

# COMPUTATIONAL MODELING OF NANOPARTICLE HEATING FOR TREATMENT PLANNING OF PLASMONIC PHOTOTHERMAL THERAPY IN PANCREATIC CANCER

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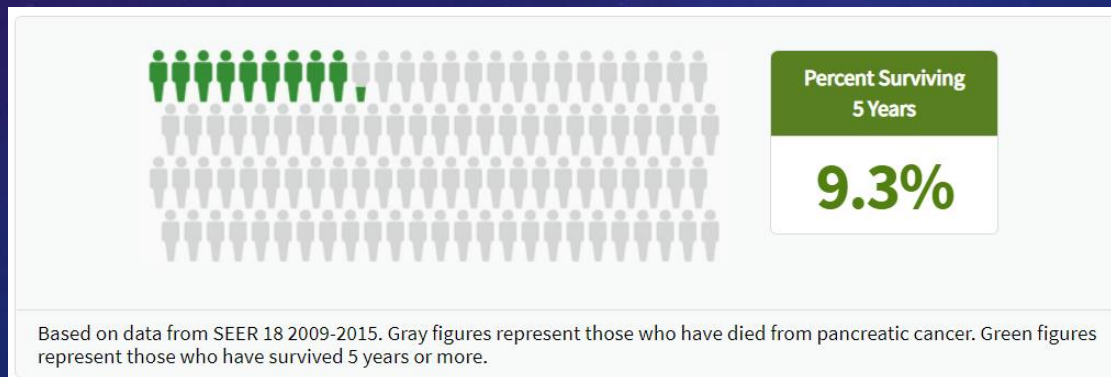
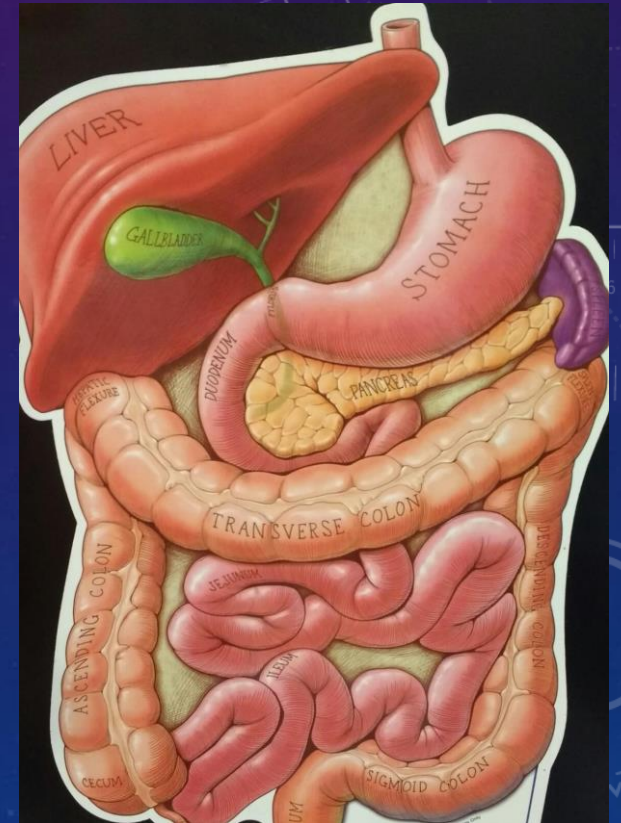
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# OUTLINE

- **THE ISSUE**
  - Part I: The pancreas
  - Part II: Current therapies
  - Part III: Limitations
- **PROPOSED SOLUTION**
  - Setup & Results
- **FUTURE WORK**

