M2 research Intership : Temperature and deformation distributions in a transparent solid in the course of multipulse femtosecond laser irradiation

Laboratory name : Institut de Chimie Moléculaire et des Matériaux d'Orsay
CNRS identification code : UMR CNRS 8182
Internship location : Henri Moissan (bât.670)
Thesis possibility after internship : NO
Funding : NO at this date but a procedure for getting support will be achieve when the candidate will be known
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Subject

Femtosecond laser is now largely employed in a wide range of applications including photonics. In our team, we use it to modify the optical properties for optical applications at the micro level and in 3D. In many microscopic processes induced by ultrafast laser direct writing, the temperature induced by the absorption of the laser light energy plays a special role in the induced transformations. Some of the processes can be thermally activated, others temperature driven, such as phase transition(s). However, the temperature is not a constant function of time, but instead exhibits oscillations that depend on the laser parameters. This is exemplified in Fig. 1, where the modeled temperature under specific irradiation conditions is shown to oscillate between a minimum and a maximum during each pulse period. While the oscillation amplitude appears unchanged of any R_τ (the ratio between the pulse period and the heat diffusion time), the temperature seems to reach a steady state as the number of pulses (N) becomes large (Fig 1 a, b, and c going from 10 to 100 pulses simulated). The number of pulses to reach this 'steady state' appears very small for large $R\tau$ but larger for small ones, impacted by the temporal overlapping between consecutive pulses.

As exemplified, analytical expressions of temperature as a function of time and distance from the center of the laser heated zone induced by multi-pulses for pulse durations below then ns scale using spherical or cylindrical energy source deposition can possibly be obtained. Such expressions would facilitate and assist the experimental work associated to laser irradiation processes in optical materials. Moreover, it enables temperature profile modeling according to laser parameters. The objective of this internship is to make available simple expressions and preparing a rigorous simulation with a professional software (e.g. COMSOL). Multiple levels of approximations are possible on both the source geometry or the temperature dependence of the physico-chemical parameters.
As an extension and application of this work will be the computation of the deformation distribution due to thermal expansion processes.

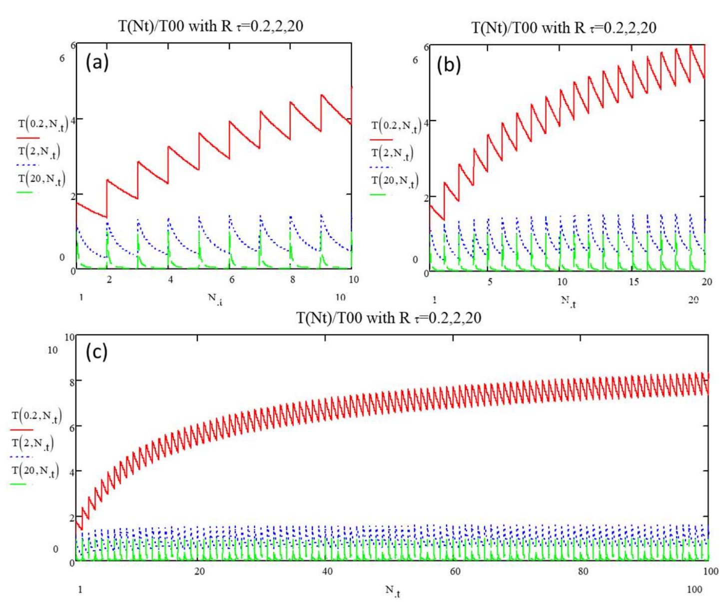

Fig.1: Plot of the reduced temperature at the center r=0 in spherical geometry as a function of pulse numbers [(a)10, (b) 20, and (c) 100.], and according to the generalized pulse number $N_t = \frac{t}{\tau_p}$, varying from 0 to N-1. $R_\tau = 0.2, 2, 20$

Methodology:

- Reading the literature (state of the art), and establishing the equations of the problem and the relevant parameters.
- Solving the equations in the frame of the following approximation: spherical source with constant physico-chemical parameters
- Modifying the geometry to cylindrical approximation but constant physico-chemical parameters
- Investigating the possibility to stay within analytical problem when relaxing physico-chemical parameters (i.e., Temperature dependent)
- Preliminary trials and implementation to COMSOL environment
- Inclusion of the mechanical problem

Applications

- To distinguish the difference between 2 types of thermally activated processes. Is it possible to favorize one process on the other by playing with the laser parameters?
- To interpret some experimental results from the literature and current ongoing experimental work.