Comsol Multiphysics as a Tool for Replacing Animals in Biomedical Research: an Application in Dermatology

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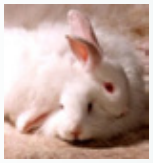
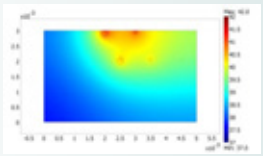
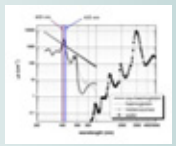
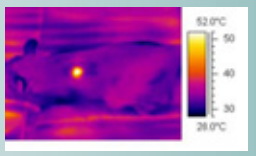
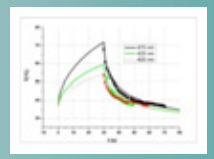
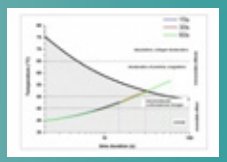
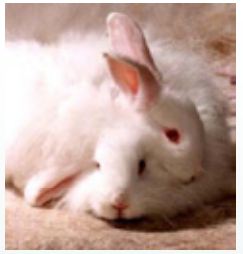





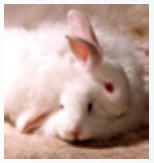
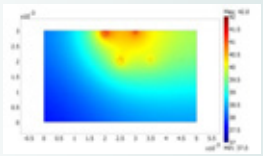
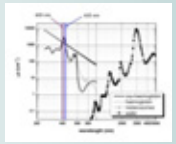
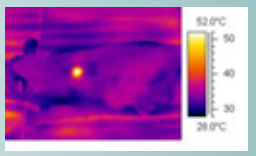
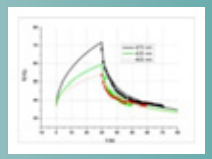
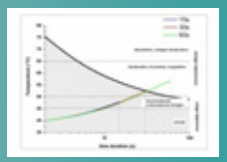



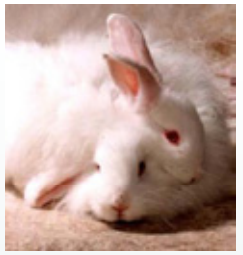


If we are to use a criterion for choosing experiments to perform, the criterion of humanity is the best we could possibly invent.

The greatest scientific experiments have always been the most humane and the most aesthetically attractive, conveying that sense of beauty and elegance which is the essence of science at its most successful.

This is the Russell and Burch "Humanity Criterion"

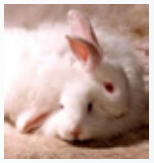
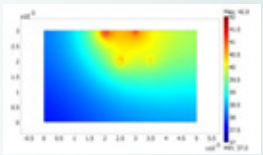
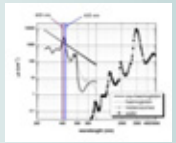
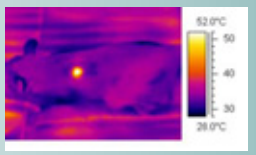







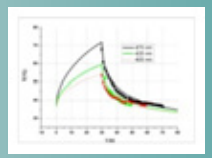
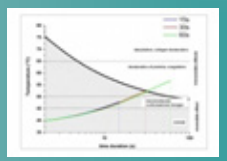


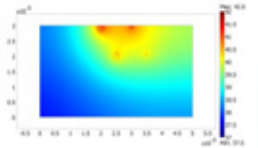
The three R's rules

1. **R**eplace the need for animal experiments
2. **R**educe the numbers of animals used to an unavoidable minimum
3. **R**efine any procedures necessarily used, so as to minimize any pain or distress suffered by animals

From *The Principles of Humane Experimental Technique*, written by William Russell and first published in 1959.

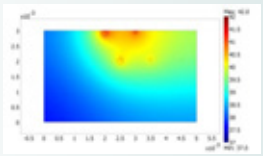
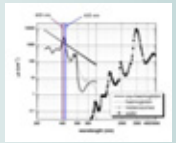
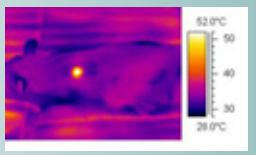


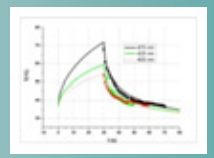
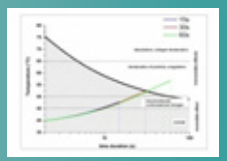
Comsol for Replace

Replace the need for animal experiments

FEM modeling may be used as a non-animal technique

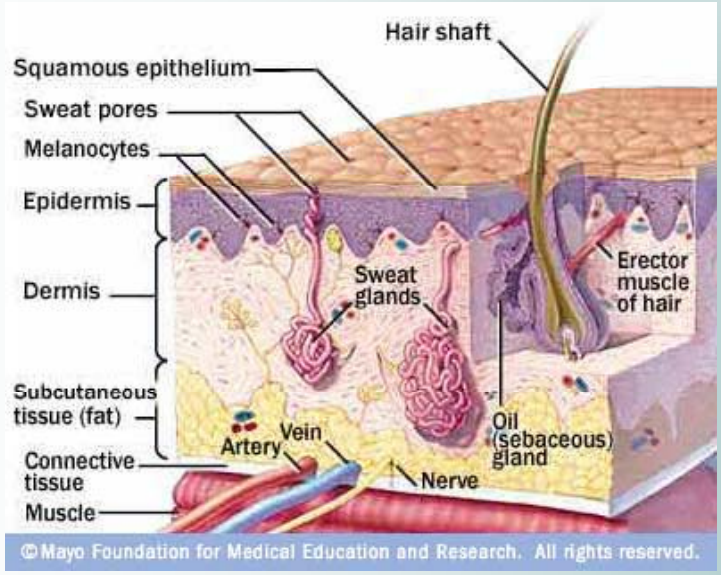
- in preliminary studies to verify hypothesis of the research study
- in the optimization phase

