The FLASHForward▸▸ Newsletter | February 2018 Edition

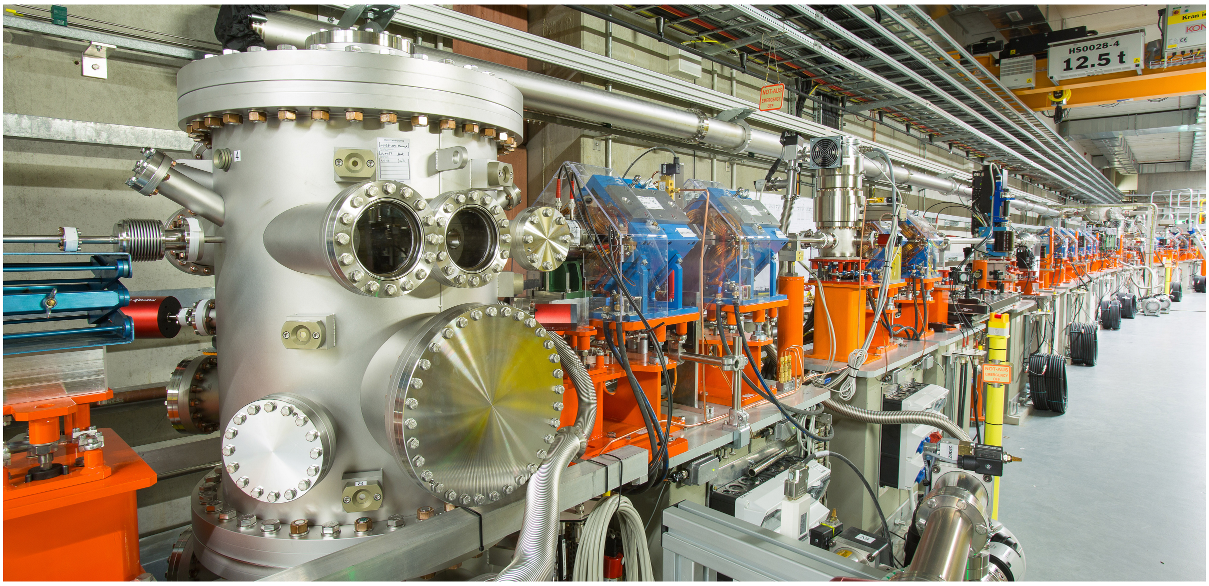

Figure 1. The FLASHForward electron and laser beamlines upstream of the central interaction chamber (2018-01-23).

General information.

Exciting times for beam-driven plasma wakefield science are ahead. As of now, the FLASHForward beamline has been completed (cf. Fig. 1) up to the point that first beam-driven experiments will be possible after the end of the final beamline commissioning phase in February/March of this year.

Unavoidably, the great progress on the installation work, the preparation activities for two project reviews in October and November 2017 (see below), plus the important Helmholtz PoF III review of all DESY activities looming in February 2018 required us to delay the composition of the newsletter by a few months, for which we would like to apologise. In the future, this newsletter should appear again at more regular intervals. A summary of important project-related news can be found below.

- The Annual Meeting of the Helmholtz Virtual Institute took place in conjunction with the European Advanced Accelerator Conference in the idyllic surroundings of Elba. There was once again an excellent attendance, with representatives from CERN, DESY, INFN Frascati, Hamburg University, IST Lisbon, JAI, LBL, and UCLA. The status of the project and activities in the partner institutions were presented and discussed. There was a meeting of the Collaboration Council following the main meeting, where discussions on the shape of the organisation to be put in place when the VI ends in Jun 2018 were discussed and agreed. The guiding idea is that the leadership and structures should be as far as possible continued over the transition period. The new organisation, "FLASHForward International Partnership for Science" (FIPS) will meet for the first time at DESY at a date to be fixed in 2018. Presentations made at the meeting can be found on the Virtual Institute Web pages at the following address: https://vi-pwfa.desy.de/e160195/e257598/.