# THE ISSUE (PART I: PANCREAS)

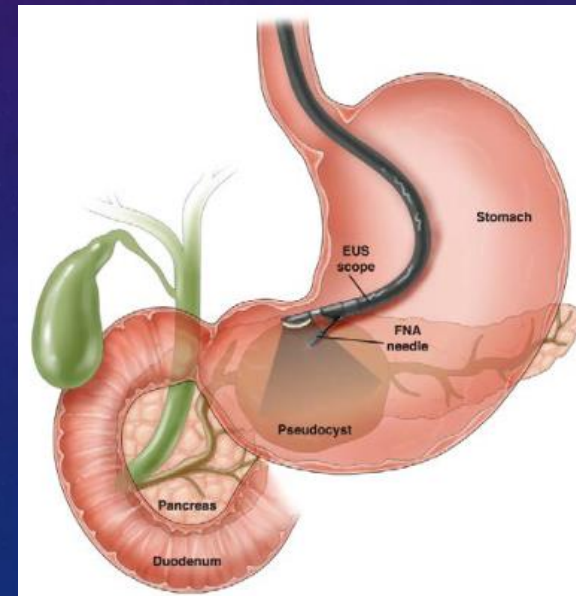
- Pancreas is hard to access
- Pancreatic cancer is often diagnosed late
- 5-year survival rates, after diagnosis, below 10%



# THE ISSUE (PART II: THERAPIES)

- Not all patients are surgical candidates
- Unresectable tumors do not respond well to chemo/radio therapies
- New treatments for unresectable tumors are needed

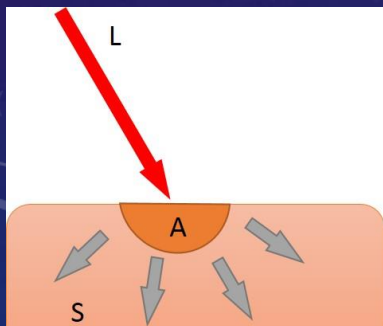
Could Endoscopic ultrasound be the answer?



<https://www.gastro.org/practice-guidance/gi-patient-center/topic/endoscopic-ultrasound-eus>

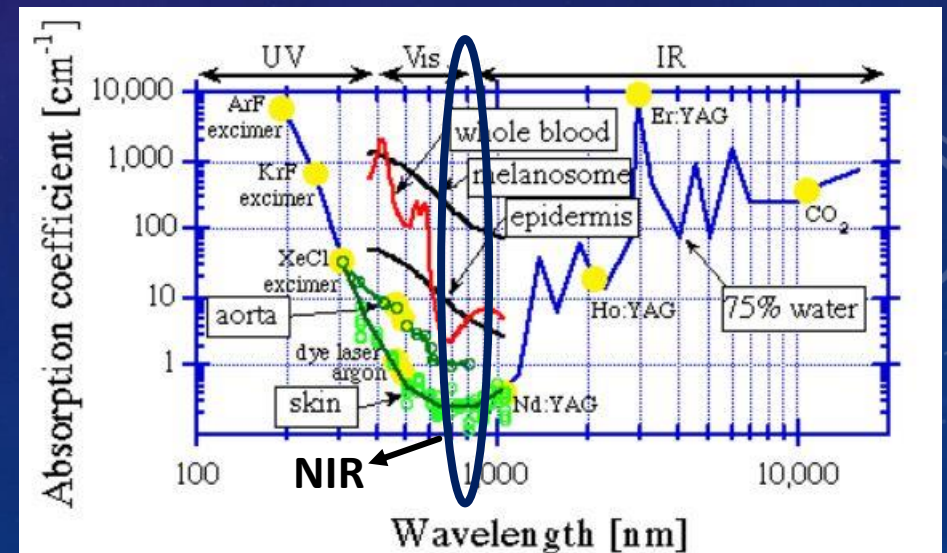
# SOLVING UNMET NEEDS: NEW TREATMENTS

- Medical lasers introduced in the 60s for ophthalmology
- Disadvantages: High power and healthy tissue damage

