LABORATOIRE INTERACTIONS, DYNAMIQUES ET LASERS

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THESE LIDYL

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Amphi Pierre Lehmann, Orsay Batiment 200

"Ultra High Intense Laser on Dense Plasmas: from Periodic to Chaotic Dynamics"

The advent of high power femtosecond lasers has paved the way to a promising and still largely unexplored branch of physics called Ultra-High Intensity physics (UHI).
Once such a laser is focused on a solid target, the laser intensity can reach values as large as 10^{18-20} W.cm^{-2}, for which matter is fully ionized. The plasma thus formed expands towards vacuum on a spatial scale characterized by a quantity Lg called the *density gradient scale length*. When Lg is significantly lower than the laser wavelength, the dense plasma therefore acts as an optical mirror that specularly reflects the incident light:, it is a *plasma mirror*. This remarkable physical system can be used in many scientific applications as compact source of high-energy and high-charge particle beams (electrons, ions) or bright source of radiations ranging from extreme ultraviolet-rays to X-rays through high harmonic generation processes.

In order to finely control these sources, it is required to properly identify the different coupling mechanisms between light and matter at play during the interaction. In this thesis, this has been made possible by performing accurate Particle-In-Cell (PIC) simulations with the WARP+PXR code. This recently developed code advances Maxwell's equations in Fourier space, which proves to correctly model harmonic and electron emissions that standard codes fail to accurately describe even at high resolution.

Based on WARP+PXR PIC simulations, we investigate the influence of Lg on the experimentally observed emission of light and particles, when a high-power laser pulse (I =10^{19} W.cm^{-2}) reflects off a dense plasma. Our study reveals an unambiguous transition from a temporally *periodic* mechanism to a *chaotic* process as the interface becomes smoother.

In particular, the latter mechanism, named *stochastic heating*, is fully characterized as well as its domain of validity in terms of laser-plasma parameters. In this regime, electrons in the underdense part of the gradient are exposed to the standing wave formed in front of the overcritical part of the plasma by superposition of incidence and reflected beams. While evolving in the two waves, electrons behave chaotically and absorb an important fraction of the laser energy. The nature of the interaction is revealed by reducing the equations of motion of particles in two waves to physical systems, such Kapitza's pendulum, well-known to exhibit chaos. That correspondence gives deep physical intuitions on how electrons behave in different laser configurations, which allows us to predict major features of stochastic heating.