SPARC_LAB activities and achievements

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The activities of the SPARC_LAB collaboration during 2020 have been totally dedicated to plasma-based acceleration measurements.

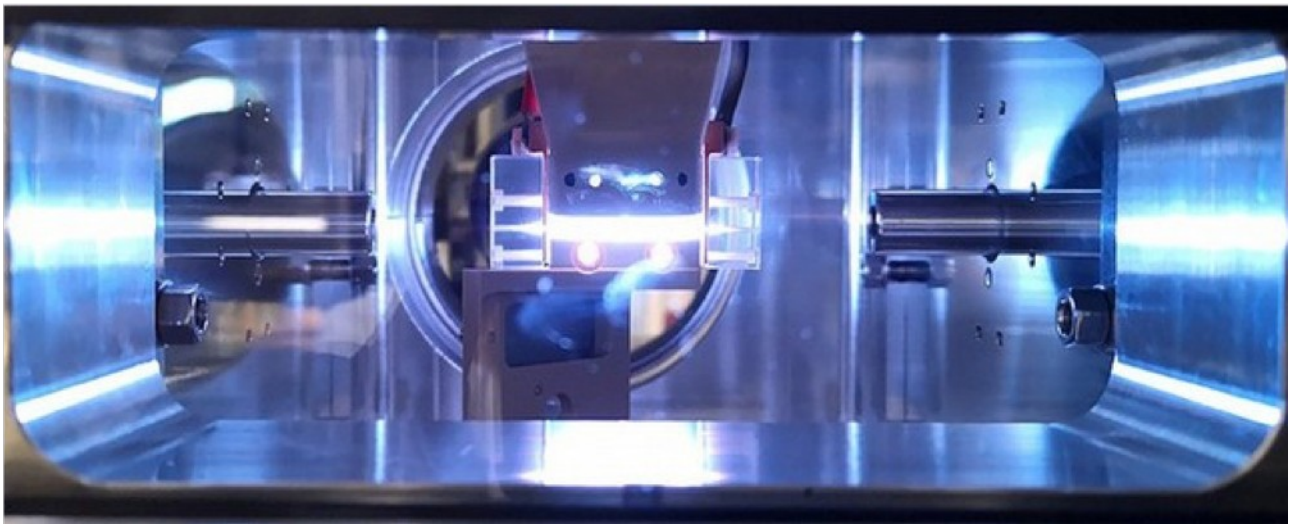

Figure 1: Discharge capillary used in the experiment and installed in the SPARC_LAB interaction vacuum chamber.

Using an innovative technique, researchers from the SPARC_LAB group have demonstrated the acceleration of a high-quality electron beam in a plasma accelerator [1]. The experiment highlighted, for the first time, the possibility to reduce the energy spread during acceleration. This important result was obtained by imprinting a positive energy-chirp on the beam (particles in the head with larger energies than those on the tail) before it enters into the plasma. By doing so it is possible to pre-compensate the energy spread induced by the plasma itself thus giving the possibility to minimize it at the exit. The experiment was carried out with the SPARC_LAB photo-injector, that generated and pre-accelerated two distinct electron bunches, driver and witness. Using a 3 cm-long capillary containing hydrogen gas, ionized in plasma by a high voltage discharge (Figure 1), accelerating fields of the order of 230 MV/m were generated by the driver and used to accelerate the witness. Figure 2 shows the two bunches at the plasma exit measured through a magnetic spectrometer. Witness and driver initially had the same energy of about 89 MeV. The plasma density was set to 2×10^15 cm-3 during the experiment. In such a way, by positioning the witness about 1 picosecond after the driver, it was possible to exploit the accelerating field produced in the plasma by the driver itself. The complexity of the experiment is considerable if we consider the dimensions that are involved. The two bunches have sizes of few

tens of microns and must be placed in the plasma with precision of the order of microns. This advancement in the generation of high-quality beams is of paramount importance because it makes the accelerated beam really “usable” for applications such as Free-Electron Lasers (FEL). For that reason, a pilot experiment is currently in progress at SPARC_LAB with the aim to inject the plasma accelerated witness into the undulators to obtain FEL radiation emission.

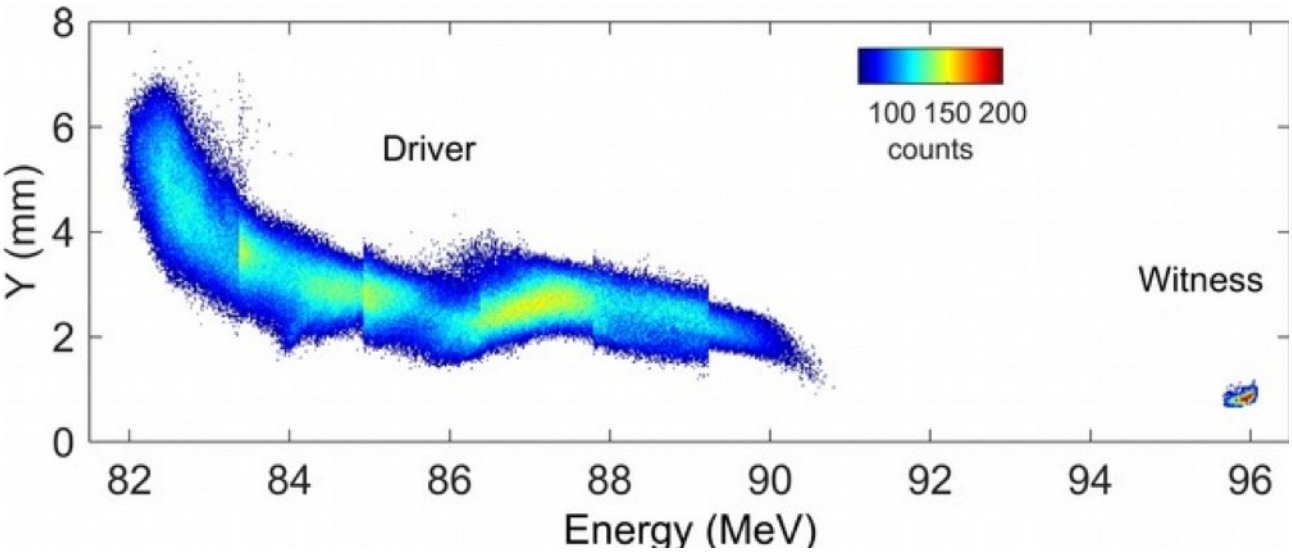

Figure 2: Driver (left) and witness (right) after acceleration in 3 cm of plasma. The two bunches had the same energy of 89 MeV before entering into the plasma.

The setup of the experiment started in January 2020 and the first measurements were done at the beginning of March and continued for two weeks until the stop of the laboratory activities due to the COVID-19 pandemic. The restart of the experiment was possible in June and continued till end of July. During that period the characterization of the plasma-accelerated beam was completed by measuring its emittance. From October to December there were the first tests to inject such a beam into the FEL, but some technical issues on the plasma module did not allowed to continue further. The new setup of the experiment has been prepared in January 2021 and, according to the first preliminary measurements, it solved all the prominent issues encountered in December.

In parallel with the beam-based measurements, the plasma related activity continued also offline in the PLASMA_LAB. Several tests were carried out by employing discharge-capillaries with different geometries. Tests with very high currents (up to 2 kA) were also done by using a new discharge pulser. One of the goals of PLASMA_LAB is to provide a complete characterization of the capillaries that are employed at SPARC_LAB with the electron beams.

References and list of most relevant publications

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