- The DESY Machine Advisory Committee (MAC) was informed about the scientific and technical progress within FLASHForward on November 8th. Along with their many positive statements they highlighted the importance of the fast kicker dipole (for the simultaneous operation of all three FLASH beamlines) and suggested to give highest priority to its rapid installation. In addition, they pointed out the requirement for a fully developed scheme to safely extract and dump FLASH drive beams while maintaining a high-quality witness bunch.
- The DESY Project Commission reviewed the project management of FLASHForward on December 6th. Their main conclusions and recommendations, all very positive and supportive, were transmitted to the DESY directorate at the end of 2017.
- The FLASHForward LWFA team in collaboration with Klaus Flöttmann (DESY Accelerator Division), Heinz Graafsma (DESY Photon Science Division) and Florian Grüner (Hamburg University) successfully applied for support through the DESY Strategy Fund to develop a prototype application of a compact plasma accelerator for medical imaging purposes. Jens Osterhoff (DESY Particle Physics Division) will lead this project as a cross-divisional activity as principal investigator starting in January 2018.
- A number of papers related to FLASHForward were published from authors within our collaboration:
    - A. Martinez de la Ossa, Z. Hu, M. J. V. Streeter, T. Mehrling, O. Kononenko, B. Sheeran, and J. Osterhoff, "Optimizing density down-ramp injection for beam-driven plasma wakefield accelerators", *Physical Review Accelerators and Beams* 20(9), 091301 (2017)
    - R. E. Robson, T. J. Mehrling, and J. Osterhoff, "Great Moments in Kinetic Theory: 150 Years of Maxwell's (other) Equations", *European Journal of Physics* 38(6), 065103 (2017)
    - R. Brinkmann, N. Delbos, I. Dornmair, M. Kirchen, R. Assmann, C. Behrens, K. Floettmann, J. Grebenyuk, M. Gross, S. Jalas, T. Mehrling, A. Martinez de la Ossa, J. Osterhoff, B. Schmidt, V. Wacker, and A. Maier, "Chirp Mitigation of Plasma-Accelerated Beams by a Modulated Plasma Density", *Physical Review Letters* 118(21), 214801 (2017)
    - T. Mehrling, A. Martinez de la Ossa, R. Fonseca, and J. Vieira, "Mitigation of the Hose Instability in Plasma-Wakefield Accelerators", *Physical Review Letters* 118(17), 174801 (2017)

- We welcome several new members to the FLASHForward team:
    - Zeng Ming, since September 2017, is a postdoctoral fellow working on plasma theory and numerical simulations.
    - Pau Gonzalez, since November 2017, started his PhD on electron beam phase-space diagnostics under the supervision of Richard D'Arcy.
    - Peng Kuang, since November 2017, obtained an OCPC - Helmholtz Fellowship and will work as a postdoc on transverse electron beam diagnostics.
    - Artemis Kontogoula, since November 2017, investigates an upgraded electron beamline design for the reduction of CSR effects in her Bachelor thesis under the supervision of Slava Libov.
    - Arathi Ramesh, since November 2017, works as a graduate student assistant in the laser wakefield laboratory under the guidance of Kristjan Poder.
    - Gregory Boyle, starting February 2018, will work as a DESY fellow on theoretical plasma theory and MHD simulations.
    - Theresa Brümmer, starting February 2018, will conduct her postdoctoral research within the medical imaging project.
    - Severin Diederichs, starting February 2018, will be tackling problems in theoretical plasma physics in collaboration with Carl Schroeder from LBNL for his Masters Thesis.
- Congratulations to Martin Quast, who has successfully completed his Masters Thesis at Hamburg University on "Hollow core plasma channels" at the beginning of this year.
- Last, but not least, we would like to express our best wishes to Timon Mehrling, who left DESY to accept a postdoc position at Lawrence Berkeley National Laboratory with Carl Schroeder.

One reminder.
Follow FLASHForward on Twitter @FForwardDESY or visit us online forward.desy.de.

WG1: Plasma simulations

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

Hose instability studies

New studies on the suppression of the hosing instability by means of wider and higher-emittance drive-beams have been conducted using the quasi-static PIC code HiPACE. The simulation analysis reveals that the hosing instability can be suppressed when beams are widened (Figure 1). When employing wider beams, the focusing plasma

