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# ESTIMATION OF TISSUE SUBSURFACE TEMPERATURE INDUCED BY LASER HEATING MEDIATED BY NANOPARTICLE

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In this paper the results of simulation of temperature distributions on the surface and inside the tissues for different parameters of laser beam and model-based object are presented. The results of surface temperature modeling are in good agreement with experimental thermography images. It is proposed to use calculated temperature distribution as a database for training of neural network for calculations of in depth temperature

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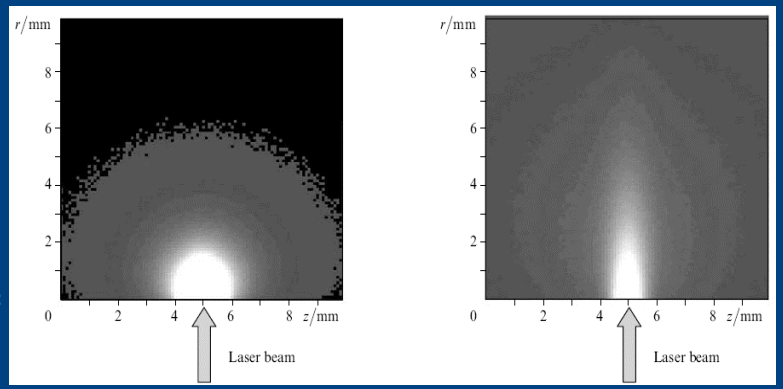
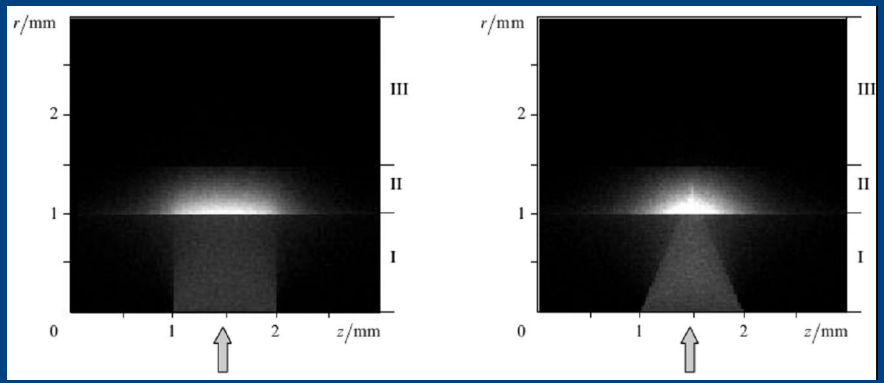
# Spatial distribution of absorbed laser radiation

We simulated the spatial distribution of absorbed photons during the propagation of an electromagnetic wave through a system of discrete particles taking multiple scattering into account. The diffusion scattering of laser radiation at 808 nm in a disperse system of gold nanoparticles was calculated by the Monte-Carlo method. The scattering probability in the speciéed direction in each scattering event was determined for a particle with the speciéed diameter of a silicon nucleus and the gold shell thickness by using the Mie theory. The realisation of scattering or absorption in each interaction
event between a photon and a particle is also a random process, whose probability is determined by the relation between the extinction and scattering coeféecients.

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# Simulation

This model uses the Bioheat Equation. The model approximates the body tissue with a large cylinder and assumes that its boundary temperature remains at 37 °C during the entire procedure. The tumor is located near the center of the cylinder and has the same thermal properties as the surrounding tissue.

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The bioheat equation governs heat transfer in the tissue

$$\delta_{ts}\rho C\frac{\partial T}{\partial t}+\nabla\cdot(-k\nabla T)=\rho_b C_b \omega_b(T_b-T)+Q_{met}+Q_{ext}$$

where δts is a time-scaling coefficient; ρ is the tissue density; $C$ is the tissue's specific heat and $k$ is its thermal conductivity. On the right side of the equality, $\rho_b$ gives the blood's density, $C_b$ is the blood's specific heat; $\omega_b$ is its perfusion rate; $T_b$ is the arterial blood temperature; while $Q_{met}$ and $Q_{ext}$ are the heat sources from metabolism and spatial heating, respectively.

