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Université Lille Nord de France
Pôle de Recherche et d'Enseignement Supérieur

Inserm
Institut national de la santé et de la recherche médicale

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Laser Interstitial Thermo Therapy (LITT) for Prostate Cancer: Animal Model, Numerical Simulation of Temperature and Damage Distribution

Mohamad Feras MARQA[*1,2]

P. Colin[1,2,3], P. Nevoux[2,3], S. Mordon[1,2] and N. Betrouni[1,2]

[1]University of Lille 2
[2]Inserm, Unit 703, CHRU of Lille
[3]Department of Urology, CHRU of Lille

[*] feras.marqa@chru-lille.fr

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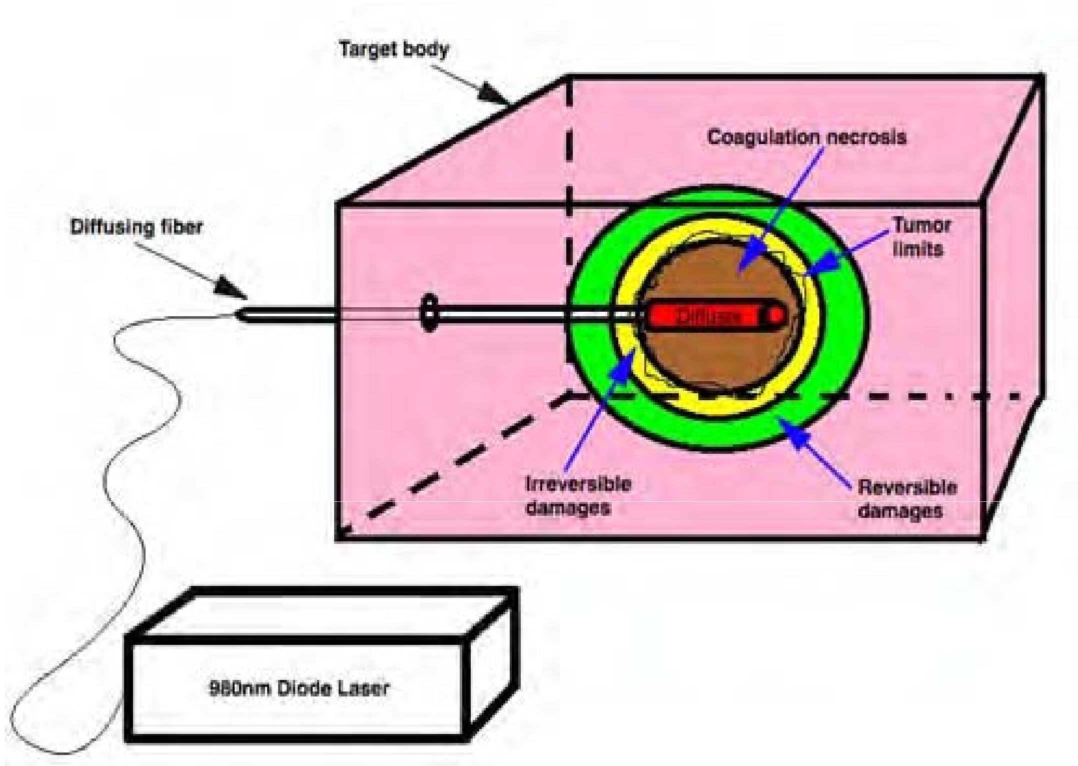
Background: Laser Interstitial Thermotherapy (LITT)



- Minimally invasive thermal technique
- Addressed to coagulate deep and solid tumors
- Tested in various tumors: breast, brain, kidney, Liver, and recently for **low risk prostate cancer**

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Applications of LITT in the Unit 703

- In liver metastases (guidance with real-time MR images)
  (Viard et al. Conf Proc IEEE Eng Med Biol Soc, 2007)

- Development of new diffusing fibers used for LITT method
  (patent pending N°. 08008613.5)

- **Pro-LITT project :** Development of a protocol on a pre-clinical model of ***prostate cancer*** using LITT method

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Objective

- Heat extent in prostate tissues
- Volume of necrosis estimated after prostate thermal laser treatment

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Material and Methods: Experimental model (1/3)