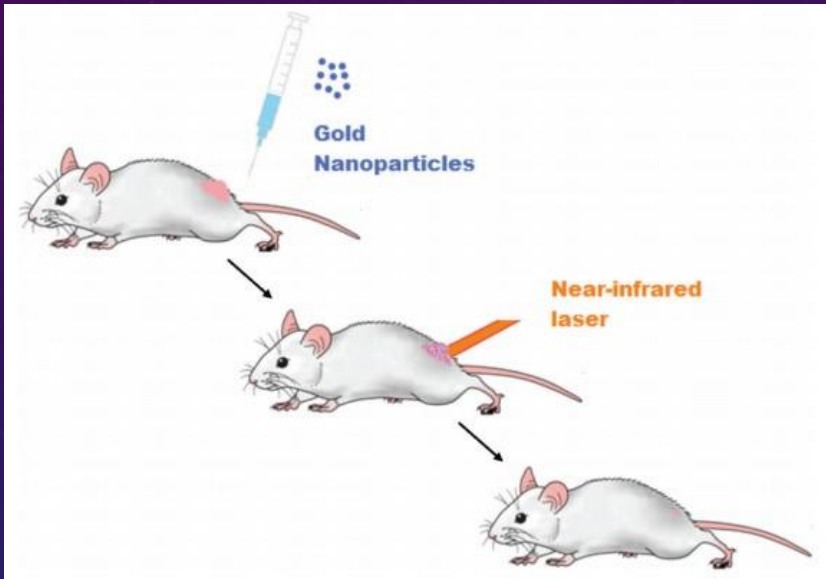


Laser light interacting with tissue

- Use near infrared light to minimize tissue absorption coupled with particles that generate heat under NIR illumination



# THE ISSUE (PART III: LIMITATIONS)



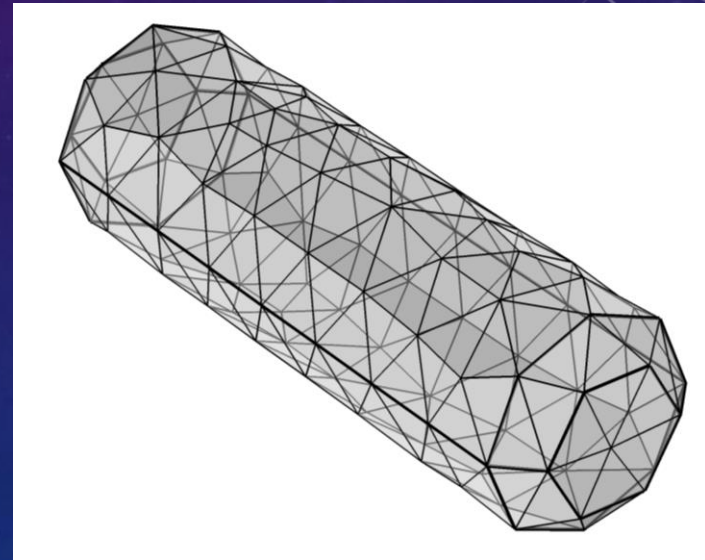
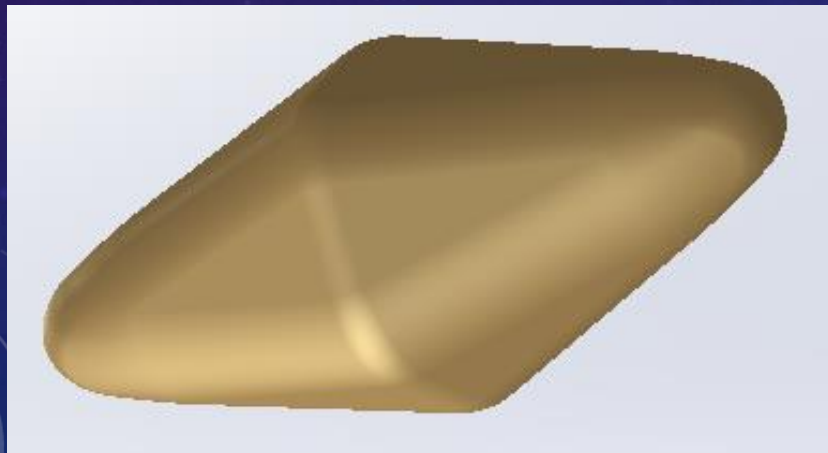
<https://nice.asu.edu/sites/default/files/Phototherapy.jpg>

- Diseases and treatments often studied in animal models
- Costly and time consuming

