Innovative concepts for particles plasma acceleration in laser – overdense plasma interaction at ultra high intensity

Abstract:

The present PHD work aims at exploring theorically and numerically the generation of fast particle beams in ultra relativistic (abobve 10^{21} W/cm^2) laser-overdense solid interaction by using properly-structured or shaped targets. Surface characteristics inducing local electromagnetic modes more intense than the laser field and where nonlinear and relativistic effects play a major role will be investigated. It may lead to groundbreaking ultra-short synchronized light and electron sources with applications in probing ultrafast electronic processes. In this context, this theoretical and numerical study will allow to suggest new experimental schemes feasible on the Apollon facility and multi-PW lasers.

The possibility of developing new compact energetic particle and radiation sources via several mechanisms involving the interaction of an ultra-intense laser (above 10^{19} W/cm^2) and plasmas has gained importance in the last decades. Since 2004, we have work on laser over-dense plasma particle acceleration in collaboration with C. Riconda (Head of the team TIPS/LULI). We proposed and demonstrated the possibility of resonantly excited relativistic surface plasma waves (SPW) [1], leading to high charge, ultrashort bunches along the target surface [2], reaching energies largely above their quiver energy and correlated in time and space with extreme ultraviolet (XUV) harmonic emission. Advanced methods in laser techniques, such as the use of appropriate WFR to control the duration and energy of the electron bunches have been also studied [3].

An alternative approach, the acceleration of electrons in the vacuum by a laser through straight energy transfer, named vacuum laser acceleration (VLA), or direct laser acceleration (DLA) has been gaining interest in the last years. In this context, we recently proposed a new electron acceleration mechanism that develops when an UHI p-polarized laser pulse irradiates the wedge of an over-dense plasma target leading to high-energy, high-charge and small angular aperture beams that make this new scheme particularly interesting with respect to other schemes such as SPW acceleration or VLA/DLA [4]. While we showed improved proton acceleration by TNSA when coupled to SPW excitation, improving proton acceleration by TNSA via this method needs to be studied.

Moreover, it is to be notice that the same technique could be also used to obtain positron acceleration when ultra-high intensity lasers are used where Radiation Reaction and Quantum Electro-Dynamical effects might become important.

The present PHD work aims at exploring this ultra relativistic regime (above 10^{21} W/cm^2) both theorically and numerically looking for new advanced mechanism of laser over-dense plasma interaction where local fields more intense than the laser field can be created during excitation inducing nonlinear and relativistic effects that will play a major role. It is of fundamental interest for the physics of relativistic plasmas and may also lead to groundbreaking ultra-short synchronized light and electron sources with important applications in probing ultrafast electronic processes. In this context, this study will allow to suggest new experimental schemes feasible on the Apollon facility and multi-PW laser now available. The simulations will be run with the Smilei PIC code [5]. Smilei is a massively parallelized code that solves Vlasov equations coupled with Maxwell's equations on a Yee mesh which was developed to include ultra-high intensity laser physical effects. In particular, it allows a self-consisting calculation of the movement of electrons and radiative emission during interaction.

All of this work will be carried out in collaboration avec C. Riconda et M. Grech (team TIPS/LULI) who initiated the development of the SMILEI code. The realization of simulations that describe realistic physical situations will be the subject of GENCI and PRACE calculation time requests. Mr. Raynaud has for many years been responsible for the submission of projects within the framework of this scientific theme that have been very successful (GENCI project 056851).

The interested candidate should contact Michèle Raynaud [a)] and Caterina Riconda[b)]. Knowing Python will prove necessary to use SMILEI but can be learned during the traineeship.

[a)] michele.raynaud-brun@polytechnique.edu

[b)] caterina.riconda@upmc.fr

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