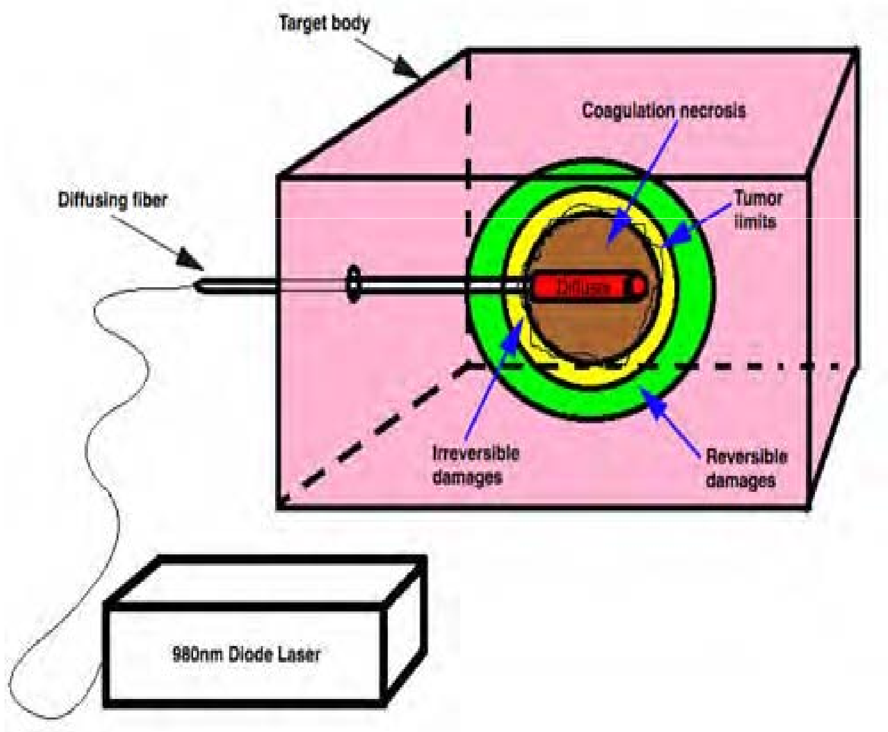
Copenhagen rat

Material and Methods: Experimental model (2/3)

- Diode laser unit (Pharaon 980, Osyris)
  Wave length of 980 nm
- Diffusing fiber :
  (10 mm, d = 500 µm)

- Maximal power output 5 W
- Diffusion time = 75 s

- Maximum temperature
  measured = 155°C



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Material and Methods: Experimental model (3/3)