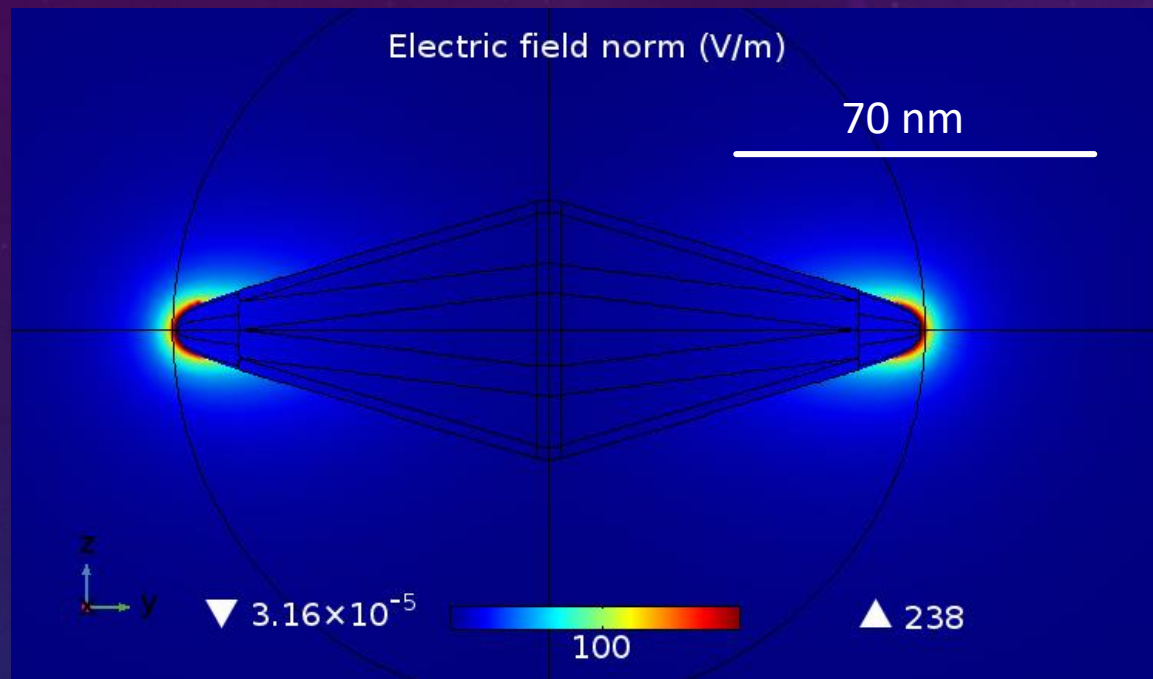
**Recap: Deadly disease. Need of new therapies. Lower cost and time**

# PROPOSED SOLUTION: COMPUTATIONAL MODELING

- FEM model of gold nanoparticles to study optical properties and heat transfer
- Computerized models based on SEM images



# MATHEMATICAL MODEL



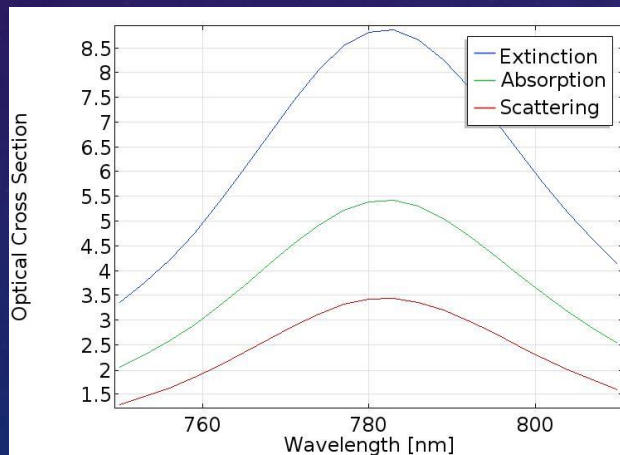
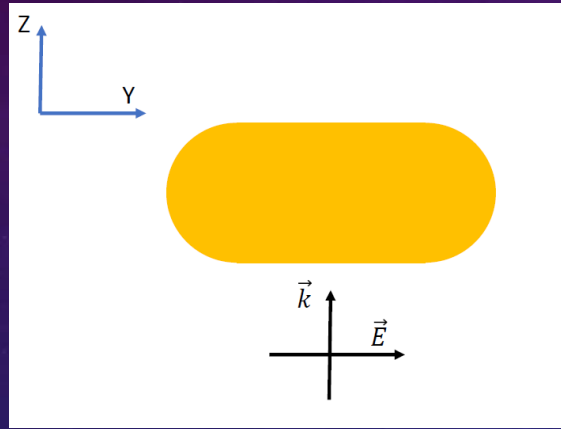
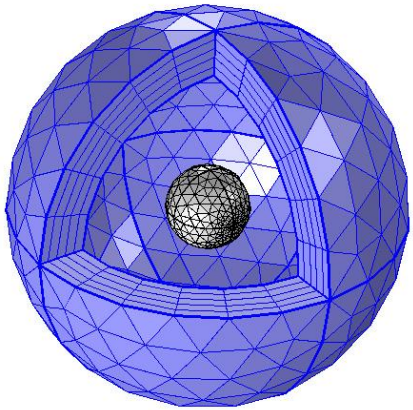
Electric field enhancement obtained for a bipyramid

