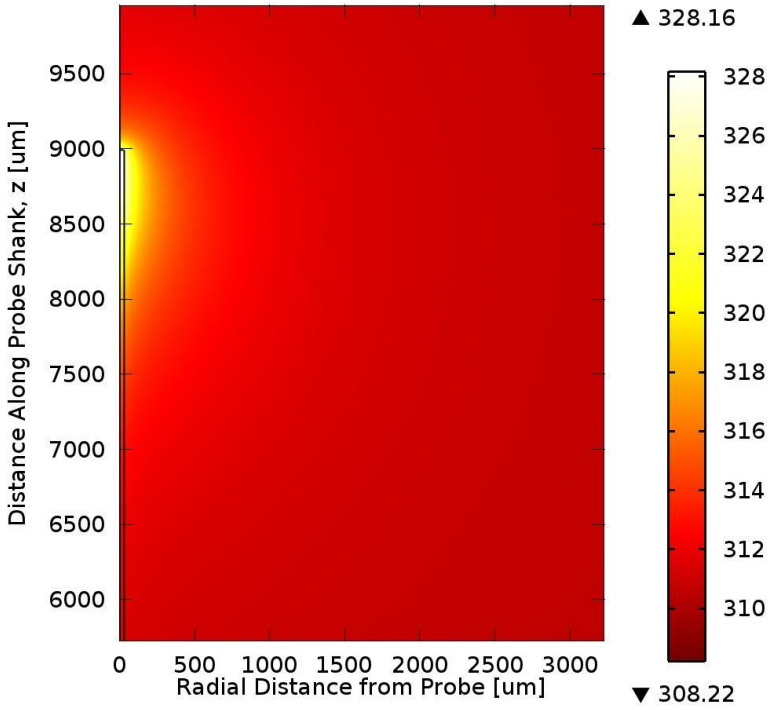
Input from MATLAB was used to determine the volumetric heat generation as a function of position along the probe.



