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High intensity femtosecond lasers at IPEN: tools for modification and characterization of materials

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High intensity femtosecond (fs) lasers have become an affordable and versatile tool to modify all kinds of materials and to characterize the induced modifications. These capabilities derive from the ultrafast interaction between the electromagnetic field and matter, which distinguishes this kind of laser from all others.

In the time frame of the fs pulses, the predominant interaction with the matter occurs through electron excitation, and several processes take place with increasing intensity: nonlinear excitation, ionization and recombination, which occur in a non-selective way due to the short time of interaction. The after-pulse evolution is due mainly to electrostatic interactions, involving the relaxation of the electrons energy to and between atoms. Coulomb and phase explosions, for example, are predominant for intensities in the range of TW/cm^2 to PW/cm^2 , and they ablate all material (metals, polymers, dielectrics, etc) with a very high precision due to the small heat effect zone of these interactions.

At the High Intensity Ultrashort Pulses Lasers Laboratory at IPEN we daily generate femtosecond pulses with intensities of $100 \text{ TW}/\text{cm}^2$ and above. In this work we describe results obtained by our group using ultrashort pulses from Ti:Sapphire lasers covering the creation of color centers in crystals, glasses and polymers, the inscription of waveguides and the creation of surface structures that can range from the colorization of metals to the manufacture of microfluidic circuits, as well as the removal of burned tissue from living organisms. The pulses can also be used to study how defects pileup during the etching of a solid by superimposing pulses, and how the ablation process is affected by the incubation.

At higher intensities the pulses can modify materials, and we present the controlled synthesis of nanoparticles, and the modification of graphite into diamond by the shockwaves generated during the ablation as a product of an evolving underdense plasma that generates local high temperatures and pressures. Also, the materials characterization is possible by spectroscopic measurements of the plasma elements atomic lines.

Furthermore, we present results on the production of radiation on the deep ultraviolet by generation of harmonics of the laser interaction with gases, and also our recent efforts towards the acceleration of electrons by ultrashort laser pulses. Both the harmonics and electrons ultrafast beams could be used to modify and characterize materials by pump-probe, spectroscopic and diffraction measurements.