The effect of geometric anisotropy on the heating of gold nanoparticles under a femtosecond pulse.

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INTRODUCTION

The interaction between a pulsed laser and nanoparticles is of great interest for several sectors including biology and nanomedicine.

The absorption resonance of spheroids (AuNps) is in the transparency window of biological tissues close to infrared (650 to 1350 nm), which is why they can be exploited for applications in cancer therapy.

In this work, we are interested in giving a descriptive analysis of the dynamics of ultra-fast thermal exchanges in a spheroid AuNp, using the two temperature model (TTM).

We will consider the following:

- One **single femtosecond** pulse (Ti-Saphire λ=800nm);
- One single **Prolate** AuNp, with an **aspect ration η=b/a >1**;
- The AuNp is assumed to be placed in water.

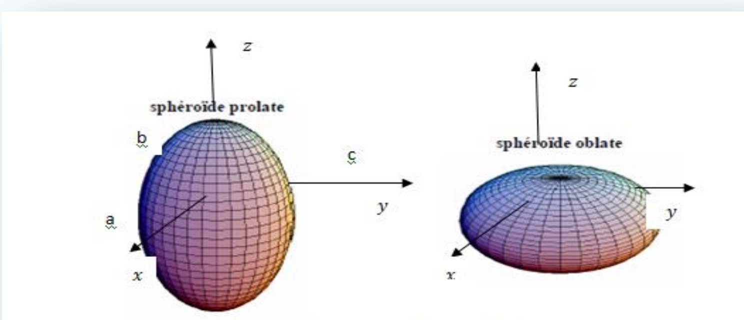


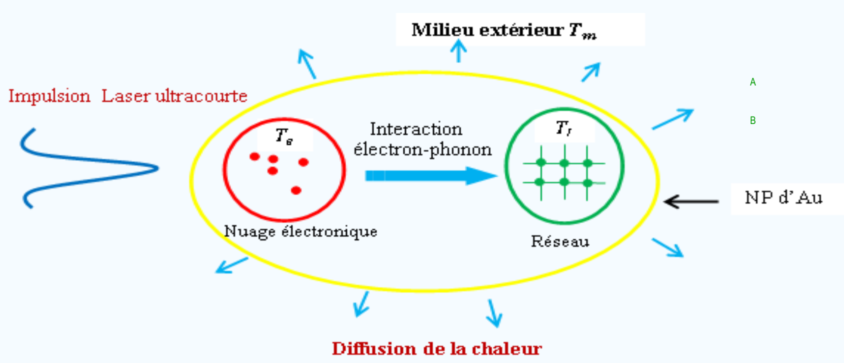
Figure 1 : Prolate form (left) a=c and b>a and Oblate form (Right), a=c and b<a

MATERIALS AND METHODS

The two temperature model

The two temperature model (TTM) allows to model the exchanges between the two subsystems in the metallic nanoparticle:

- The first electronic;
- The second phononic.



The process of thermal exchanges in the AuNp is described by a TTM consisting of two coupled differential equations:

$$\begin{cases} C_e(T_e)\dfrac{\partial T_e(t)}{\partial t} = -g(T_e - T_L) + S(t) \\ C_L(T_L)\dfrac{\partial T_L(t)}{\partial t} = g(T_e - T_L) - Q \end{cases} \quad (1)$$

$T_e(t)$ and $T_L(t)$ are the electron and lattice temperatures, respectively;

$C_e(T_e)$ and $C_L(T_L)$ their specific heats respectively, they depend on the temperatures;

g is the electron-phonon coupling factor.

S(t) is the laser energy absorbed by the GN.

Q is the term of thermal energy loss.

RESULTS

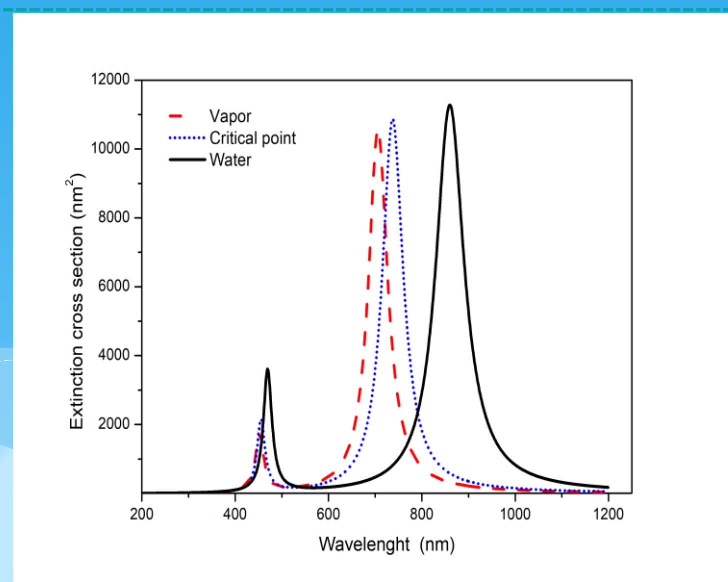


Fig. 1: Absorption, cross-section as a function of wavelength calculated on the basis of quasi-static approximation scattering theory. **the aspect ratio η=b/a=5**