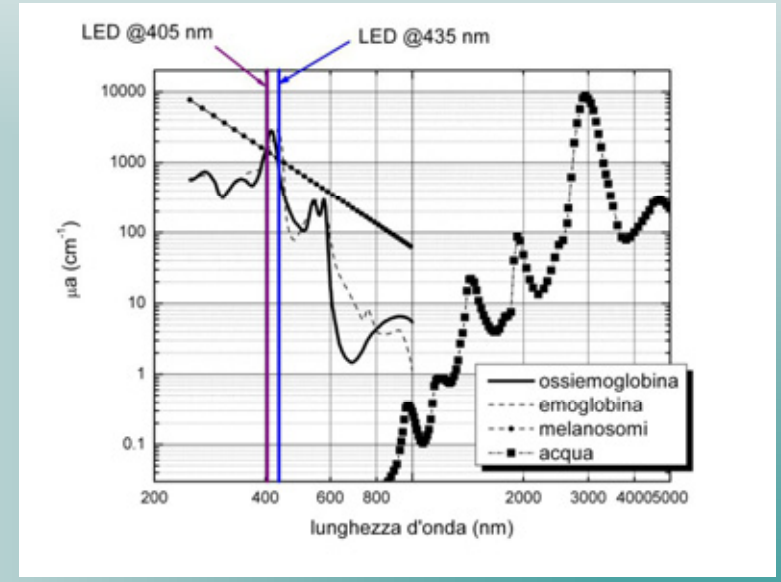





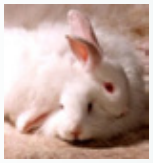
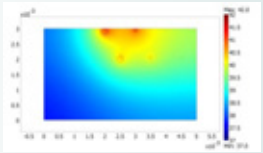
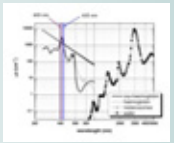
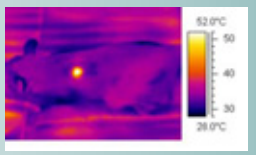
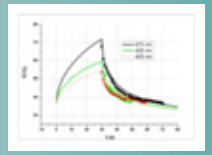
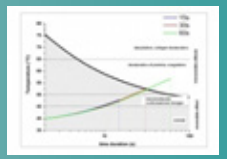



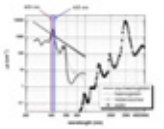
An application in Dermatology

Design of a high-power Blue LED device for selective photocoagulation of skin superficial bleeding (http://www.youtube.com/watch?v=b_B8urjXSIc)



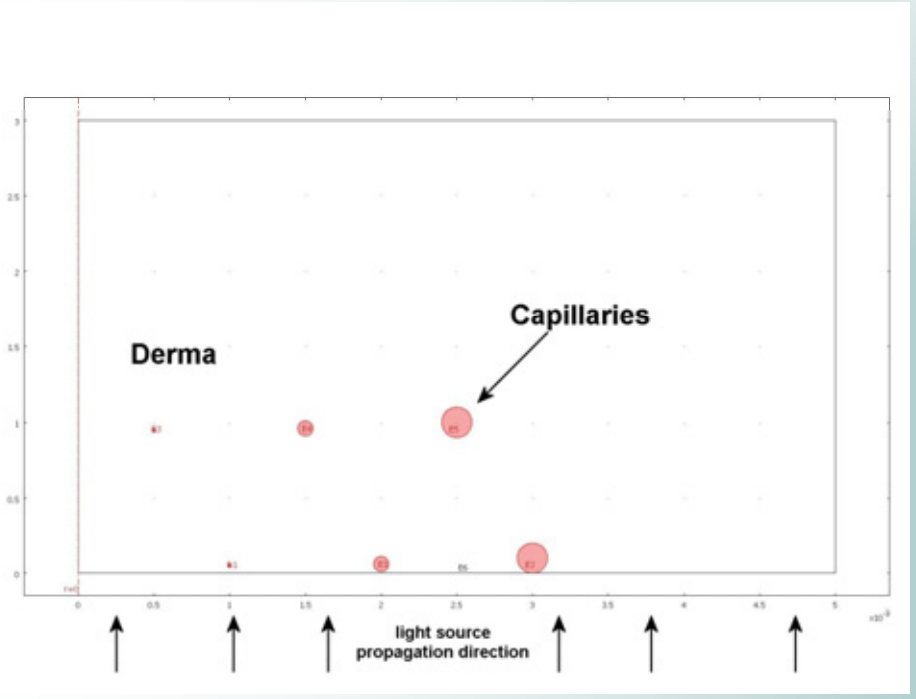




An application in Dermatology

1. Selective absorption?



Diffusion +
Bioheat Equation

405 nm

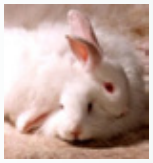
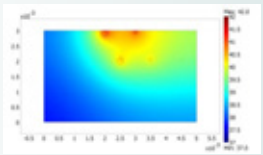
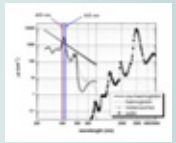
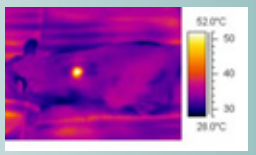
$$\frac{\partial \Phi(x,y,t)}{\partial t} - \nabla\left(\alpha^n \nabla \Phi(x,y,t)\right) = -c_n \mu_a^n \Phi(x,y,t)$$