- Complex geometries need numerical solutions (COMSOL)
- Maxwell's equations and irradiation in media (RF Module)

$$\nabla \times \mu^{-1}(\nabla \times \mathbf{E}) - K_0^2 \left( \epsilon_r - \frac{j\sigma}{\omega\epsilon_0} \right) \mathbf{E} = \mathbf{0}$$



# NP MODEL SETUP



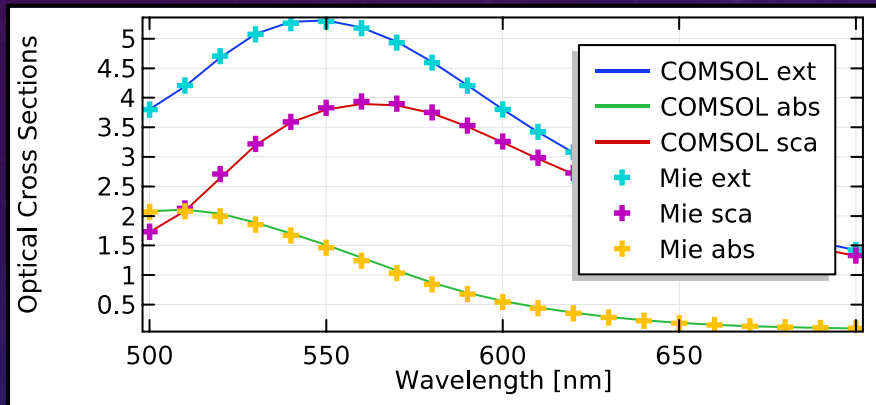
Gold permittivity from well accepted published data

