Quarterly Newsletter of the FLASHForward Project | May 2017

General information. Work in the last quarter has concentrated on preparations for the FLASH summer shutdown, which should culminate in the installation of a first version of the FLASHForward (FF▸▸) beam line that allows for beam-based commissioning starting in August. Some milestones in this period include:

- The Scientific Advisory Committee (SAC) of our Helmholtz Virtual Institute (VI) met on March 23 and 24 for the yearly evaluation of the progress and plans of FLASHForward and the VI. The meeting took place remotely by video conference. The report was very positive: for example, the SAC noted that "A major scientific capability is being developed in FLASHForward". The SAC was particularly asked about the future direction when the funding for the VI terminates in 2018. It endorsed the current structure as a template for the future and gave a variety of recommendations on the future form that international collaboration at FLASHForward should take. The SAC also gave detailed advice to the four VI Working Groups. All of these recommendations will be worked on in preparation for the VI Annual Meeting, which will be held in conjunction with the EAAC meeting in Elba on September 24th. We would like to express our gratitude for the tremendously helpful advice and substantial input by Ilan Ben-Zvi as the SAC chair and its members Brigitte Cros, Stephan Karsch, Philippe Piot, and Mitsuhiro Yoshida. Their recommendations have greatly improved FLASHForward and the Virtual Institute over the past years and we greatly appreciate their commitment.
- Additionally, FLASHForward underwent the annual review by the DESY project management commission on February 22. This panel focusses on the quality of various aspects of project management at DESY, i.e. budgetary and personnel resources and planning, project controlling, management structures and reporting, risk management and mitigation, and scheduling. The outcome of this review was very positive, with the commission attesting solid project planning and emphasising their belief that the FLASHForward project coordination has adequate measures in place to reduce major scientific, technological, personnel, and financial risks to a minimum.
- The core FLASHForward team has been strengthened by the addition of several new positions. At the beginning of April, Richard D'Arcy assumed the position of FF▸▸ Scientific Coordinator. Richard will be responsible for the day-to-day operation of the FLASHForward science program and will become the future anchor point for our international collaborations. He will help us to develop a programme for experimental access to the FF▸▸ facility for the broader PWFA community, possibly through an open call for proposals. More details will be provided soon - stay tuned!
- Kristjan Poder from Imperial College London joined us on March 20 as a DESY fellow and immediately took over responsibility for the FLASHForward laser and preparation laboratories. His laser team was strengthened by three new students at the beginning of April: Martin Meisel (U Hamburg) and Jeyathasan Viswanathan (U Paris Sud) are working on their Masters Theses; Severin Diederichs is working as a graduate research assistant.

- Pardis Niknejadi (DESY) agreed to fill the void left by the departure of Matthew Streeter and act as the VI WG4 co-coordinator.
- The FLASHForward theory and simulation team successfully applied for computational time on the supercomputer system JuQUEEN in Jülich, Germany. They were granted 14.2 million core hours over the course of the next 11 months, which is actually slightly more hours than was applied for. We thank Alberto Martinez de la Ossa for his coordination and this great success.
- Timon Mehrling published an important study and an extended theory on the mitigation of the hosing instability: T. Mehrling et al., Phys. Rev. Lett. **118**, 174801 (2017). See the WG1 report below for further details.
- Another scientific highlight was the very successful experiment at the Mainzer Mikrotron at the beginning of May on the characterisation of active plasma lenses. This experiment was a collaboration between DESY, U. Hamburg, U. Mainz, and Lawrence Berkeley Lab. The data from the beam time is currently being analysed and will be presented at the EAAC in September.

Two reminders.
- Please follow the FLASHForward Twitter feed @FForwardDESY.
- As mentioned about, the VI Annual Meeting will take place starting mid-morning on Sunday September 24th, the day before the EAAC meeting begins.

Reports from Working Groups

WG1: Plasma simulations

Coordinators: Alberto Martinez de la Ossa (UHH), Jorge Vieira (IST)

Hosing instability studies. The manuscript on an advanced theoretical description of the hosing instability of particle beams in the blowout regime of plasma wakefield accelerators, authored by T. Mehrling et al., has been accepted for publication in Physical Review Letters. This work demonstrates that the inherent drive-beam energy loss, along with an initial beam-energy spread, detunes the betatron oscillations of beam electrons and thereby mitigates the instability (cf. Figure 1). It is also shown that tapered plasma profiles can strongly reduce initial hosing seeds.

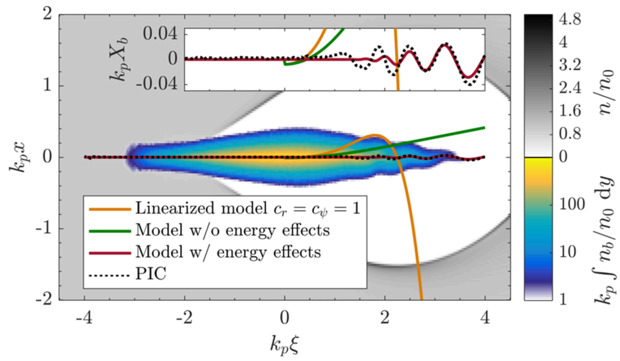


Figure 1. Result from a 3D PIC simulation showing plasma (grey scale) and beam (colour) charge densities after some propagation time. The simulation result (dashed curve) is compared with previous models for the beam centroid oscillations (yellow and green curves) and the newly developed model (red).