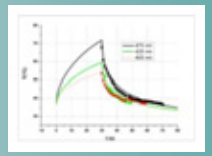
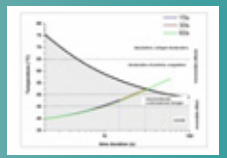
$$\alpha^n = \frac{c_n}{3\left(\mu_a^n + (1-g)\mu_s^n\right)}$$

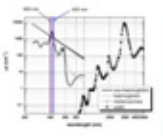
470 nm

$$\rho_n C_n \frac{\partial T(x,y,t)}{\partial t} - \nabla\left(k^n \nabla T\right) = \rho_b C_b \omega_b \left(T_b - T\right) + Q_{met} + Q_{ext}$$

$$Q_{ext} = \mu_a^n \Phi(x,y,t) h_p \nu$$

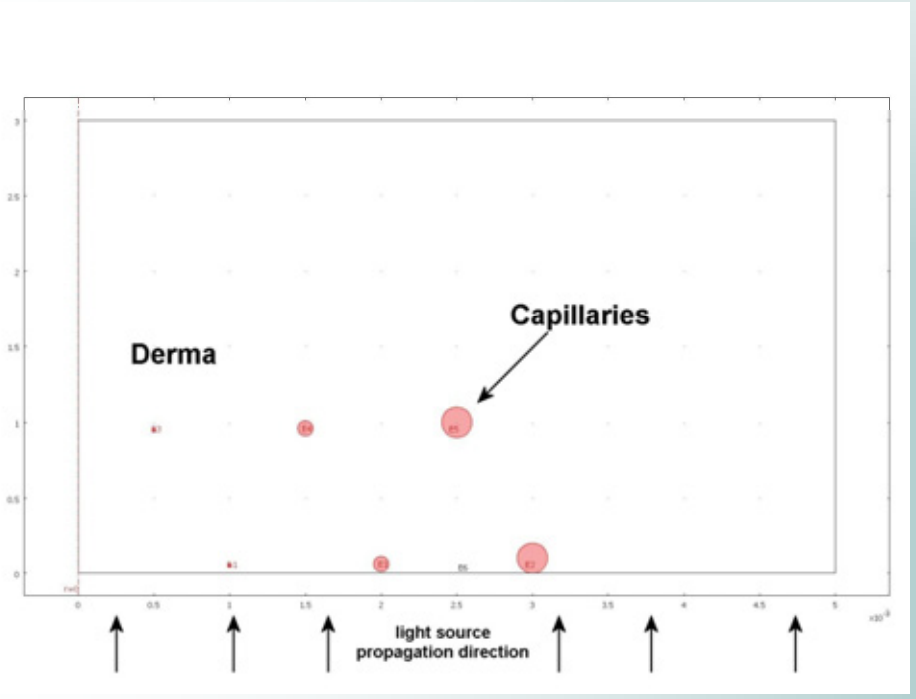





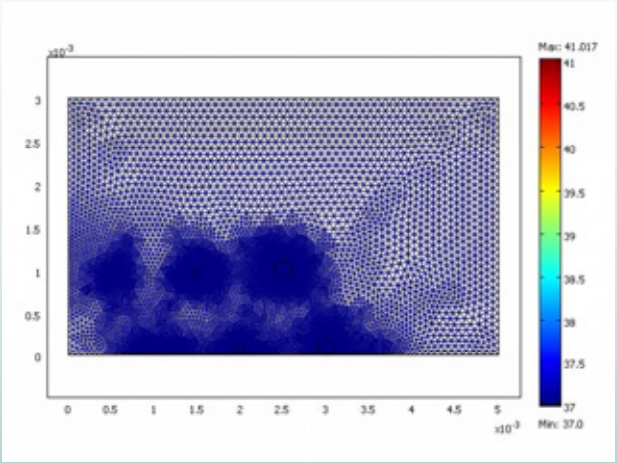





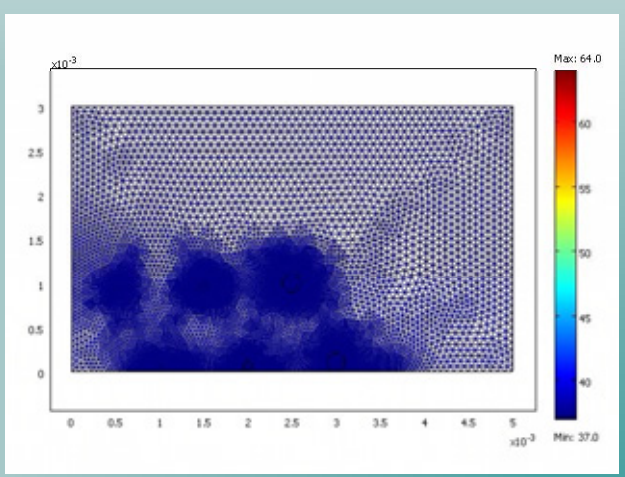
An application in Dermatology

1. Selective absorption?

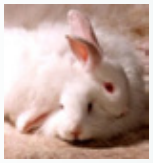
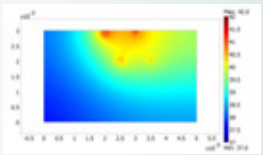
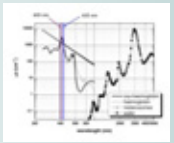
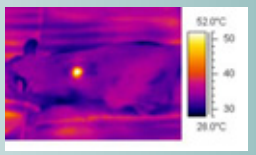