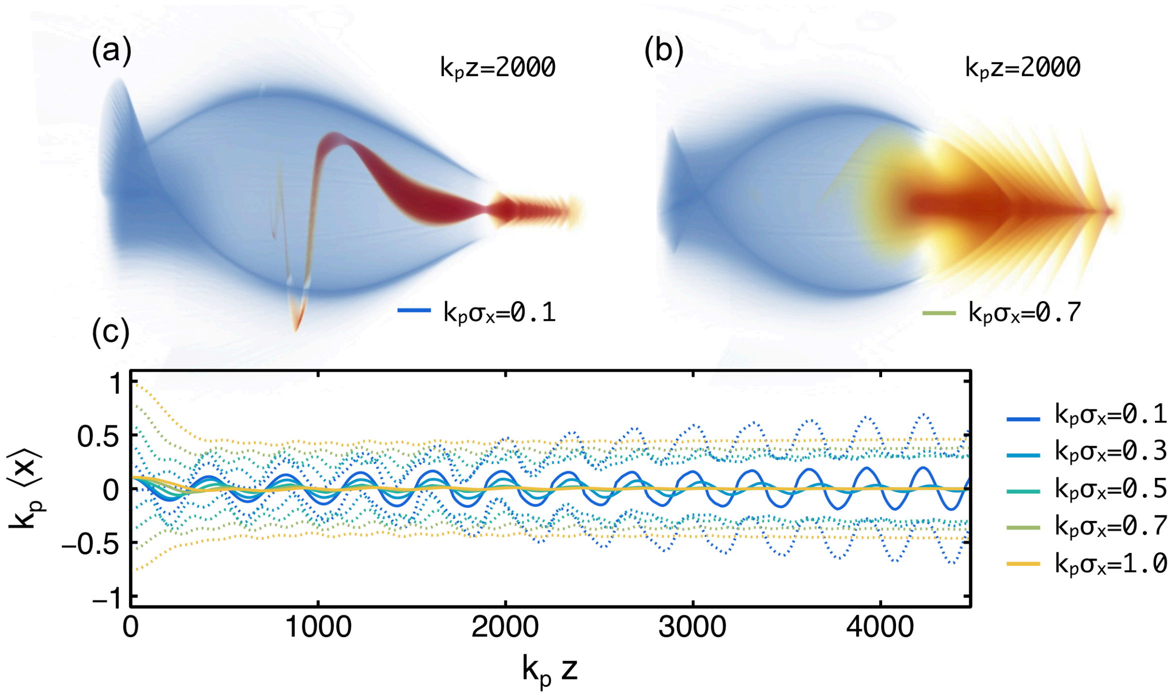

Figure 2. Results from 3D PIC simulations with HiPACE, showing the beam (red) and the plasma (blue) electron density after some propagation. (a) A narrow beam with an initial tilt is driving a plasma wave in the blowout regime and undergoes hosing. (b) The same beam with a seven times greater spot size at focus exhibits stable transport. (c) Centroid (solid lines) and transverse rms size (dotted lines) evolution for one beam slice, at 1 σ_z behind the peak.

wakefields are non-linear and uniform along most of the drive-beam (in contrast to the narrow-beam case in which a perfectly clear plasma blowout with linear and uniform focusing fields is produced). These non-linearities in the focusing field cause a strong decoherence in the betatron motion of the electrons of the beam, which suppresses the centroid oscillation amplitude on a short time scale. However, a clear blowout is still formed behind the drive-beam and the focusing fields are uniform and linear, thereby preserving the quality of the acceleration of the witness beam. A manuscript describing these findings is in an advanced state of preparation and will be submitted soon.

Start-to-end simulations

Start-to-end simulation studies employing ELEGANT simulated beams from FLASH injected into the plasma acceleration section have been continued, now using wider beams at focus (to suppress hosing) and HiPACE for the plasma simulations. A significant reduction of the centroid oscillations has been observed (see Fig. 2), in qualitative agreement with the results obtained with linearly tilted and Gaussian beams (see previous section). Further optimisation of the FLASHForward beams is ongoing, with the aim of compensating the centroid offsets caused by CSR effects in the bunch compressors, and therefore further diminishing the hosing seed.

Density down-ramp injection

A comprehensive study of the density down-ramp injection mechanism in beam-driven plasma accelerator has recently been published in Physical Review Accelerators and Beams (A. Martinez de la Ossa et al., PRAB 20, 091301 (2017)). It contains novel insights regarding the optimisation of the electron-injection process in density transitions in PWFAs with experimental parameters close to FLASHForward. Using the PIC code OSIRIS, we were able to demonstrate the generation of witness electron beams of ~140 pC charge, with an emittance of ~200 nm, uncorrelated energy spread of ~0.3% and an approximately flat-top current profile of ~1.0 kA.

WG2: Beam dynamics and instrumentation

Coordinators: Vladyslav Libov (UHH), Ivan Konoplev (JAI)

The summer shutdown of FLASH came to an end in August 2017. It resulted in the installation of all vacuum components down to a few meters upstream of the plasma chamber. Therefore, work in WG2 up until the end of 2017 focused on commissioning the newly installed first part of the FLASHForward electron beamline.