In this model, the bioheat equation also models heat transfer in various parts of the probe with the appropriate values for the specific heat, $C$ and thermal conductivity, $k$ . For these parts, all terms on the right-hand side are zero. The model next sets the boundary conditions at the outer boundaries of the cylinder and at the walls of the blood vessel to a temperature of 37 °C. Assume heat flux continuity on all other boundaries. The initial temperature equals 37 °C in all domains.

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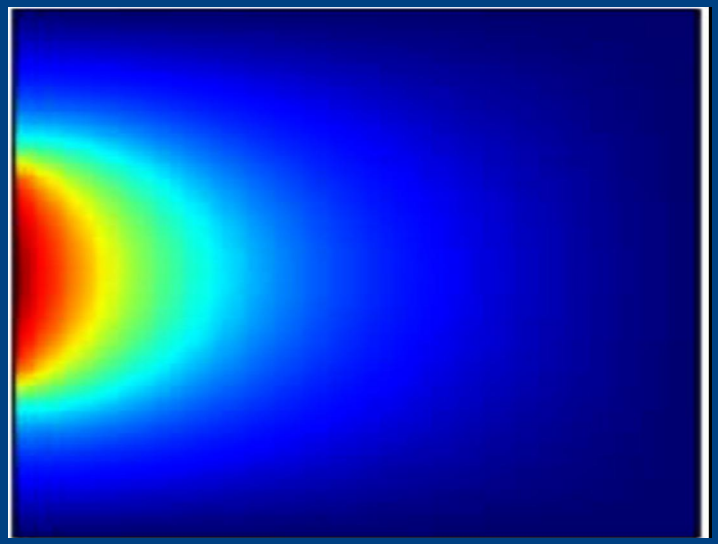
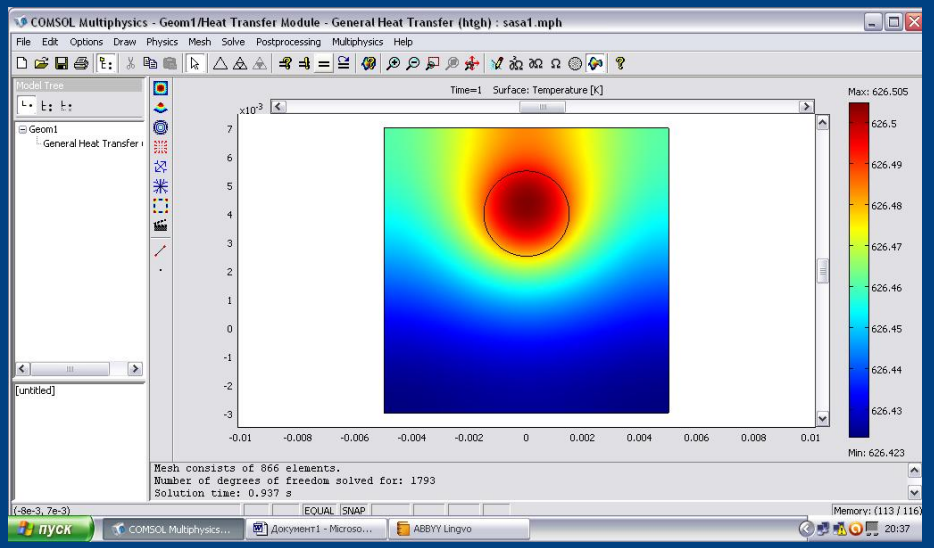
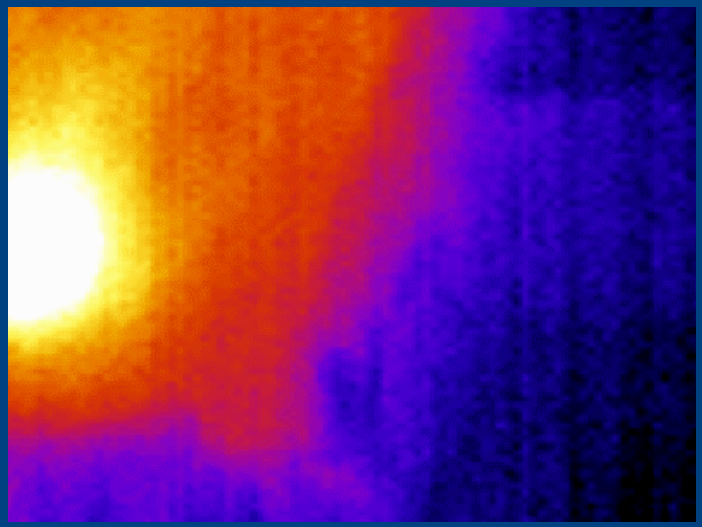
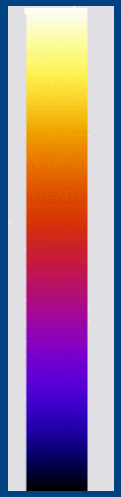
# COMSOL Multiphysics Model
# Heat Transfer Module