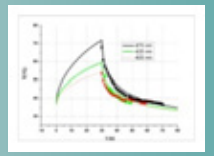
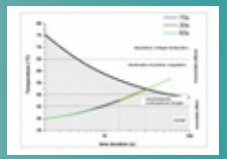


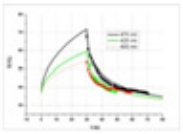
405 nm



470 nm

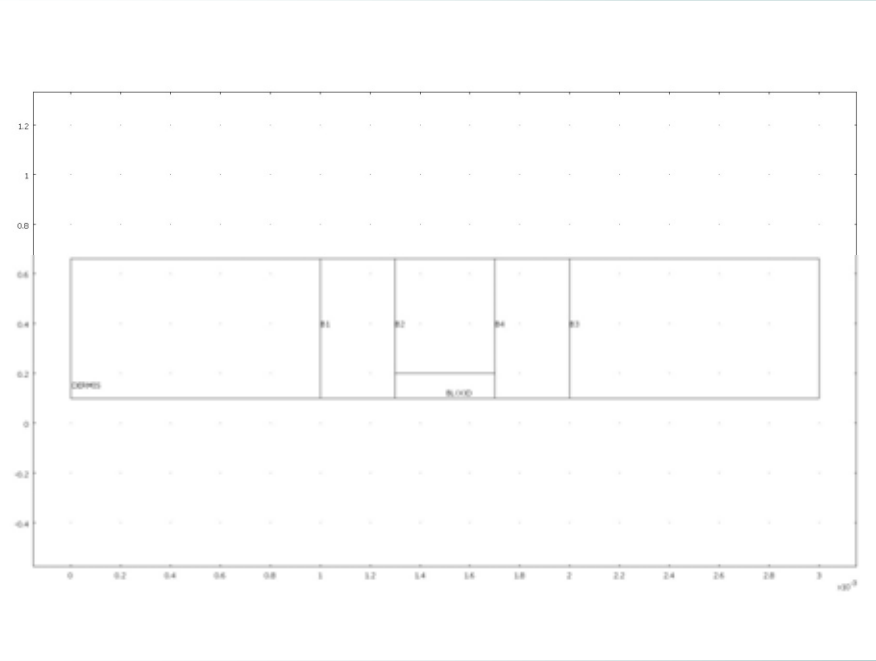







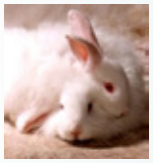
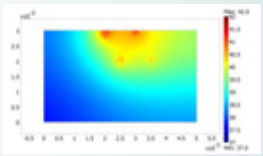
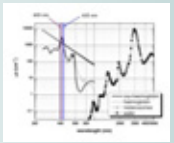
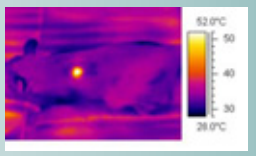
An application in Dermatology

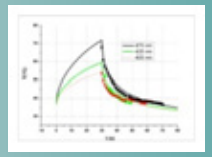
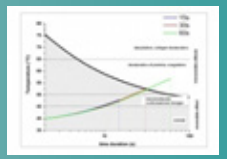
1. Selective absorption $\Rightarrow \lambda = 405$ nm
2. Irradiation conditions?