Start-to-end simulations. Thanks to the latest improvements in the field solver and the particle pusher, HiPACE is now capable of dealing with hosing dynamics with high physical fidelity at noise levels significantly below those of typical finite-difference time-domain codes. This step is of high importance to continue the start-to-end (S2E) simulation studies for beam optimisation in FLASHForward using

HiPACE, which promise to greatly improve performance. Thanks to the latest advances in the code, we will be able to analyse, efficiently and in full detail, the suppression of the hosing instability observed in S2E simulations with higher emittance driver beams. The aim is to determine the ideal conditions for transverse stability and acceleration performance.

Density-down-ramp injection. A comprehensive simulation study on the density-down-ramp injection mechanism in FLASHForward has been completed and is currently being reviewed by our collaborators. The observed effect that shorter ramps lead to witness beams of higher charge and current, lower energy-spread and lower emittance is explained therein. The produced bunches feature high charge (140 pC), long duration (110 fs), increased energy (1.5 GeV), low uncorrelated relative energy spread (0.3%) and low normalised emittance (0.3 μm). Future studies employing further optimised ramps will focus on reducing the correlated relative energy spread of the witness, which currently is –1.45 % per μm bunch length at best.

WG2: Beam dynamics and instrumentation
Coordinators: Vladyslav Libov (UHH), Ivan Konoplev (JAI)

Activities in WG2 are focused on preparations for the beam-line installation during the summer 2017 shutdown and on the subsequent commissioning phase. Design of the vacuum system has been completed and all components are ordered or delivered.

A critical issue turned out to be the ceramic chambers, which are to be installed inside the two pulsed dipoles in the FF▸▸ extraction area. Unfortunately, the supplier of the chamber had to renege on the commitment to deliver the contracted parts, which made an installation this summer impossible. A temporary solution based on DC dipole magnets and standard metallic chambers will be implemented in order to start FLASHForward commissioning on schedule. With the help of the MEA group of DESY, we identified two suitable replacement magnets, type “BZ” which have been recycled from the now defunct HERA collider. The DESY construction group ZM1 in the meantime has completed work on the interim chamber with high priority.

The tender for the differential pumping stages upstream of the plasma-cell is completed. Integration of FLASHForward into the control system of FLASH has been started, with the support of the MCS group of DESY. Components to be integrated have been identified; they include standard beam diagnostics, magnets, vacuum pumps, pressure sensors, vacuum valves as well as some other components, such as a beam absorber and plasma-cell positioning system (hexapod). Discussions of best possible software integration with the corresponding DESY groups are ongoing. Preparations for the commissioning of the beam line after the installation are in progress. A general plan for the commissioning has been devised and a beam-time request has been submitted to the FLASH machine coordinators and is currently under review by the appropriate committee.

Several other activities, independent of the summer shutdown, are advancing well: a scraper is foreseen to be added to the dispersive section of FLASHForward to produce driver-witness pairs. Detailed simulations have been performed, including the complete FLASH linac and FLASHForward extraction (using ASTRA and elegant), as well as particle-matter interaction with GEANT4. The scraper length of 20 mm was found to be sufficient to remove all intermediate particles between the driver and the witness bunches at the end of the dispersive section.

Beam-line simulations have now been compared to actual measurements at FLASH to validate our predictions on the longitudinal bunch centroid offset induced by coherent synchrotron radiation. Based on this, the design of the scraper is being finalised.

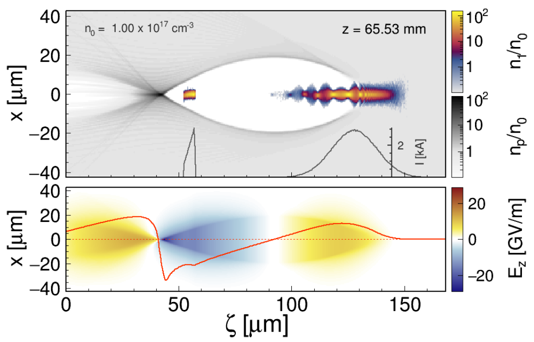
WG3: Plasma sources
Coordinators: Lucas Schaper (DESY), Patric Muggli (MPP)

In the first months of 2017, several experimental campaigns, both external and on the DESY site, as well as preparations for the FLASHForward installation in the summer shutdown, were major points on the agenda of WG3. Experiments in the FF▸▸ preparation-laboratory included obtaining the calibration data for electron density determination via Stark broadening, a collaborative experiment on characterisation of a specific density-down-ramp target type together with a group from the LUX experiment, and the investigation of the electron-density profile inside active plasma lenses. Some of the next experiments in the plasma-cell-preparation beam line will include tests of the FF▸▸ prototype targets.

