SL_EXIN

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1 Experiment description

The goal of the SL_EXIN (external injection) project is to merge two technologies that are nowadays of paramount importance: high brightness linacs and plasmas. In particular, the project aims to use the high accelerating gradient that can be achieved with plasmas to further accelerate high brightness electron bunches coming from the SPARC conventional accelerator and above all preserve the high quality of the electron bunch (*i.e.* low energy spread, small emittance). This will be done by injecting a high power laser beam into a hydrogen-filled capillary tube: the laser beam will both ionize the gas and create plasma waves; at this point, high brightness electron bunches can be placed (with a very high synchronization accuracy) on the crest of the wave to be further accelerated.

In the last year, the first vacuum interaction chamber needed to the project has been delivered, vacuum tested and fully characterized (Fig. 1); the second chamber will be delivered in the first half of this year. The two chambers will allow to complete the transport line for the FLAME laser.

In parallel, simulations of the electron beam dynamic inside the plasma have been performed, showing that it is possible to preserve the electron beam quality; the working point consists into the injection and extraction of the electron beam into/from the plasma using density ramps, which help not only to preserve beam quality, but also to control the focusing of the laser beam into the plasma. Beam loading effects have been studied as well and simulations show that this effect is an useful tool that can be used to achieve the electron beam size matching conditions adiabatically [1].

During the last year, a step forward has been done also on the diagnostic part of the project. Different types of plasma diagnostic have been studied and experimentally tested, starting from Stark broadening of hydrogen lines to Mach-Zender interferometer (Fig. 2 and Fig. 3).

The difference between the two methods is essentially the density range where they can be used: Stark broadening is particularly useful at very low densities (between 10^{14} to 10^{17} particle/cm^3), while Mach-Zender interferometer is a very good tool at higher densities (from 10^{18} particle/cm^3) and higher). The knowledge grown on the use of these two measurement devices will allow us to cover a very wide range of plasma densities.

Alternative diagnostics have been studied as well: betatron radiation, for instance, which is a very useful tool to understand what is happening during the acceleration process and to reconstruct the emittance growth and behavior during acceleration.

Finally, another achievement has been obtained on the synchronization part, which is one of the most critical aspects of this experiment. Both laser and electron beams have to be synchronized at the femtosecond level in order to be able to place the electron bunch exactly on the crest of the plasma wave. Last year we have installed a new optical line based on optical fiber and an optical phase cross-correlator, which has allowed us to have the first correlation signal from SPARC to FLAME. The optical connection between the two machines will allow us to have a synchronization at the tens of femtosecond level.

Figure 1: *First vacuum chamber of the SL_EXIN project for the FLAME laser transport during the vacuum tests at INFN.*

2 Publications

1. R. Pompili et al., *Beam manipulation with velocity bunching for PWFA applications*, Nucl. Instrum. and Meth. in Phys. Res. A **829**, 17-23 (2016).

2. A. R. Rossi et al., *Stability study for matching in laser driven plasma acceleration*, Nucl. Instrum. and Meth. in Phys. Res. A **829**, 67-72 (2016).

3. F. G. Bisesto et al., *Laser?capillary interaction for the EXIN project*, Nucl. Instrum. and Meth. in Phys. Res. A **829**, 309-313 (2016).

4. V. Shpakov et al., *Betatron radiation based diagnostics for plasma wakefield accelerated electron beams at the SPARC_LAB test facility*, Nucl. Instrum. and Meth. in Phys. Res. A **829**, 330-333 (2016).

References

1. A. Bacci and A. R. Rossi, Nucl. Instrum. and Meth. in Phys. Res. A **740**, 42 (2014).

Figure 2: *Mach-Zender interferometer fringes measured during a plasma acceleration campaign at FLAME, which allows to estimate the plasma density used during the experiment.*

Figure 3: *Reconstruction of the laser front which is ionizing the gas. Measurement of density has been done using a Mach-Zender interferometer.*