2nd PANHELLENIC CONGRESS OF MEDICAL PHYSICS
4-6 OCTOBER 2024| EUGENIDES FOUNDATION

Computational Study of Gold Nanoparticle's Enhanced Photothermal Treatment of Pancreatic Cancer

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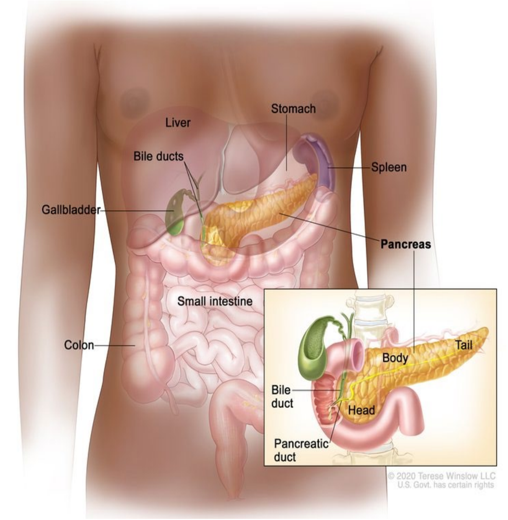
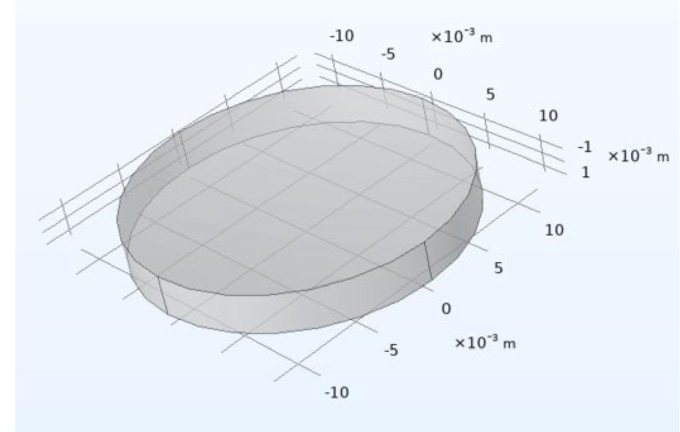
Background: Pancreatic cancer is one of the leading causes of cancer-related deaths worldwide, often detected too late to be successfully treated. In addition to conventional treatments, the feasibility of photothermal therapy combined with gold nanoparticles, to enhance its action through surface plasmon resonance phenomenon, seems promising. **The purpose of this work is the computational study of the utilization of plasmonic photothermal therapy, combined with nanoparticles, to achieve the optimal photothermal effect in inoperable pancreatic cancer.**

Materials and Methods: In this work, the absorption spectra of gold nanospheres of different dimensions were first calculated, as a function of the wavelength of the incident radiation, through mathematical simulation based on Mie theory. Then, through simulation with COMSOL Multiphysics software, different combinations of laser - nanoparticle irradiation parameters were examined, to determine the optimal parameters for this treatment, for photothermal effect enhancement.

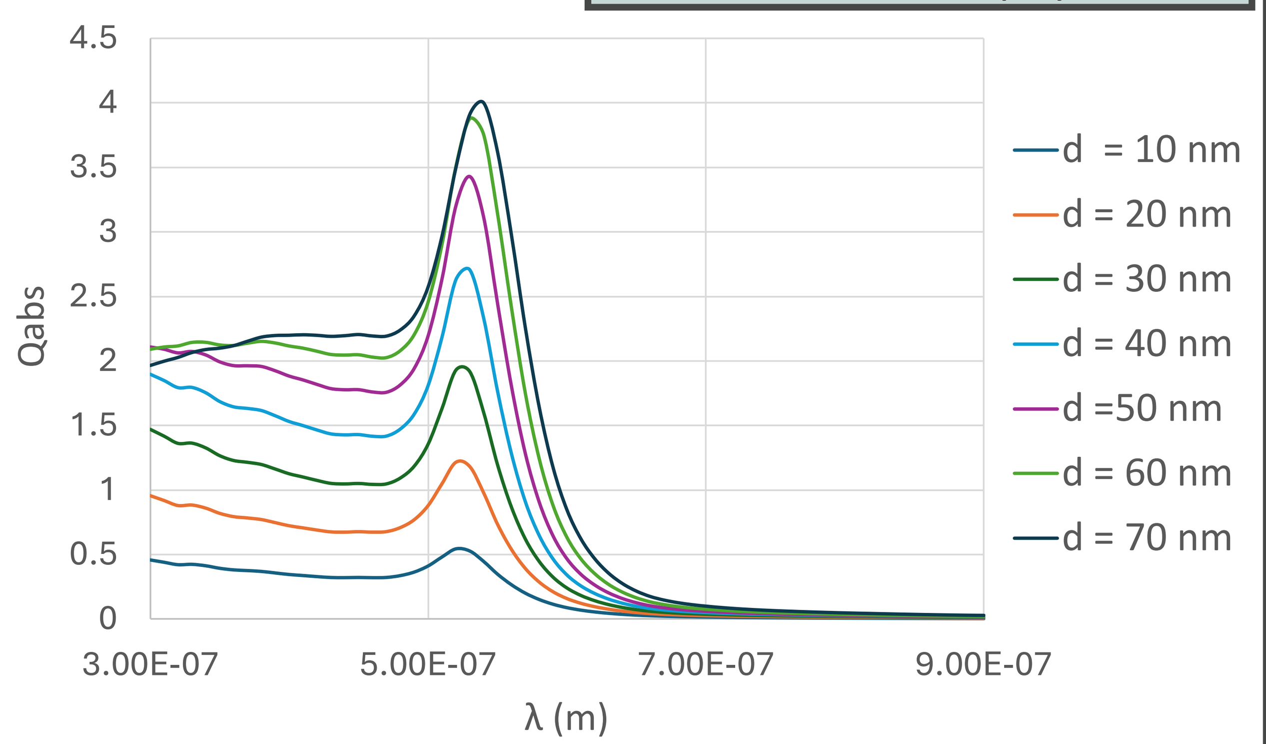
Results: By choosing the laser emission wavelength at the maximum absorption peak, for the size of nanoparticles introduced into the pancreatic tissue, and by adjusting their numerical density appropriately with the laser power, the temperature of the tissue can be locally increased to 44 - 45°C, to induce hyperthermia and cause cancer cells to undergo apoptosis. The simulated tissue target volume was considered to be a disc of pancreatic tissue of radius dr = 12 mm and thickness dz = 3 mm, of which the thermal properties were taken from the literature.

