Study of Ultra-Fast Phenomena Generated in Femtosecond Laser-material Interactions

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Introduction

The great technological progress in the field of pulsed lasers and in particular femtosecond lasers attracts a lot of attention whether for academic research or in industry because of the interest of its justified applications in multiple fields. The interaction of light with matter is very different for these pulses compared to longer pulses. The matter is almost instantly changed and then evolves as the laser pulse is terminated; the thermal effects are profoundly changed. These mechanisms are of course studied for themselves, but already it is possible to understand that many new applications are accessible. The innovative applications of laser technology are linked to the advancement of knowledge of the mechanisms of laser-matter interaction. The aim of this work is to understand the ultra-fast phenomena generated during the interaction of ultrashort lasers with metallic surfaces such as gold for thermal machining.

RESULTS AND DISCUSSION

The two-temperature model (TTM) was used for modeling the laser-gold interaction. TTM offers the possibility of describing heat transfer and energy exchange between the ion network and the electrons in the material. It also allows us to properly analyze the spatial and temporal distribution of the energy flow from hot electrons to the cold ionic network where each of these two subsystems is supposed to be in thermodynamic equilibrium [1,2]. Fig 1 shows the evolution of the electronic temperature T_e and of the network temperature T_i as a function of time on the gold surface, in the case of the three pulsed regimes: fs, ps and ns.

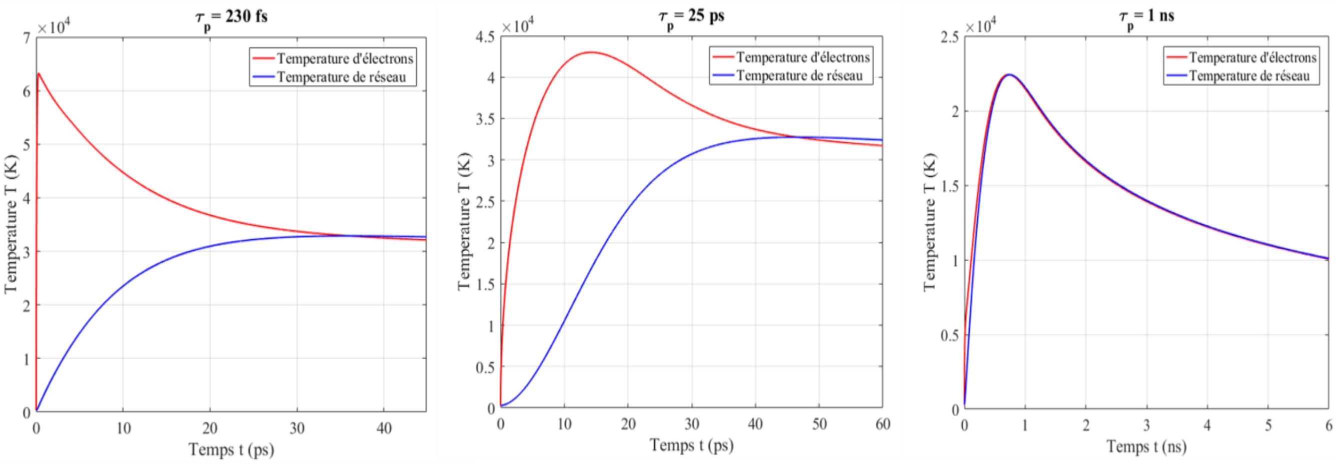

Fig 1: Evolution of the electronic temperatures T_e (red line) and of the T_i network (blue line) as a function of time on a gold surface irradiated with fluence F =10 J/cm^2 and laser wavelength = 800 nm. (a) a femtosecond laser with a pulse duration of 230 fs, (b) by a picosecond laser with a pulse duration of 25 ns, (c) irradiated for 1 ns.

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We have found that one can achieve purely thermal fusion and ablation accompanied by the ejection of the molten material during the ns laser and ps laser interaction with the material, but with an amount of scattering lower in the case of a picosecond laser. Whereas in the case of femtosecond pulses, the tearing of the material is very fast and takes place before the thermalization of the energy and the propagation of the heat, which makes it possible to confirm that fusion is non-thermal and the ablation occurs by ejection of the material in the form of plasma.

CONCLUSION

The time required to effect a change in a material during the ablation is a factor of great importance, in this respect we have studied the evolution of the temperatures of the network and of the electrons as a function of the time at the sequence of nanosecond and picosecond pulses in order to compare them with the femtosecond pulse rate. It can be concluded that, from the point of view of precision, fs lasers have very specific characteristics due to the ultra-fast mechanisms which govern the interaction of the laser with the material are non-thermal producing.

REFERENCES

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