PML truncating the computational domain

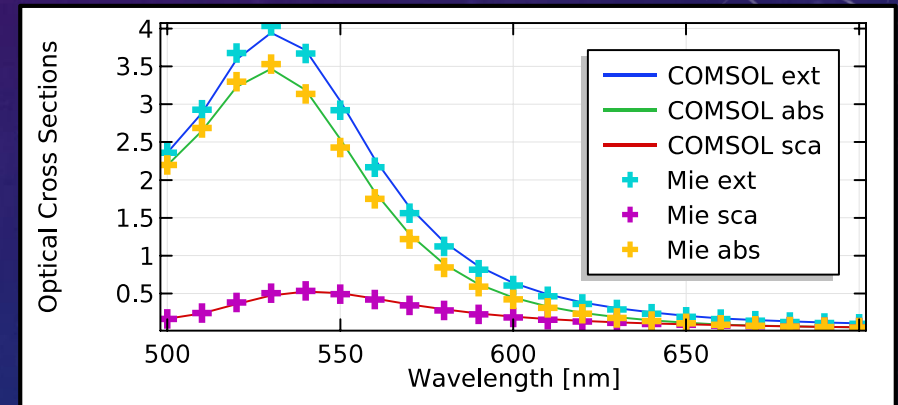
Scattered field formulation: Plane wave

Postprocessing

# VERIFICATION OF THE NP MODEL



150 nm sphere in air



50 nm sphere in water

The accuracy of the model was validated using Mie theory

2.3% Avg Error for air and 4.2% Avg Error for water

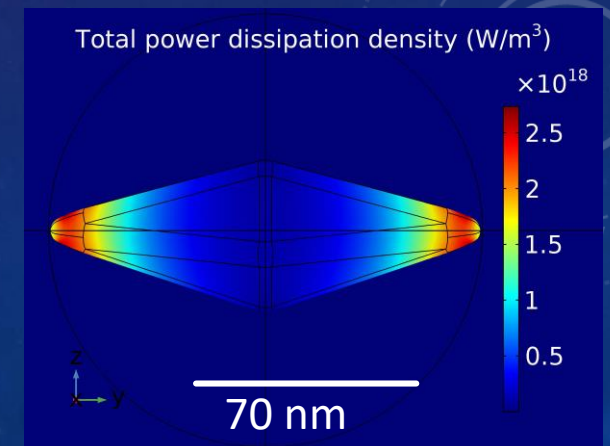
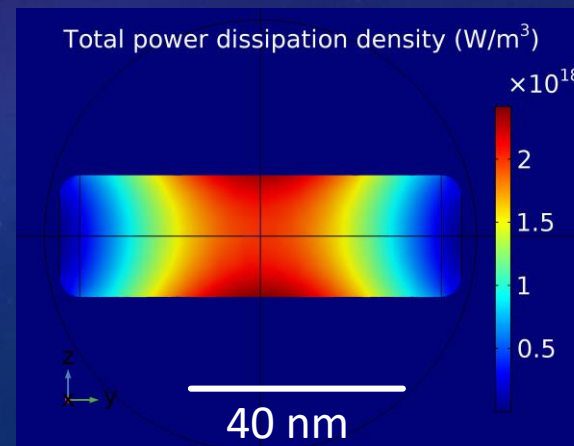
# ENERGY ABSORBED BY NPS

Nanoparticle Type	Dimensions (nm)	Energy Absorbed (W/m <sup>3</sup> )
Nanorod	80	1.37E18
Nanorod	60	7.41E17
Nanobipyramid	110	4.90E17
Nanobipyramid	146	4.40E17
Nanosphere	40	5.81E14
Nanosphere	150	8.43E14

- Power absorbed by NPs is transformed into heat

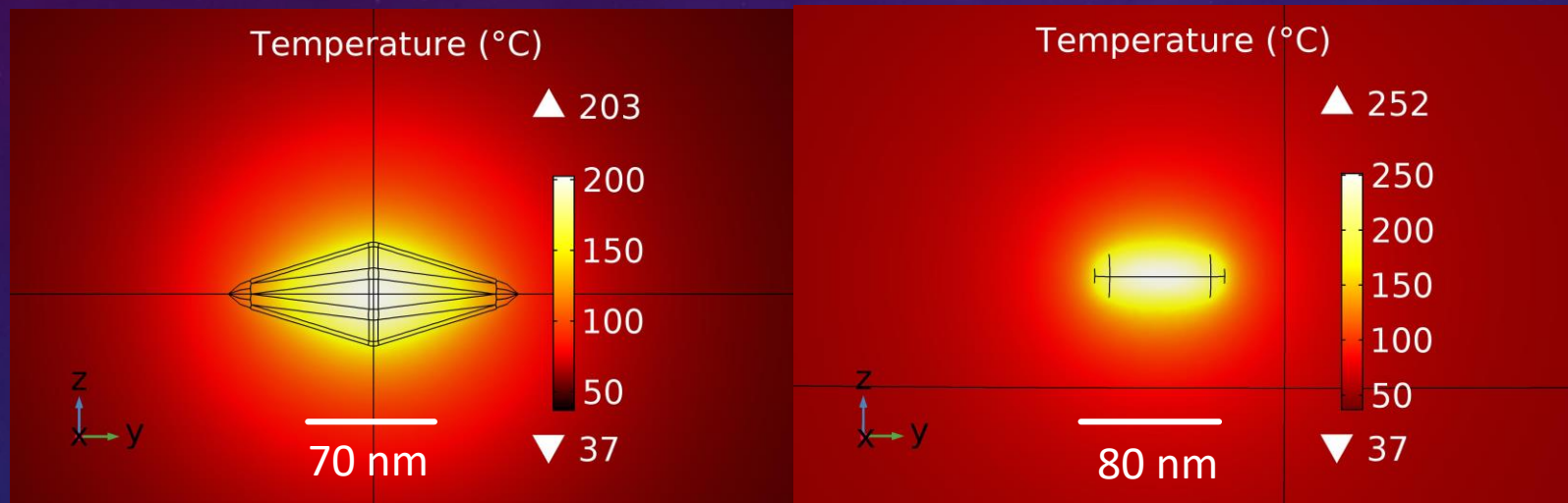
$$\text{Energy Absorbed} = \iiint_V Q_h dV$$