2D Axisymmetric Model Results

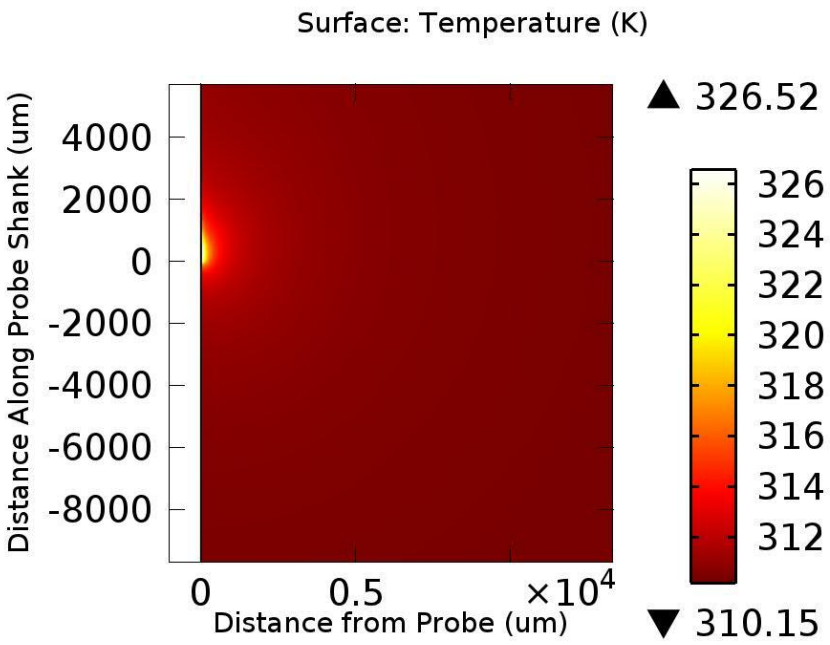


Without Perfusion and Metabolism

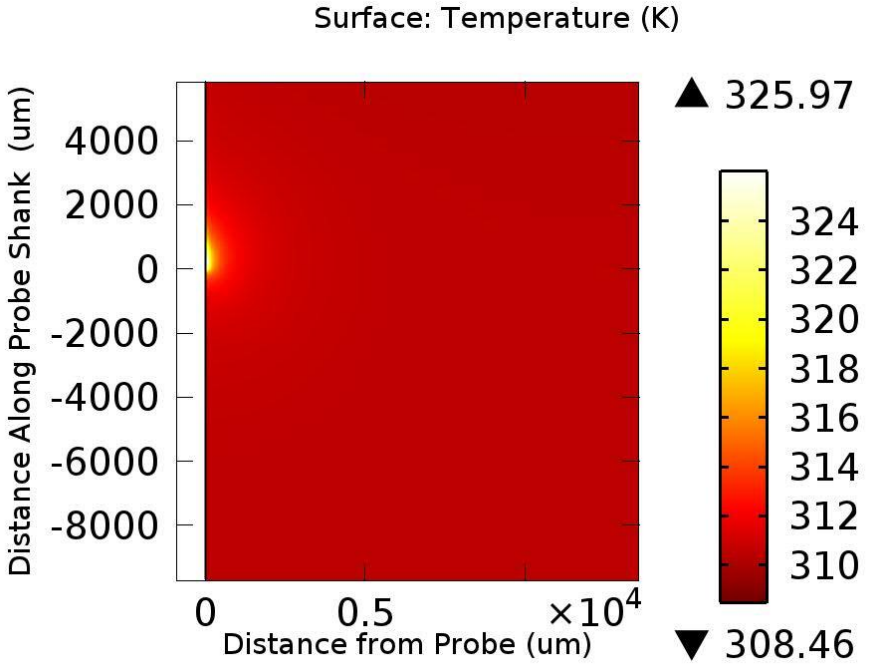


With Perfusion and Metabolism

3D Quarter Model Results

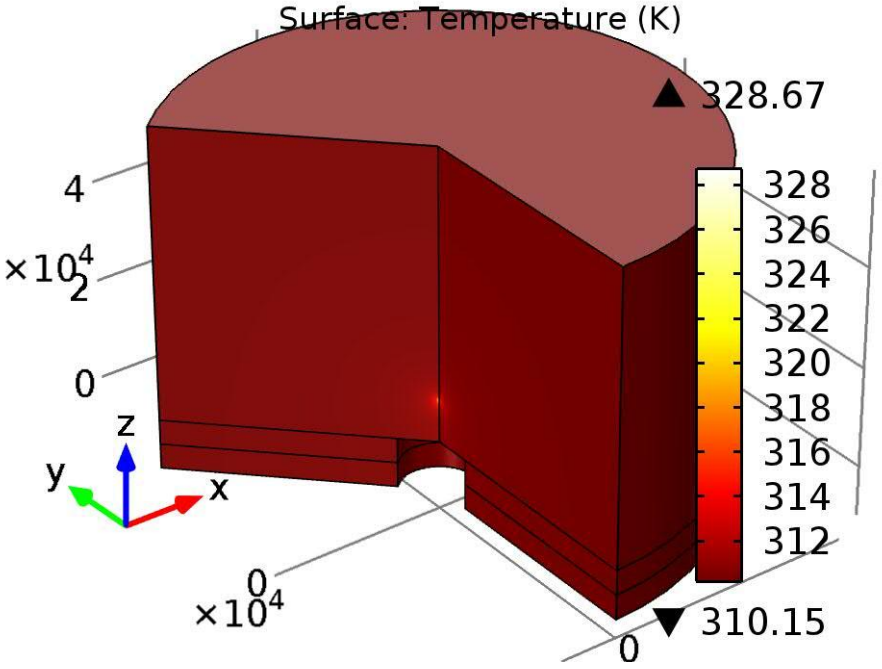


Without Perfusion and Metabolism

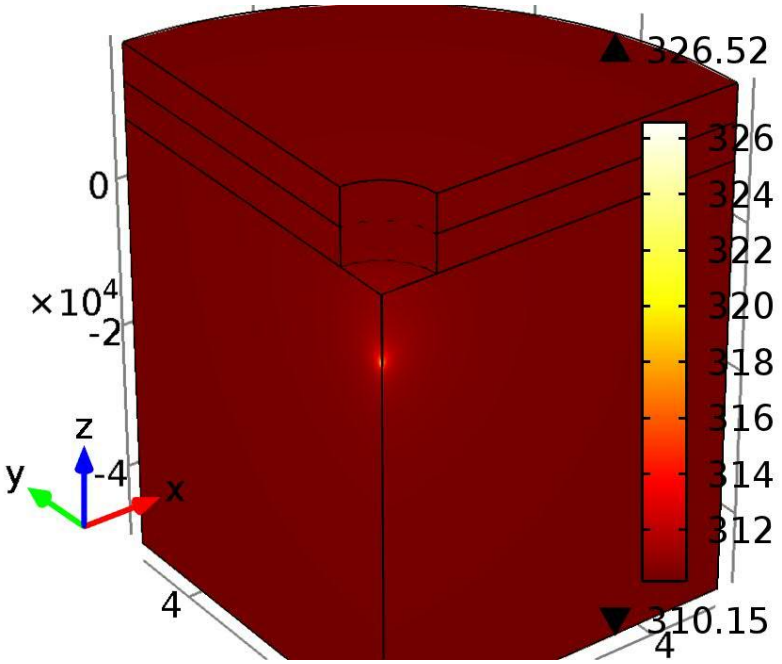