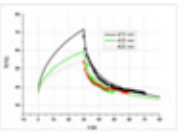


Same governing equations

Different boundary conditions,
source dimensions,
treatment time duration

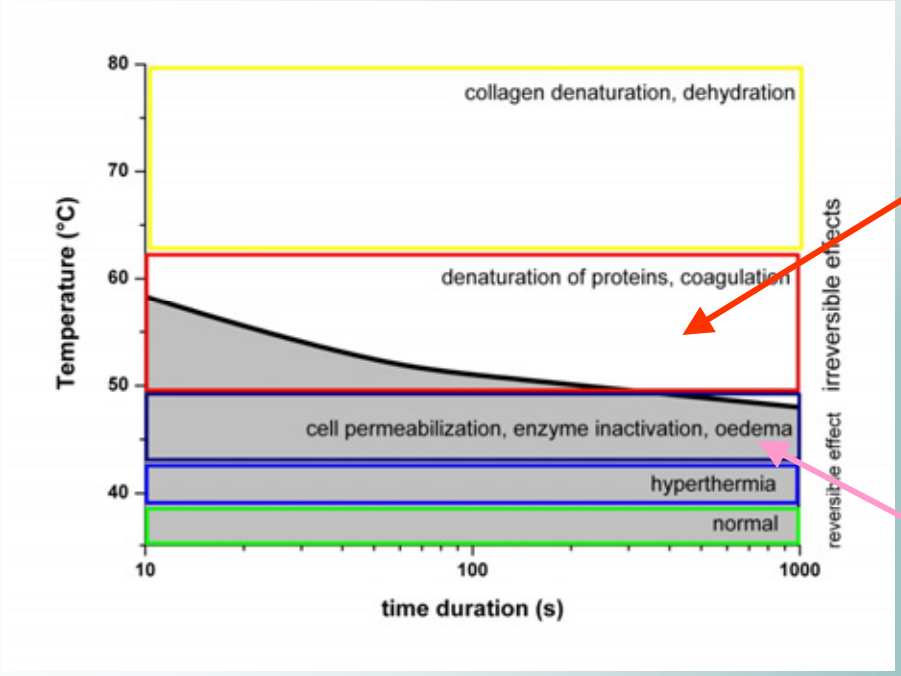







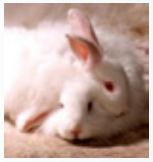
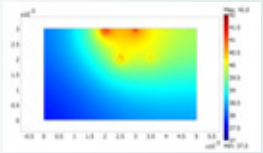
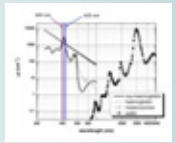
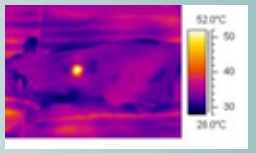
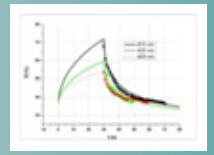
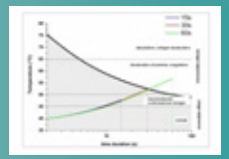
An application in Dermatology

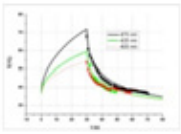
1. Selective absorption $\Rightarrow \lambda = 405$ nm
2. Irradiation conditions: **the goal is....**



Only in the blood layer

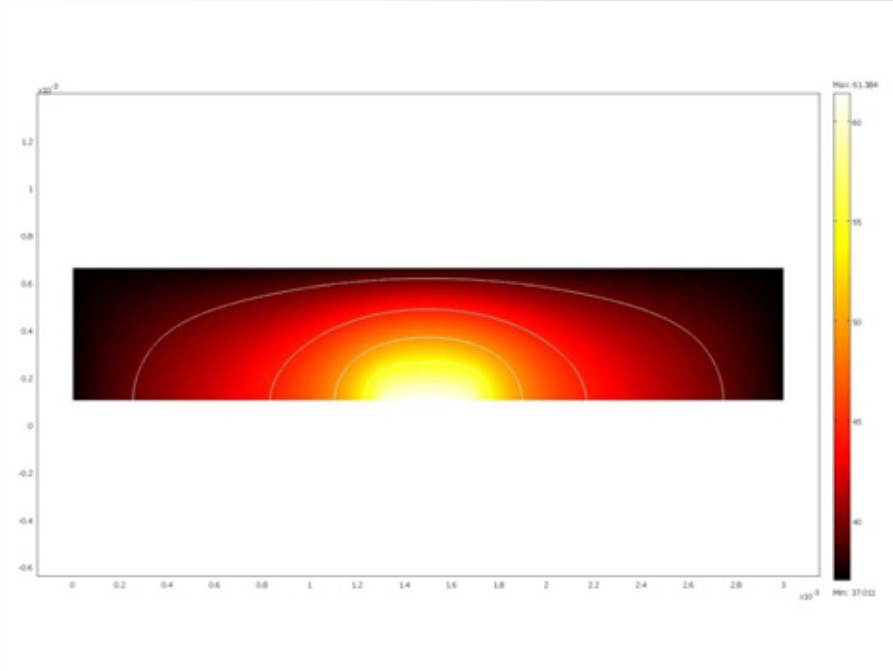
In the surrounding

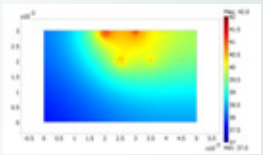
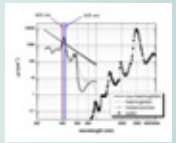
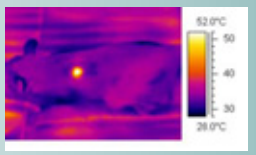
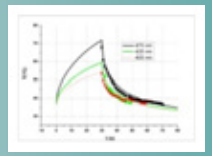
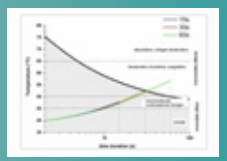


