Hybrid Plasma Wakefield Acceleration and Light Sources

Großprojektantrag


In Short

• The successfully completed (March 2016) experimental campaign of E210 [10] at FACET-SLAC requires computational support to increase the impact of results. Hence, simulating the electron bunch generation via laser induced ionization (“Trojan Horse”) [8][9][5] and laser generated plasma density spike injection (“Optical Plasma Torch”) [3] is necessary, to support and explain experimental findings.

• Overcome the prime bottleneck of particle bunch driven plasma wakefield acceleration (PWFA) – the lack of facilities providing suitable electron driver bunches – by generating drive bunches in an antecedent laser driven plasma accelerator (LWFA). This combines the advantages of both LWFA and PWFA [11]. To model the full system several steps are required, including:

  • Optimization of electron beam generation from LWFA as a suitable driver for nonlinear plasma wakes.
  
  • Simulation of possible plasma lens characteristics as a means of electron beam transport from LWFA stage to PWFA stage.
  
  • Exploration of different injection techniques for PWFA, such as Trojan horse, plasma torch and density downramps, to obtain high quality electron bunches.
  
  • To model the last step of this start-to-end simulation chain the application of electron bunches from hybrid LWFA-PWFA as light sources, such as undulator/FEL radiation and inverse Compton scattering process, is investigated.

High quality electron bunches from plasma-based accelerators, driven by either high intense lasers (LWFA) or very dense particle beams (PWFA), have been continuously gaining interest as the next generation light sources. This is fueled by the ability of these accelerators to sustain extremely large electric fields at a reduce size and therefore, cost. The small cavities in plasma wakefields – compared to RF-cavities – lead to intrinsically short electron bunches (~ fs scale), which is favorable for many applications. In addition, with the Trojan Horse electron bunch generation principle, the bunch brightness and emittance may be pushed to new levels, which are key parameters for applications on high energy physics and sources of coherent radiation. The Trojan Horse witness bunch generation technique in PWFA [8] is the central part of our research. In this scheme, one or more modestly intense ($a_0 \ll 1$) laser pulses are used to locally release electrons from high ionisation levels within the plasma blowout, generating ultralow emittance witness electron bunches. The core idea of this technique is to separate the wakefield excitation from the witness bunch generation, resulting in two, to a large extent, independent processes. In TH-PWFA, a high current electron bunch drives the wakefield that is based on a plasma source with a low ionization threshold (LIT). The synchronized, strongly focused laser, termed as the “injector” (or Trojan Horse) laser, is then used to ionize a neutral gas component or higher ionization levels which are present in the underdense gas mixture. The injector laser releases electrons at arbitrary locations with respect to the blowout, and in an arbitrary volume via tuning of the laser intensity. Geometries with co-propagating laser pulse(s) with respect to the electron bunch driver as well as at arbitrary angles are possible. In principle, TH injection offers a high precision control of injection due to the decoupling of the wake driver and the injection method. However, experimental progress for PWFA is impeded due to very few facilities offering high current, very dense electron bunch drivers. It
is therefore the goal of our research to utilise the rapidly increasing progress of LWFA as a potential driver for PWFA. A schematic setup of the experimental realization including LWFA stage, plasma lens, and PWFA stage with Trojan Horse injection is depicted in figure [1]. Recent LWFA experiments have produced electron bunches up to GeV levels with bunch duration in the fs scale levels. Nevertheless controlling microscopic and extremely short processes in plasmas is very challenging. Hence, even with the technological advances obtained in this field during the past years, there are still many problems to be solved. For this purpose, substantial computational effort in PIC simulations is undeniably needed.

Over the past years, we have made significant progress in our research using HLRN resources (project hhp00024), without which, this would not have been possible [3][1][2][6][5] (all of which acknowledging HLRN). Just recently, our research has come to a very exciting point, where our long-term experimental campaign (E210) for the proof-of-principle Trojan Horse scheme at the FACET-SLAC facility has come to a successful conclusion. For efficient post-processing and analysis of our data, computational resources are urgently needed. Moreover, the physics behind our experimental results needs numerical supports which can only be done using high power computers.

WWW

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More Information


Project Partners

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