- MR images performed after 48h

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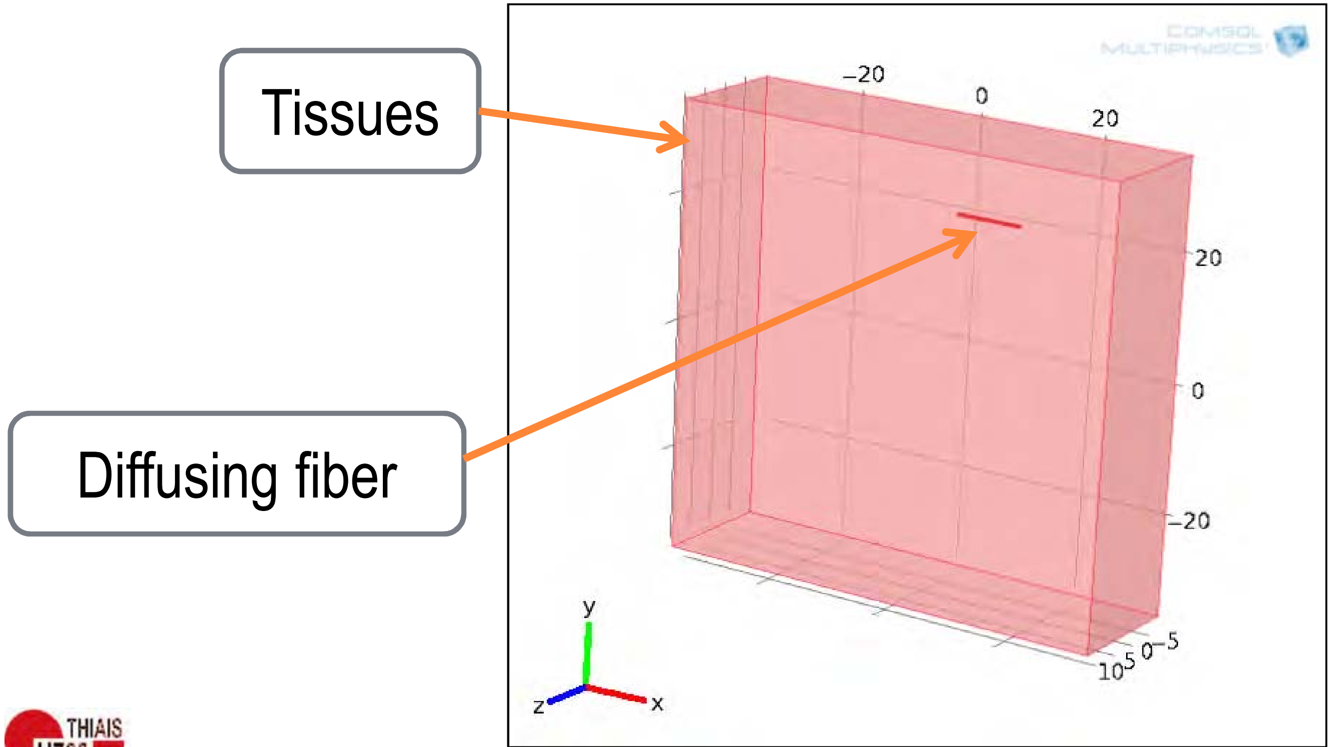
Material and Methods: Simulation model (1/4)

- COMSOL Multiphysics 4.0

1 – Geometry: Dimensions
- Tissues ($70\ \mathrm{mm} \times 70\ \mathrm{mm} \times 20\ \mathrm{mm}$)
- Fiber (L=10.0 mm, d=500 μm)



Material and Methods: Simulation model (2/4)

2 – Heat distribution

Thermal conductivity

Blood Temperature

Temperature

$$C_p.\frac{\partial T}{\partial t} - \nabla.(\mathcal{k}.\nabla T) = w_b.C_p.[T_b - T] + \cancel{Q_{met}} + \cancel{Q_{ext}}$$

Heat capacity

Time

Blood flow rate

Metabolic heat

External heat

Material and Methods: Simulation model (3/4)

3 – Thermal damage

Activation energy

$$\Omega(r,\tau) = A_f \int_0^{\tau} \exp\left(\frac{-E_a}{RT(r,t)}\right) dt$$

Frequency factor

Universal gas constant

$$\Omega(r,\tau) \begin{cases} 1 \longrightarrow & \text{(100\% destroyed tissues)} \\ 0 \longrightarrow & \text{(100\% healthy tissues)} \end{cases}$$

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Material and Methods: Simulation model (4/4)