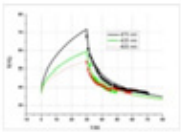
An application in Dermatology

1. Selective absorption $\Rightarrow \lambda = 405$ nm
2. Irradiation conditions?



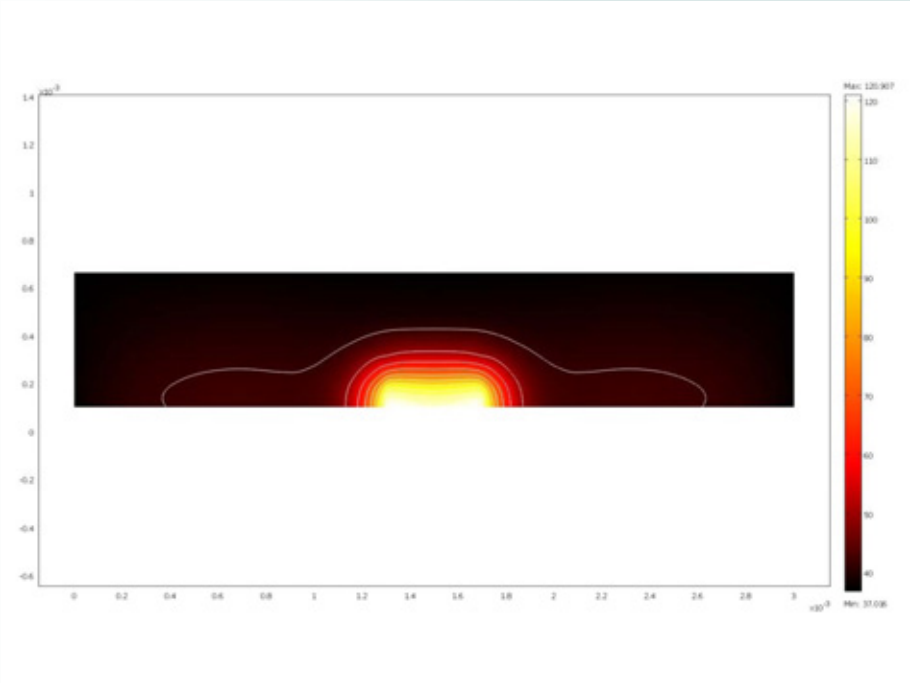
- **Led External surface in contact with the skin (thermal insulation)**
- **1.5 mm spot radius**
- **150 mW Power output**
- **5 s treatment time**
- **T_{max}= 61.4°C**

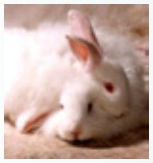
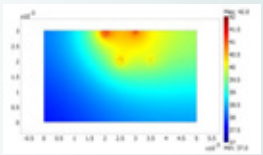
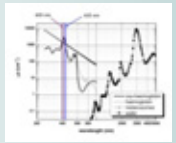
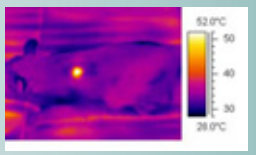


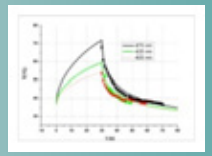
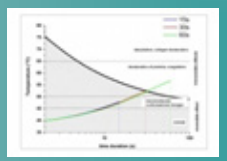
An application in Dermatology

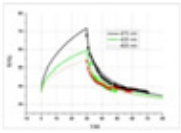
1. Selective absorption $\Rightarrow \lambda = 405$ nm
2. Irradiation conditions?



- **Non contact irradiation (convection at air/blood interface)**
- **0.5 mm spot radius (LED light delivered with optic fibers)**
- **150 mW Power output**
- **0.1 s treatment time**
- **T_{max}= 120°C**



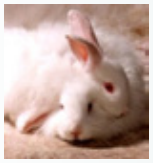
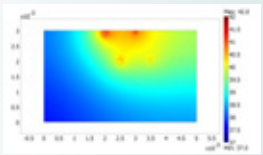
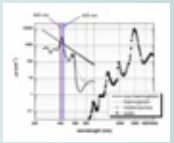
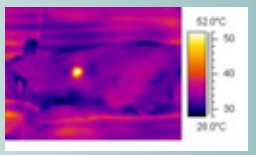
An application in Dermatology

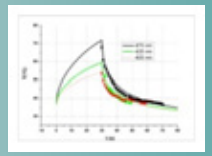
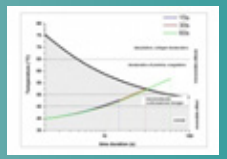
1. Selective absorption $\Rightarrow \lambda = 405$ nm
2. **Real** irradiation conditions:

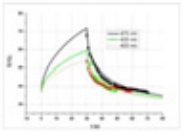
•Three commercially available LED sources:

•405 nm, 300 mW radiative power
•435 nm, 720 mW radiative power
•470 nm, 600 mW radiative power