Shortly after the shutdown, general commissioning of the beamline started, involving components such as magnet power supplies and polarity tests with a Hall probe. Integration of new components into the FLASH control system (DOOCs) was achieved and tested. In particular, the so-called FLASH3 mode was established - the control system now treats FLASHForward as a third, separate beamline (in addition to FLASH1 and FLASH2) allowing independent control of the beam properties.

At the end of August 2017, first tests with beam were initiated. On August 31st, 2017, at 2am first beam was seen on the scintillating screen station in the compression section of FLASHForward (FLF-COMP, screen station 14FLFCOMP). Subsequently, the beam diagnostic group of DESY (MDI) joined us and commissioned the beam position monitors, screen stations, and the charge monitors by performing beam-based studies. More advanced beam studies, such as orbit response measurements, took place in parallel to FLASH operation during the following weeks.

On November 9th, dedicated beam time within the framework of the FLASH Accelerator Research and Development (ARD) programme commenced. During this beam time, we performed more advanced optics studies and introduced the possibility of simultaneous on-crest operation (uncompressed beams) at FLASHForward and off-crest operation (longitudinally compressed beams) at FLASH1, which greatly enhances the flexibility and parameter space for simultaneous experiments.

Additional activities of this WG that occurred in parallel to beam-based studies included the finalisation of the technical design of the variable mask in the dispersive section (to produce driver-witness bunch pairs), and the finalisation of the conceptual design of the post-plasma-beamline extension to accommodate the transverse-deflecting structure and undulators in the future.

WG3: Plasma sources

Coordinators: Lucas Schaper (DESY), Patric Muggli (MPP)

FF>> plasma cell

The design of the plasma source for first observation of interaction and wakefield generation of the electron drive beam delivered by FLASH was revised. In particular, the safe transport of the plasma-forming high-voltage pulse to the target while still complying with the accelerator-vacuum standards at FLASH required a design adjustment. This first plasma cell will be based on concepts already tested and proven to be successful in experiments on active plasma lenses. Together with some modifications to the experimental chamber, this will allow us to completely preassemble the target under cleanroom conditions and thus minimise the number of process steps inside the target chamber and the time for installation on maintenance days, as well as mitigating the risk of vacuum contamination.

Fragmentation and ionisation dynamics

The current focussing geometry implemented in the ionisation test-beam line using transmissive optics has been shown to degrade beam properties and thus impact plasma generation. A new setup incorporating the same reflective focussing geometry as implemented in the FLASHForward line has been designed and will be implemented in the spring of 2018. This setup will also allow phase-objects to be introduced into the laser beam and thus generate, for example, ring-shaped modes allowing hollow-core plasma channels to be produced. The generation of such modes via a phase object has already been tested successfully in the setup described in an earlier newsletter. Results on the formation of hollow-core plasma channels are currently being analysed.

Active plasma lenses

The data obtained during the last experimental campaign at the Mainz Microton (MaMi), has been used in a publication on the measured gradients, non-linearities and resulting emittance degradation that has been prepared and will be submitted soon. In parallel, plasma-lens experiments at the CLEAR facility at CERN led by collaborators from the University of Oslo are now installed and operational. In December plasma-lens operation was confirmed and first data was taken.

WG4: Photon sources

Coordinators: Pardis Niknejadi (DESY), Carl Schroeder (LBNL)

Auxiliary photon sources

The focus in the FLASHForward test and preparation laboratory has shifted from testing betatron radiation diagnostics for FLASHForward to using harder X-rays generated from inverse Compton scattering (ICS). The goal is to investigate the usability of ICS photons as a diagnostic of the scattering electron beam. In addition, an upgrade of the LWFA setup to operate at full 10 Hz repetition rate is underway. A new differential pumping system has arrived and is being installed. Meanwhile, analysis of the data from the betatron-radiation experiments is in progress.

FEL photon source

The focus of FEL beamline studies was on the post-plasma beamline for the X-band transverse deflecting structure (TDS) that will be compatible or easily adaptable to the 2020+ beamline which will include undulators (possibly of TTF FLASH-type). The major challenges are matching the post-plasma beam into the first undulator section with a minimum waist in the vertical direction, as well as the debunching in the focusing elements between the undulator sections. The beam-optics lattice designed by WG2 for the X-band TDS has been modified to be more adaptable to a beamline with undulator sections. However, further studies and additional modifications are foreseen.

Additionally, the expected SASE signal is estimated to be initially on a nJ-level. Therefore, options for photon diagnostics such as microchannel plate detectors are discussed with the photon diagnostics group at FLASH.