$Q_h$  is the total power dissipation density



# HEAT GENERATED BY NPS

- Average energy absorbed is then used as source term on heat transfer mathematical model (Coefficient form PDE Module)

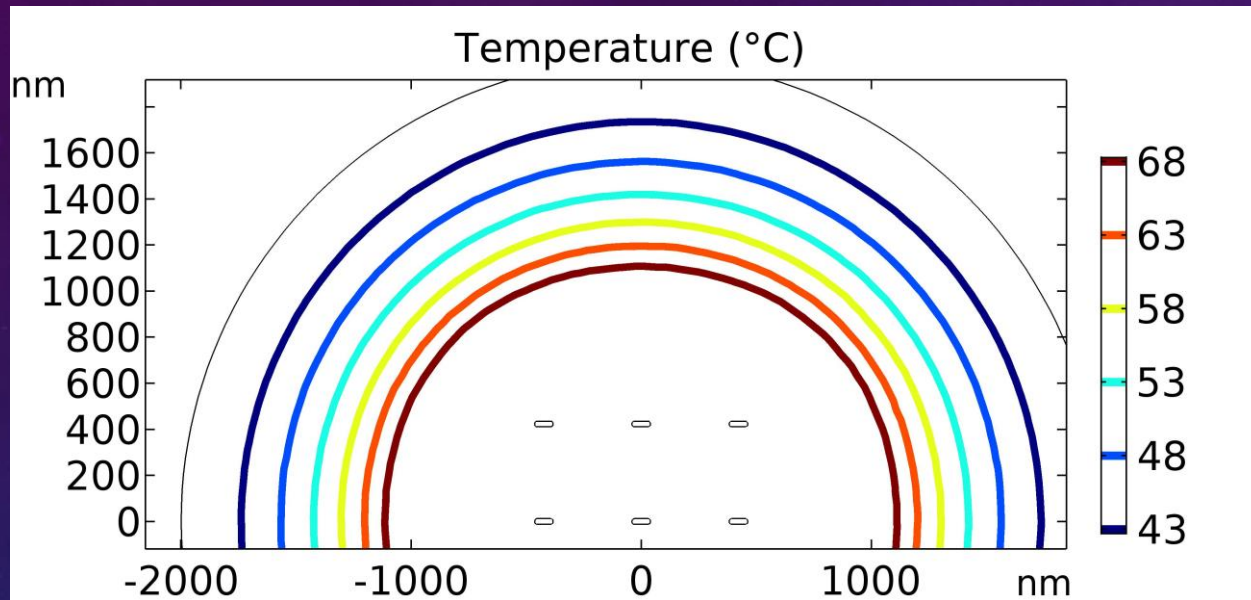


$$\nabla \cdot (-c\nabla T) = f$$

$$f = \text{Energy absorbed} \left[ \frac{W}{m^3} \right]$$

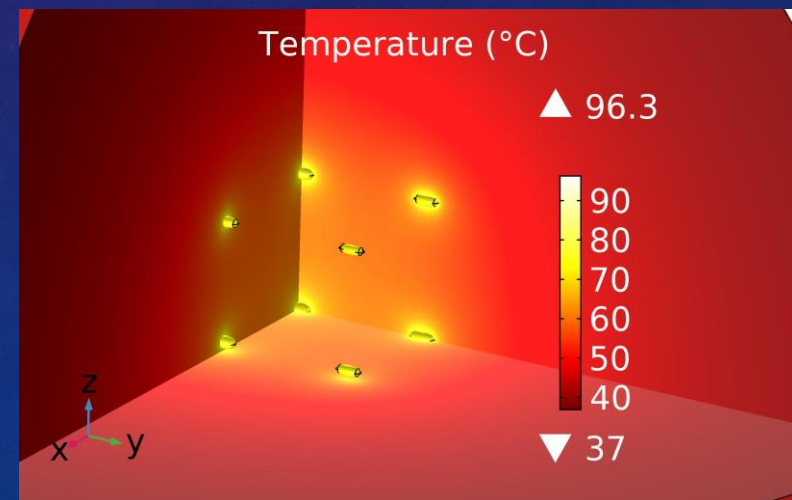
3  $\mu\text{m}$  sphere of water at 37°C on the outer surface