•Active area radius ~4.5 mm

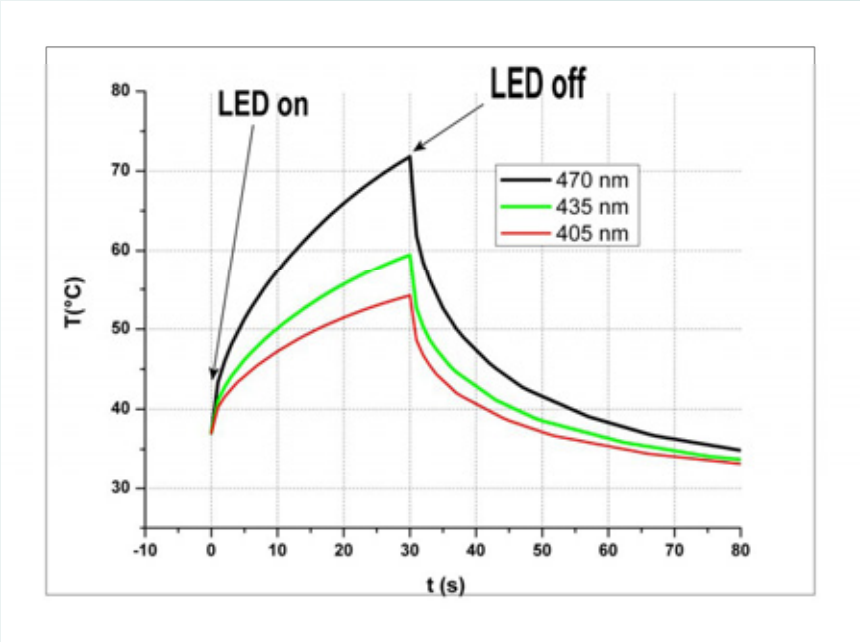





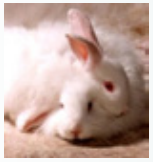
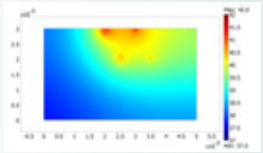
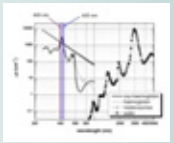
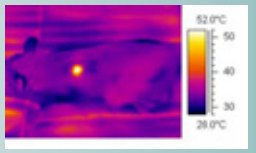



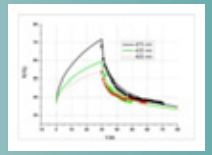
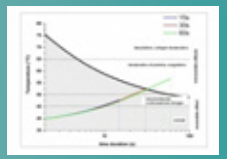


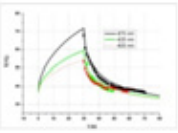
An application in Dermatology

1. Selective absorption $\Rightarrow \lambda = 405$ nm
2. Real irradiation conditions:



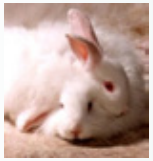
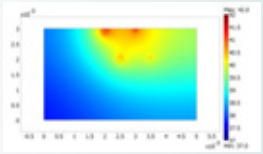
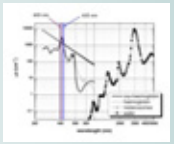
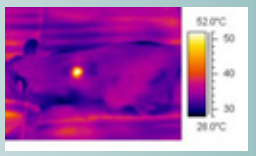





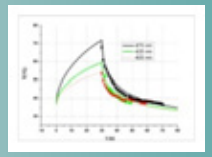
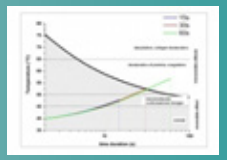



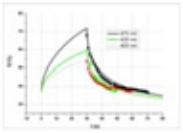


An application in Dermatology

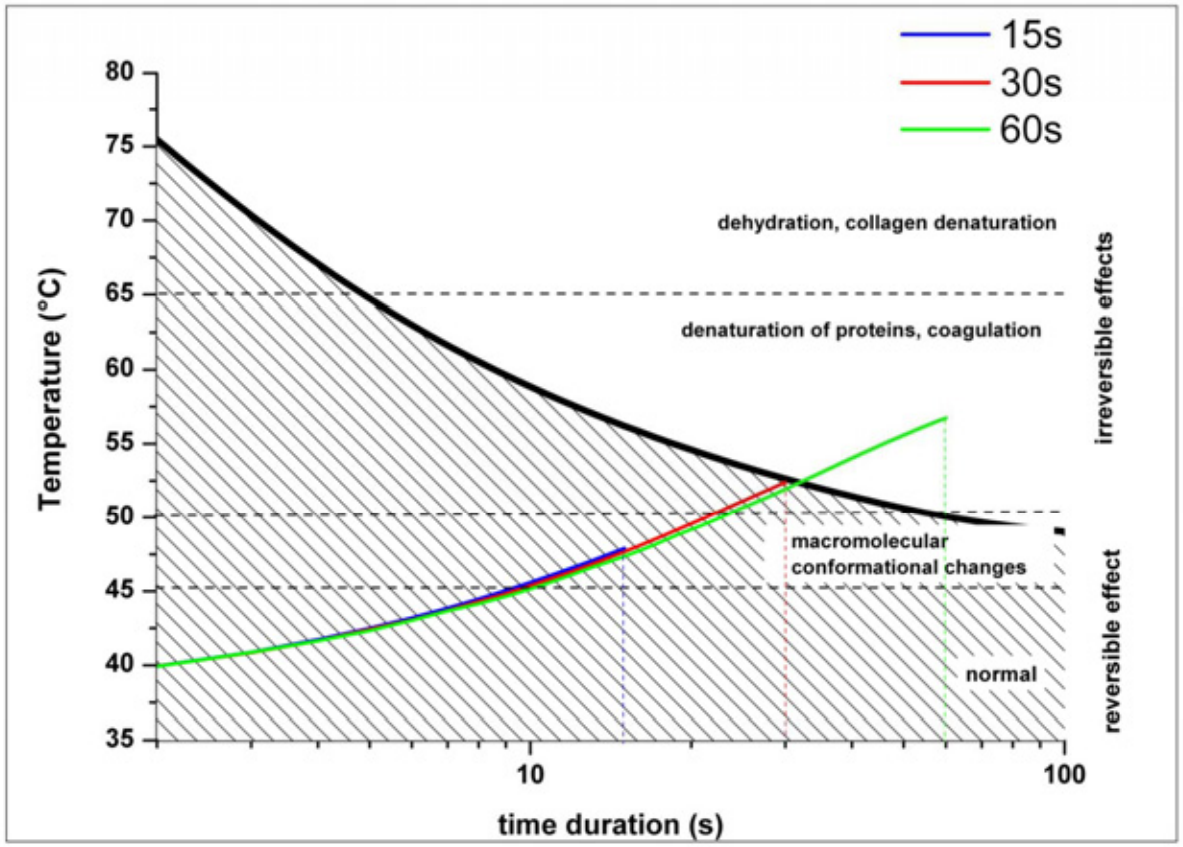
1. Selective absorption $\Rightarrow \lambda = 405$ nm
2. Real irradiation conditions: 300 mW radiative power, 4.5 mm spot radius, irradiation time....