Moreover, electron-beam generation via laser-wakefield acceleration for testing of e-beam diagnostics is now used on a daily basis and has been used to calibrate a cavity-based charge monitor. Data analysis of the last experiments on active plasma lenses at the Mainz Mikrotron (MaMi) in November proved inconclusive with regard to the emittance evolution of the transported electron beams. A modified experimental setup was implemented at MaMi and a further campaign was conducted in early May. Detailed data analysis is ongoing.

WG4: Photon sources
Coordinators: Pardis Niknejadi (DESY), Carl Schroeder (LBNL)

Free Electron Laser (FEL). External injection and density-down-ramp injection will be the first two injection methods studied at FLASHForward. Figures 2a and b show results of a PIC simulation of an externally injected shaped witness beam accelerated to 2 GeV (injected at 1 GeV) with a current of approximately 3 kA. Figure 3 shows the calculated gain length for TTF-type undulators, as an example, based on the beam parameters shown in Fig 1b. Based on these results, an investigation of an FEL beam line with strong focusing has been initiated. A full beam-line design and 3D FEL simulations will be performed. Collaborations with other groups at DESY have been initiated for performing 3D FEL simulations with an un-averaged 3D FEL code: Puffin (Parallel Unaveraged FEL INtegrator). WG 4 is working closely with WG1 (PIC simulations) and WG2 (Beam Diagnostics) to develop the FEL application.



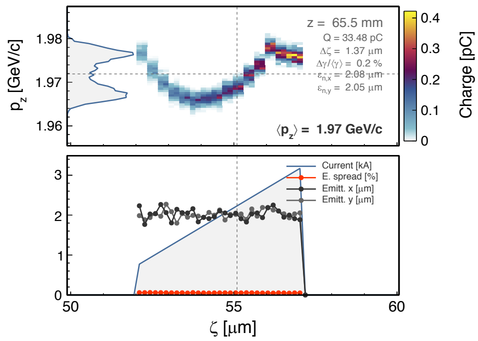


Figure 2a: Drive and witness beam currents and density (top). Accelerating field, E; the red curve is the on-axis field (bottom).

Figure 2b: Longitudinal phase space (top). Witness beam parameters (bottom).

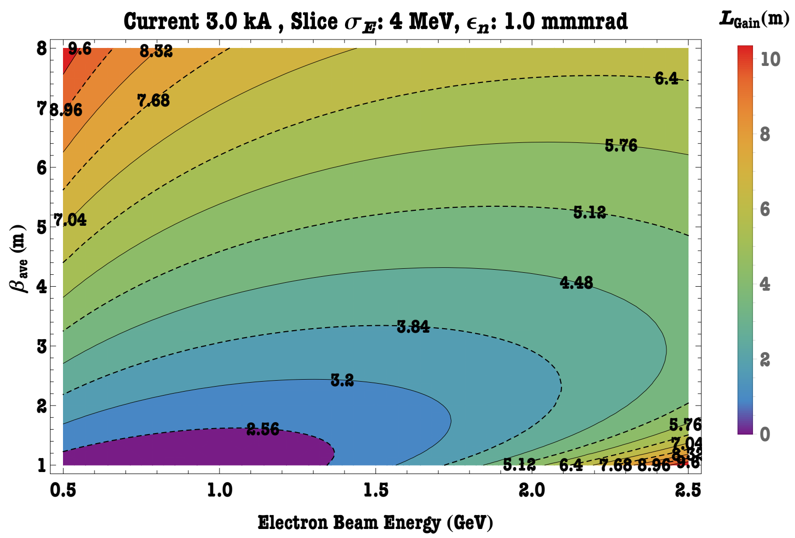


Figure 3: Gain length of the accelerated witness bunch in TTF undulators (evaluated using Ming Xie formalism).

Inverse Thomson Scattering. Auxiliary photons in the MeV range have been investigated as a diagnostic of the electron beams. Simulation studies have shown that electron properties, such as divergence and electron spectrum, can be reconstructed from the photons generated by inverse Thomson scattering. For such reconstruction, a well-collimated beam is required. Furthermore, it is possible to obtain the transverse properties of the electron bunch from a multi-shot experiment in a 90-degree scattering setup (after removing the divergence). Since there are currently no off-the-shelf spectrometers available for the measurements of the MeV γ-ray spectrum that are required for these diagnostics, a collaboration has been initiated with the ILC group at DESY to design a detector that measures the spectrum by means of detecting and tracking the e+e- pairs produced by the γ-rays using a time-projection chamber.

Betatron radiation. Auxiliary photons in the keV range generated by betatron emission have been investigated as a diagnostic of the electron beams. Two possible diagnostic measurements from the betatron radiation are being investigated. One is a measurement of the beam source size —with the assumption that the plasma boundary is not affecting the electrons—for the purpose of approximating emittance. The second is a beam-tilt measurement. The feasibility and requirements of both methods are being studied. The vacuum window and camera for the betatron measurements have been received and are being tested.