With Perfusion and Metabolism

Model Comparison

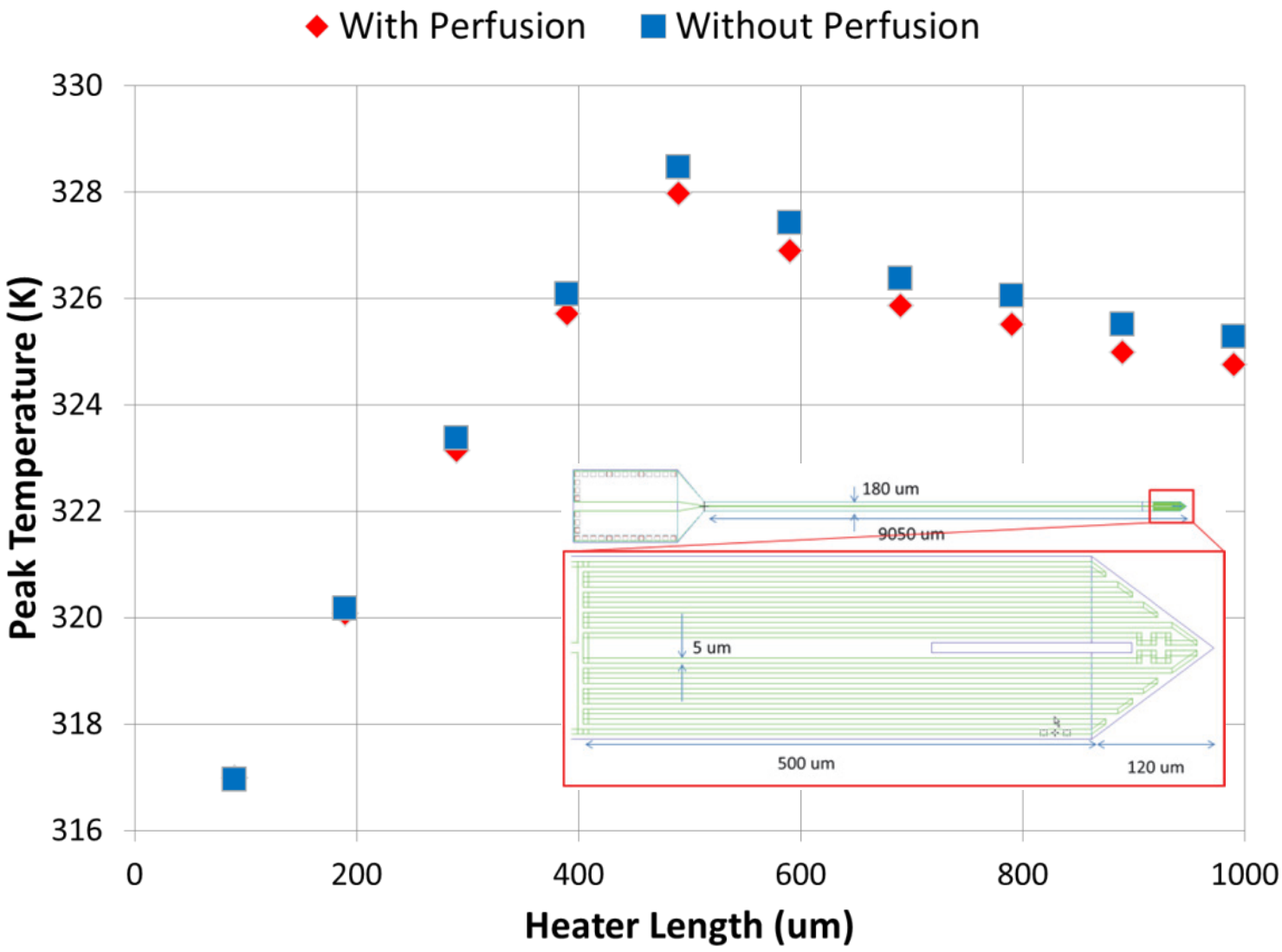


2D Axisymmetric
w/o Perfusion and Metabolism



3D Quarter Model
w/o Perfusion and Metabolism

Parametric Study of Heated Length

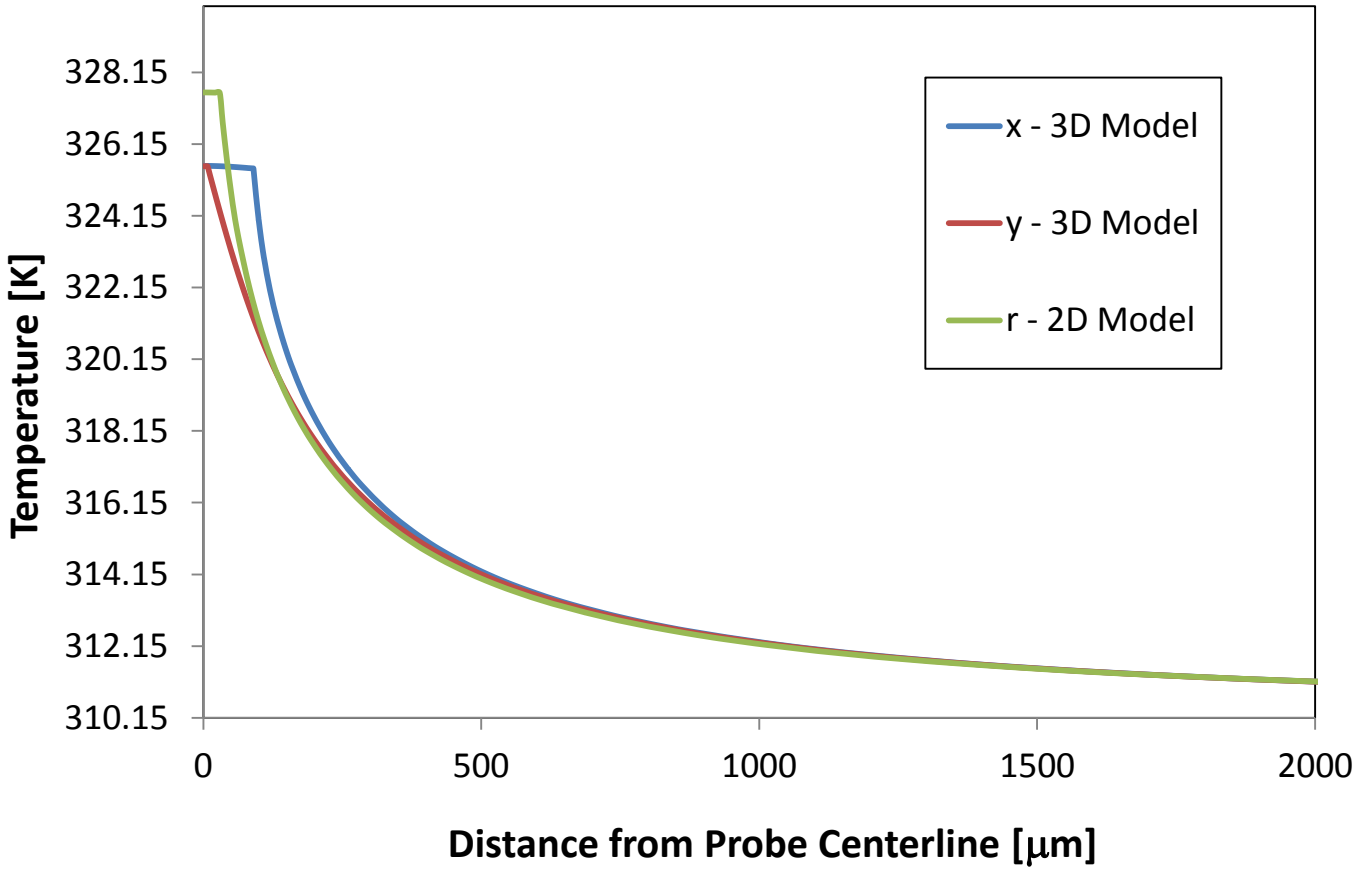


Summary

- Our probe design will be effective in generating a detectable temperature change in physical experiments
- Our initial assumption of using the 2D axisymmetric model was reasonable for the probe design
- COMSOL provides the ability to run various parametric studies to determine most effective probe design to mitigate tissue heating
- Model will be modified to include injected fluid flow and vascular fluid removal