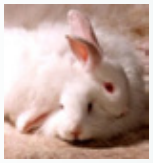
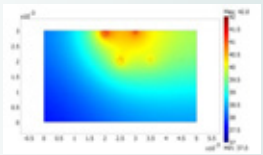
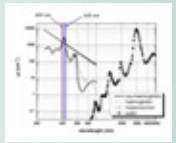
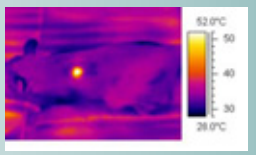





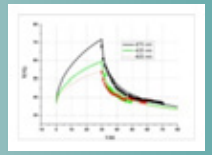
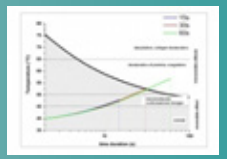



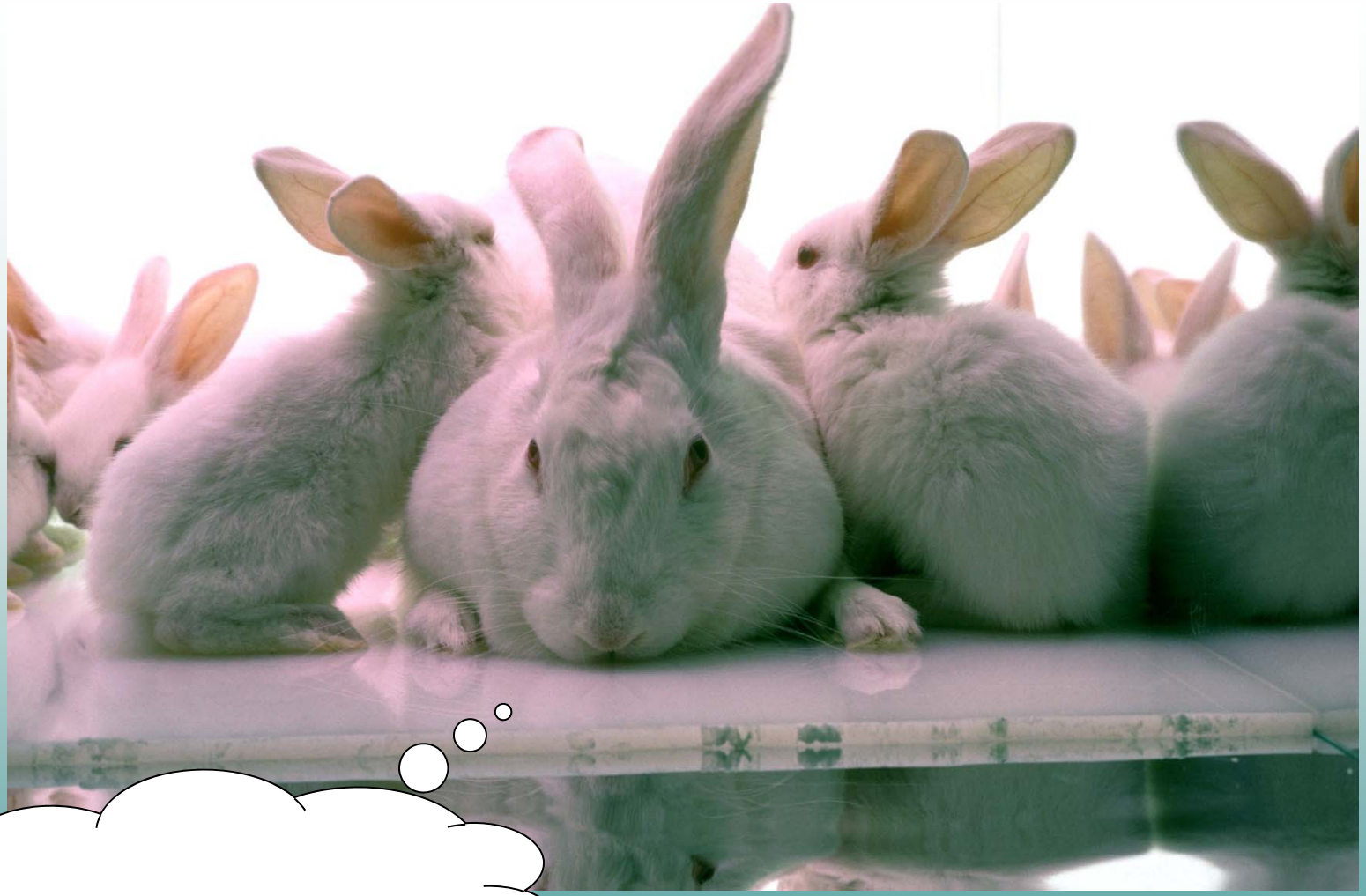


An application in Dermatology





Thank you!!!