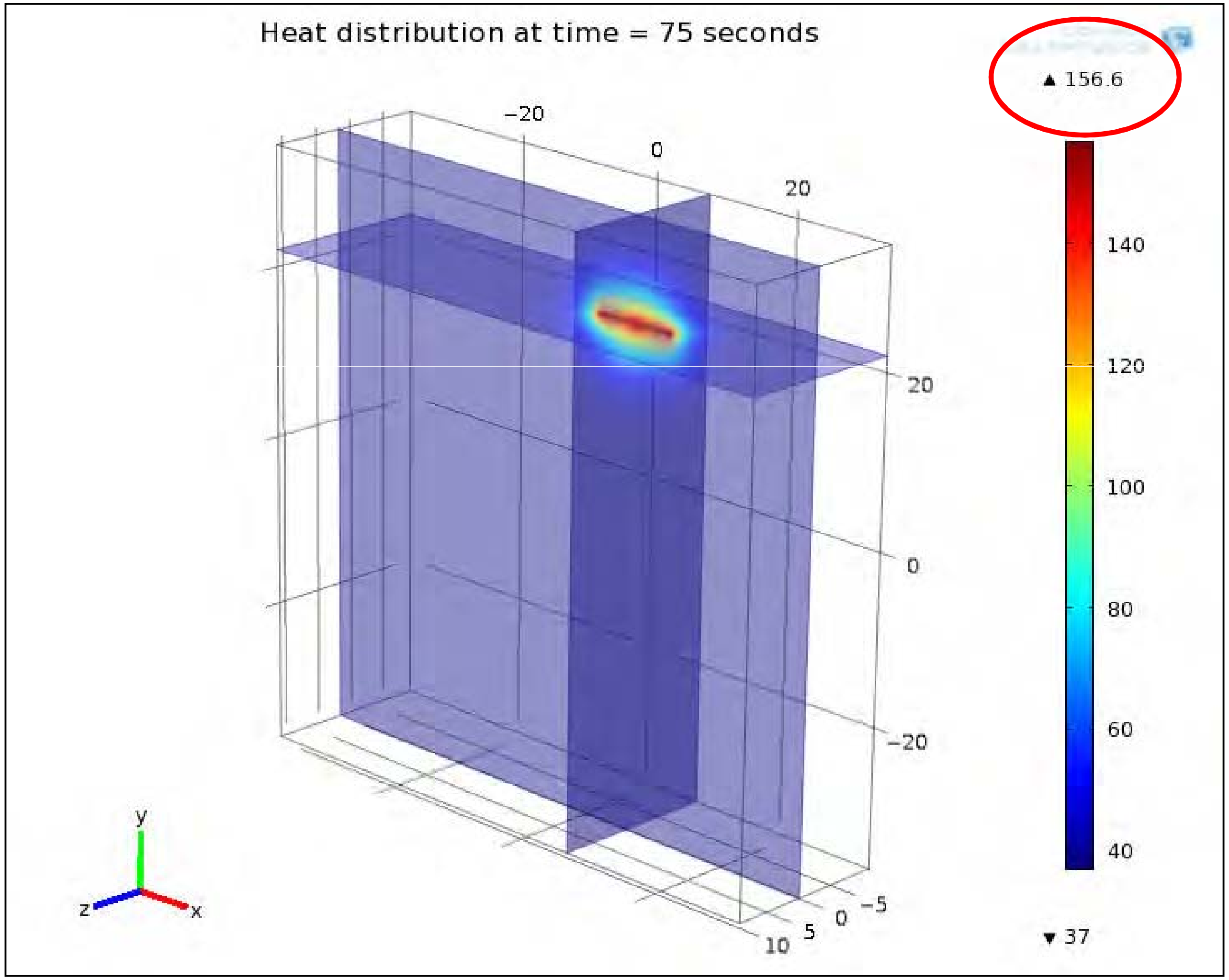
Physical parameters of the rat used in numerical simulation:

$\lambda = 980\ nm$	Parameters	Values
Thermal coefficients	$C\ (\mathrm{J.g}^{-1}.{}^{\circ}\mathrm{K}^{-1})$	4.20
	$\rho\ (\mathrm{g}.mm^{-3})$	0.999×10^{-3}
	$k\ (W.mm^{-1}.{}^{\circ}K^{-1})$	5.52×10^{-4}
	$w_b\ (ml.\mathrm{g}^{-1}.min^{-1})$	0.10
Tissue Damage Coefficients	$\mathrm{A_f}\ (\mathrm{s}^{-1})$	1.50×10^{101}
	$\mathrm{E_a}\ (\mathrm{J.mole}^{-1})$	6.33×10^{5}
	$R\ (J.mole^{-1}.{}^{\circ}K^{-1})$	3.41847

J.C. Bischof, D. Smith, P.V. Pazhayannur, C. Manivel, J. Hulbert, and K.P. Roberts, Cryosurgery of Dunning AT-1 Rat Prostate Tumor: Thermal, Biophysical, and Viability Response at the Cellular and Tissue Level, *Cryobiology*, **34**:42–69 (1997).