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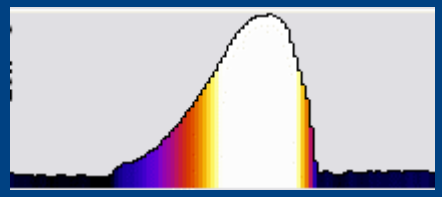
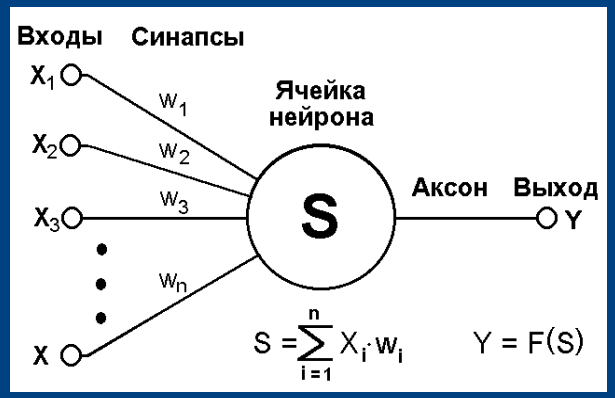
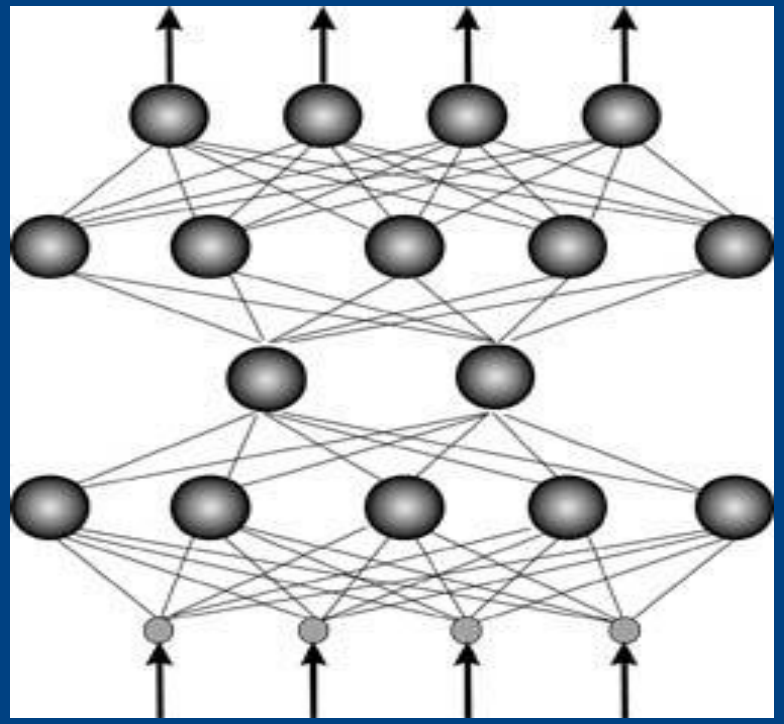
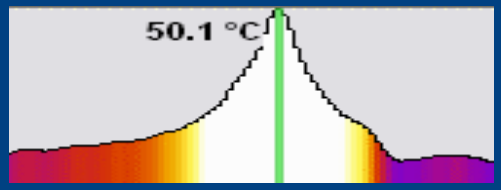
# Neural network for calculations of in depth temperature

**TISSUE SUBSURFACE TEMPERATURE**








Parameters of input laser beam

surface temperature

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