Longitudinal and axial absorptions at 2 wavelengths 500 nm and 800nm

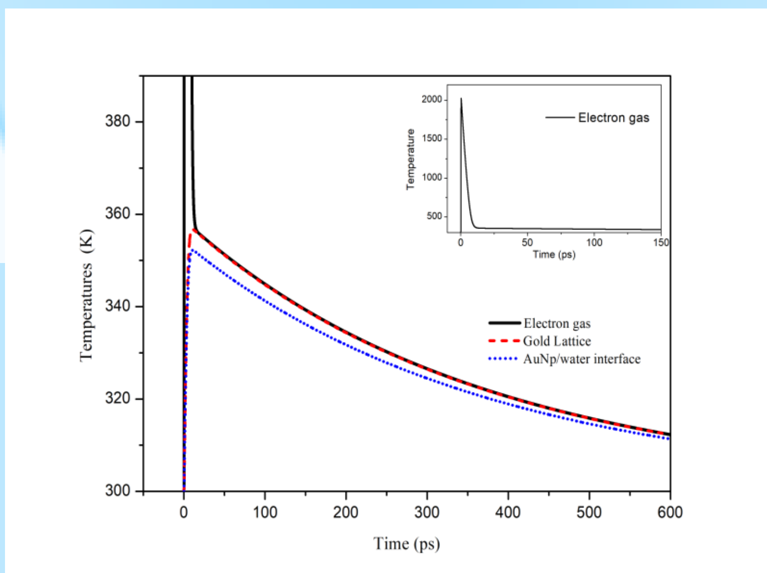


Fig. 2: Temporal evolution of Te, TL and the AuNp/water interface temperatures of a single spheroid AuNp (η=b/a=5) heated by 100 fs pulse and cooled in water. The fluence is of 1 J/m². In inset, temporal evolution of electron temperature.

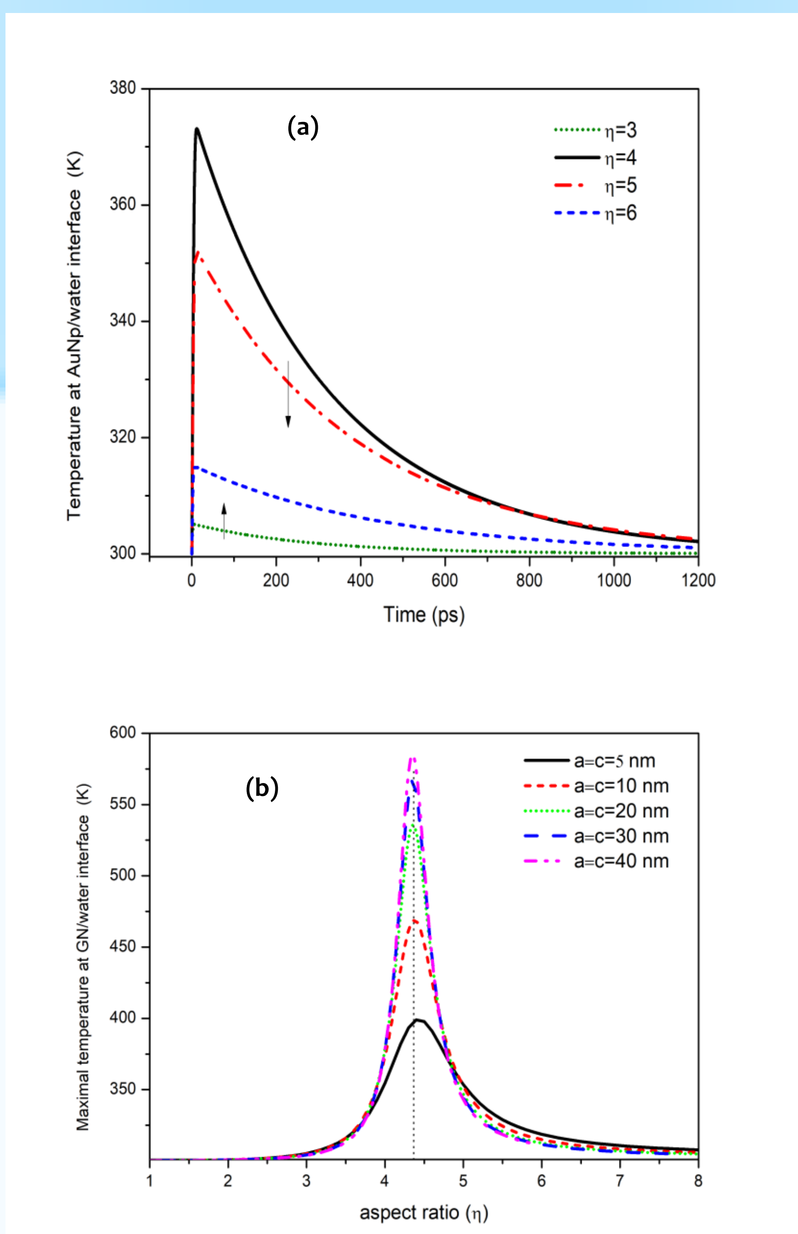


Fig. 3: (a) Time-temperature profile of single Prolate AuNp irradiated by 100 fs pulse and fluence of 1 J/m²; (b) Effet of η=b/a on the maximum Temperature for different value of AuNp width.

CONCLUSIONS AND PERSPECTIVES

- We studied the dynamics of ultra fast thermal exchanges within a spheroid AuNps.
- We used the TTM to describe the heat exchange process. The heat flux at interface AuNps/water can be used to compute the temperature at the interface.
- The results founded show that the temperature at the interface increasing with the aspect ratio up to 4 then it decreases.
- The maximum temperature is always in an aspect ratio of 4.4 whatever the dimensions of the spheroids AuNp. **Our future work will focus on the diffusion in the surrounding medium.**

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