Conclusion: The innovative use of nano-biophotonic techniques and the use of gold nanoparticles can enhance the phenomenon of hyperthermia, giving hope for the treatment of intractable diseases, such as pancreatic cancer. Through COMSOL simulation, isotherm curves in the target volume can also be calculated and used as a future treatment plan design tool.

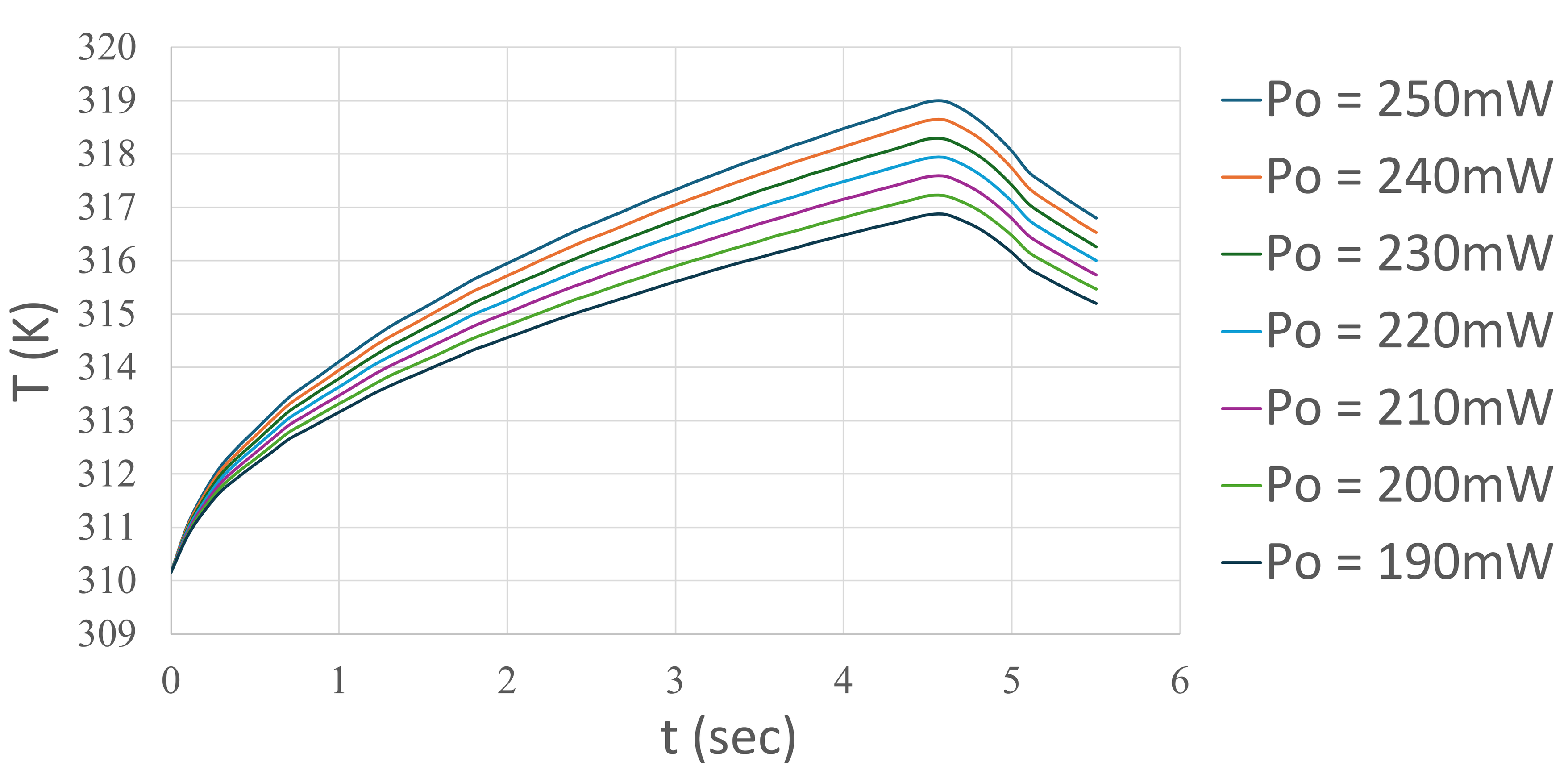




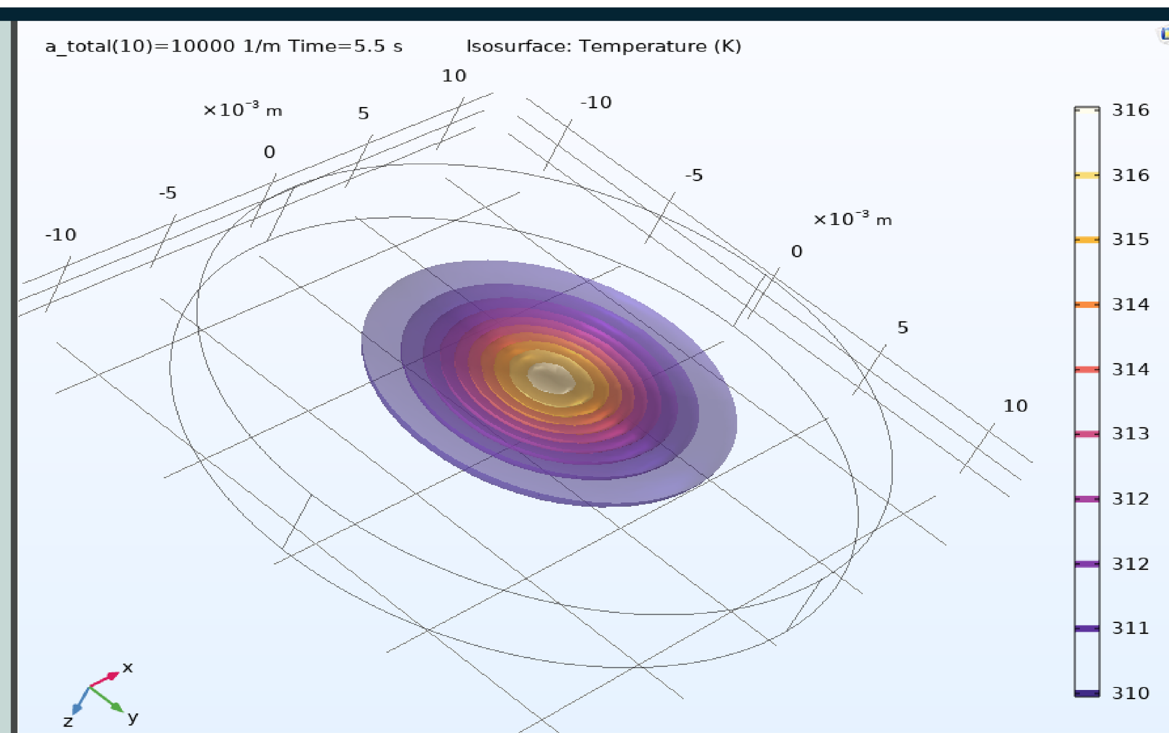
Target Volume simulation in COMSOL Multiphysics



Absorption spectra of gold nanospheres of different dimensions, calculated based on Mie Theory



Graph on the left is showing the temperature increase over time, in the center of the target volume, from 37°C (310.15 K) to 43.72°C (316.87 K) - 45.84°C (318.99 K), using total mass of 0.3mg of gold nanospheres with 20nm diameter, uniformly distributed in the target volume. A laser wavelength of 514 nm was used varying its power from 190 – 250mW. **These temperatures are capable of causing hyperthermia in cancer tissue and apoptosis of cancer cells!**



Isotherm curves in the target volume, calculated through simulation in COMSOL Multiphysics.

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1. .https://www.wcrf.org/cancer-trends/pancreatic-cancer-statistics/#:~:text=Latest%20pancreatic%20cancer%20data,of%20pancreatic%20cancer%20in%202020, accessed 2024.
2. Yang, W. *et al,* "Gold nanoparticle based photothermal therapy: Development and application for effective cancer treatment". Sustainable Materials and Technologies 2019, 22, doi:10.1016/j.susmat.2019.e00109.
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