# HEAT GENERATED BY NP CLUSTERS



- Similarly, computed the thermal effects of the average power absorbed by a cluster of nanorods

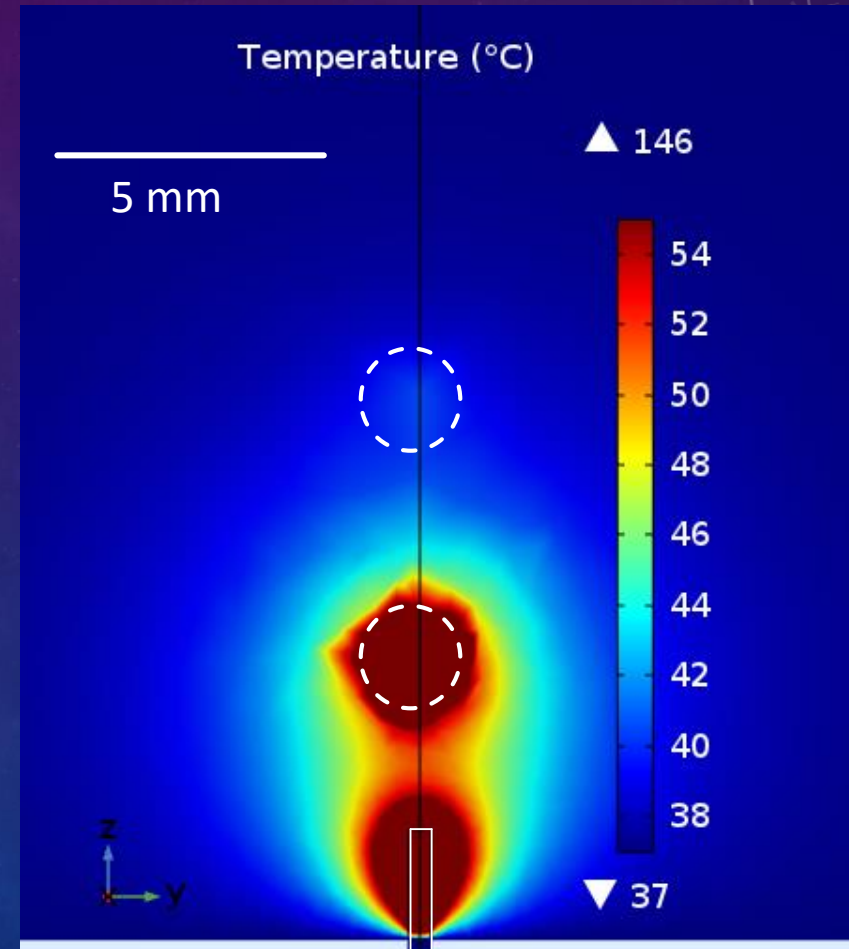
$$\nabla \cdot (-c\nabla T) = f$$



4  $\mu\text{m}$  sphere of water at 37°C on the outer surface

# MACROSCOPIC EFFECT

- Pancreatic tissue properties extracted from literature.
- 400  $\mu\text{m}$  laser fiber.
- Clusters of NPs along the laser beam path represented as point sources with power depending on distance.



# FUTURE WORK

- Further refinement of the model to account for tissue properties in the NIR region
- Validation of the model using laser experiments both in the visible and NIR regions
- Include a more realistic distribution of the nanoparticles and nanoparticle clusters in media

# ACKNOWLEDGMENTS

- Advisors: Yusheng Feng PhD and Kathryn Mayer PhD
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- Colleagues: Priscilla Lopez, Tara Gray, Shaquan David, and Mohammad Abdul-Moqueet.



The background is a gradient of blue, transitioning from a darker purple-blue at the top to a lighter blue at the bottom. It is filled with a pattern of small, white, star-like specks. Overlaid on this background are several faint, white, technical diagrams. These include circular gauges with numerical scales (e.g., 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210) and arrows, as well as dashed lines and solid lines forming various geometric shapes and paths. The overall aesthetic is clean, modern, and technical.

THANK YOU!!!