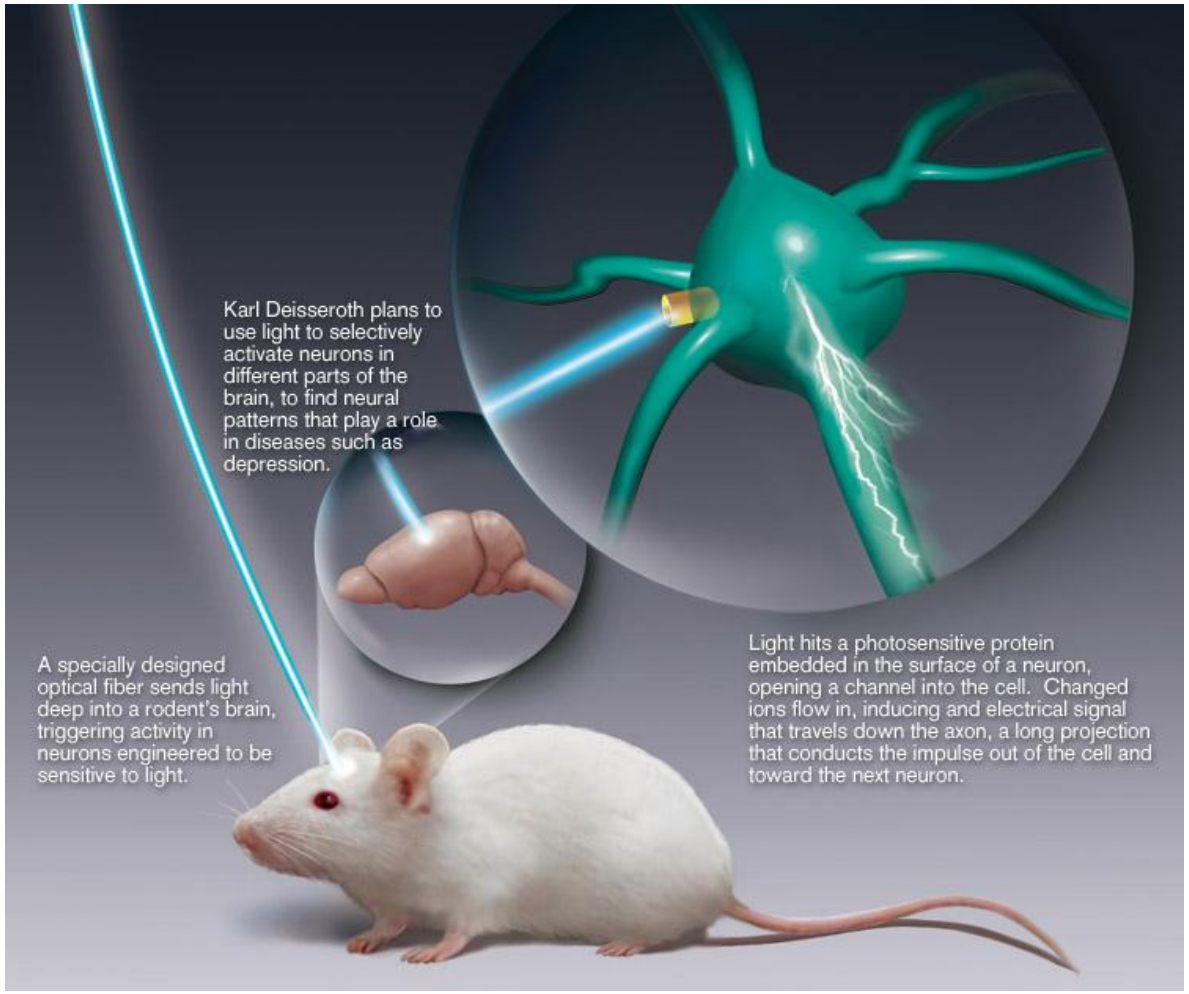
Questions?

Comparison of 2D and 3D Models



Temperature profile normal to the probe starting from the center of the heated length in the (x, y) dimension for the 3D Model and (r) for the 2D Model

Light Stimulation



http://www.technologyreview.com/player/07/03/Mice/images/1.jpg