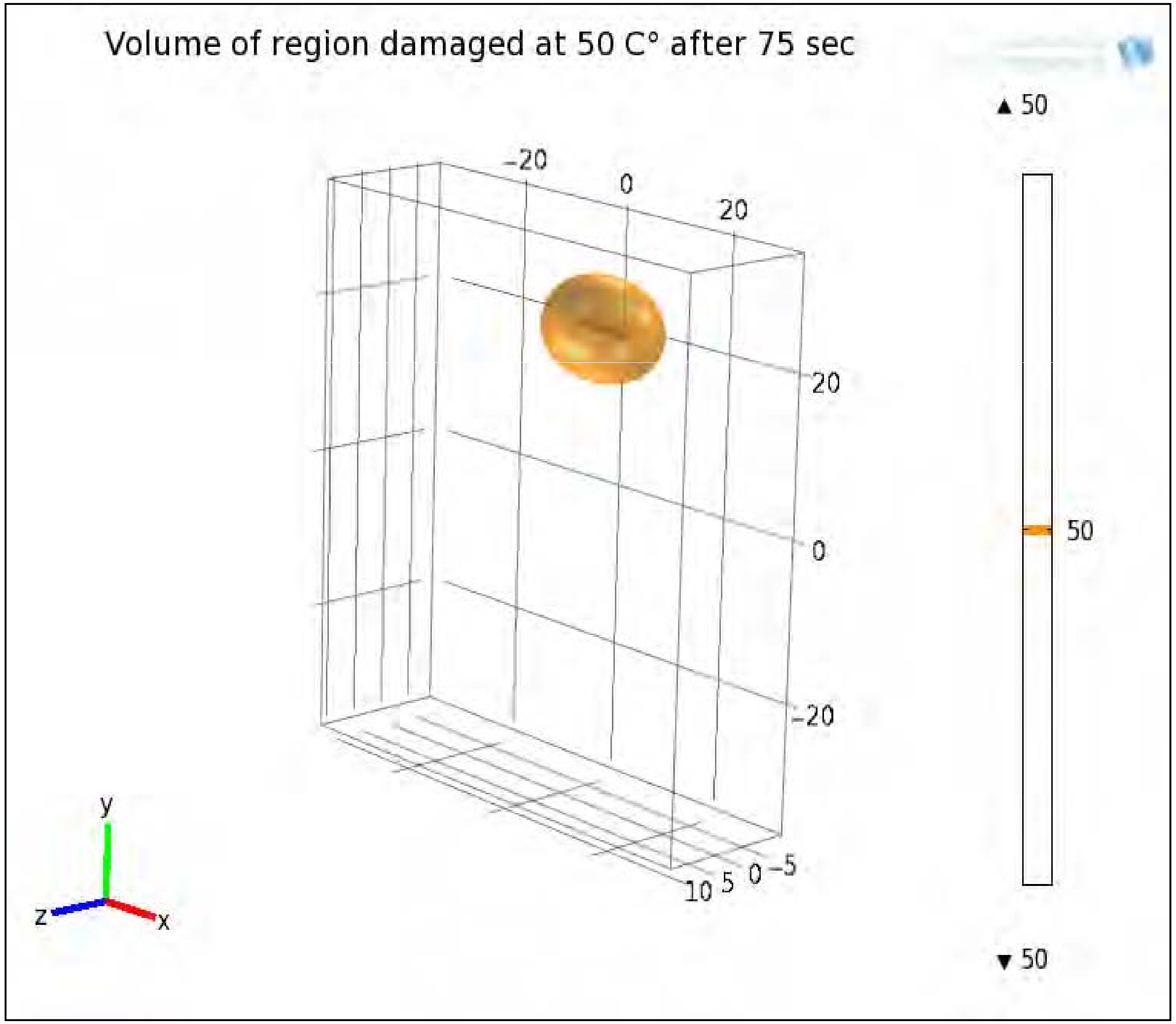
Results

1 – Heat distribution



Results

2 – Thermal damage



Results

	Experiment	Simulation	Deviation
Maximum heat diffused	155 C°	156.6C°	≈ 1%
Volume of thermal damage	0.98 ± 0.05 cm^3	1.00 cm^3 when T=50℃,	< 1 %

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Conclusions

- LITT treatment of prostate cancer is a promising method
- The heat extent in tissues and thermal damage can be estimated by simulation
- Results presented from simulation are in good agreement with the experimental results
- This therapy needs further evaluation and understanding of the heat extent in tissues to become a surgical method applied in a routine hospitalization[2]

THANK YOU

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QUESTIONS ?