Quarterly Newsletter of the FLASHForward Project - January 2017

General information

FLASHForward has made significant progress since the last newsletter. The beamline installation inside the FLASH 2 tunnel continues; it is foreseen that it will be concluded in time for for first experiments by summer 2017. In the recent shutdown of the FLASH machine in November and December of 2016, various support components could be installed: all beam-line-related mounts and supports, cabling for all standard diagnostics and magnets, cooling water, a new clean-room rail system (needed for the vacuum beam-line installation), most magnets, and the majority of the laser beam line. We are now in a good position to add the missing electron-beam-line vacuum components to allow technical commissioning to commence in August 2017.

Additional news:

- New collaboration partners from the German university landscape could be added to the project. Groups from the Universities of Jena, Düsseldorf, and Hamburg have formed a collaboration funded through the BMBF Verbundforschung scheme to implement Trojan Horse injection at FLASHForward over the next few years. Prof. Georg Pretzler from Düsseldorf is acting as the chair. The collaboration kick-off workshop was hosted at DESY on December 15.
- Our recent success in the realisation and implementation of active plasma lenses has been funded by the President of the Helmholtz Foundation within the HGF IuVF Zukunftsprojekte scheme with ~600 kEuro over the next three years to further develop this technology. Such plasma lenses may prove to be of paramount importance not just for FLASHForward but for the application of many plasma-wakefield acceleration techniques.
- FLASHForward was evaluated by the DESY machine advisory committee (MAC) last November. Their evaluation was very positive with constructive suggestions to investigate additional schemes for the mitigation of hosing induced by coherent synchrotron radiation (see WG 2 report below), and for tests of the simultaneous operation of FLASHForward with the FLASH FEL user beam lines.
- We have two new team members: Pardis Niknejadi joined us in December from the University of Hawaii as a DESY fellow, Alex Knetsch will strengthen our team starting in February 2017. After submitting and defending his PhD thesis in spring 2017 at Hamburg University, he will start a post-doc at DESY.
- We are currently advertising a position as FLASHForward Scientific Coordinator: http://www.desy.de/v2/docs/1482159289-e.pdf
  Please forward the job opening to potential candidates.

Reports from Working Groups

WG1: Plasma simulations

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

Significant progress has been made in the following sub-projects of the simulations working group over the past three months.

Hosing. A manuscript on an advanced theoretical description of the hosing instability of particle beams in a plasma wakefield, authored by T. Mehrling *et al.,* is currently under revision after a first round of peer-review. In this context, a new field solver and particle pusher has been implemented into our quasi-static particle-in-cell (PIC) code HiPACE, which is now capable of dealing with hosing dynamics with high physical fidelity at numerical noise levels significantly below those of typical finite-difference-time-domain codes, whose artificial numerical fluctuations may seed beam hosing and alter its growth dynamics, in particular for long propagation distances in the plasma.

Start-to-end simulations. We have prepared an article for the DESY highlights report 2016 about start-to-end (S2E) simulation studies and our S2E simulation framework used for beam optimisation in FLASHForward. In this article we show improvement of the beam longitudinal profile and a reduction of longitudinal beam-centroid deviations, which may seed the undesired hosing instability. It was observed that when the drive-beam emittance was increased by passing it through a thin (~20 μm) slab of aluminium situated in a non-dispersive section of the FLASHForward beam line, a greatly reduced hosing effect was produced (see Figure 1).

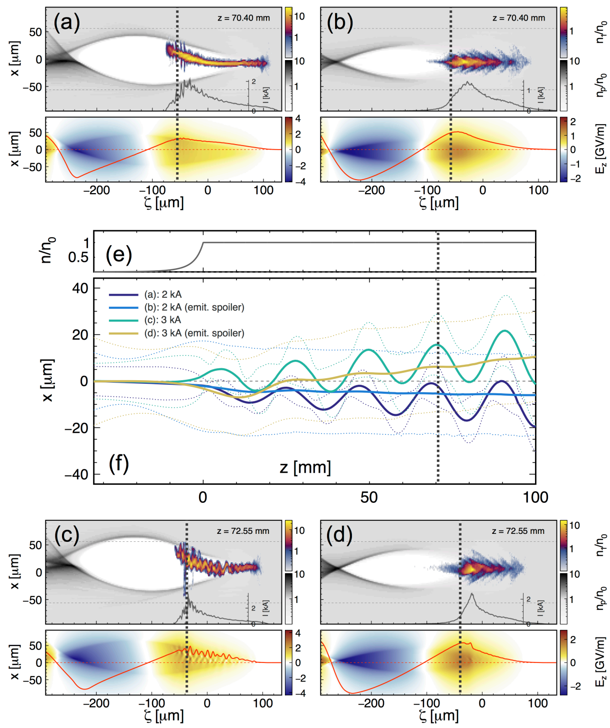

Figure 1. Full S2E PIC simulation results showing centroid oscillations (f) of a FLASHForward beam for four different beam configurations [(a) - (d)]. Those beams which were sent through a thin slab of aluminium [(b) and (d)] show greatly reduced beam hosing. (e) displays the longitudinal plasma-density profile.

Density down-ramp injection. We have been working on a theoretical description of the density down-ramp injection mechanism at FLASHForward over the past months. The draft of an article exists in an advanced state. It includes theory and numerical studies about the role of the length of the density transition and its influence on witness beam properties. The observed effect that steeper ramps lead to beams that are longer, have higher current, lower energy-spread and lower emittance is explained. We highlight a case for FLASHForward consisting of a Gaussian-shaped density spike with a top (bottom) density value of $4\text{x}10^{17}$ ($4\text{x}10^{16}$) cm^{-3} and a total length of ~100 μm. The injected bunch has 130 pC of charge, 130 fs duration, GeV energy with ~0.3% un-correlated relative energy spread and 0.3 μm sliced normalised emittance.

WG2: Beam dynamics and instrumentation

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

Fast dipole magnets. In-situ tests of the pulsed dipoles (of type TDG) that will be used to extract beams from FLASH2 into the FLASHForward beamline are being performed. One of the two magnets has been temporarily installed into a position in close proximity to its final location in the FLASH extraction area, and connected to its half-sine pulser to check for the influence of electromagnetic noise on existing FLASH electronics. A small perturbation on some sensitive FLASH diagnostic components was observed when the magnet is in operation. This is being investigated and is expected to be improved with advanced shielding. In addition, the heat load generated by Eddy currents in the TDG magnets, in particular caused by fringe fields at the edges of the entrance and exit openings, are being examined both in simulations and experimentally,

FLASH 2017 summer shutdown preparations. The technical design of the vacuum system for the FLASHForward pre-plasma beam line has been finalised (with the exception of the beam scraper, see below). The focus is now on the final design of the initial post-plasma section of FLASHForward, including the capturing section and the beam energy spectrometer.
Design of the scraper, a variable mask in the dispersive section allowing for beam shaping and the production of double-bunches for external injection, is still ongoing. The main questions under study pertain to the overall feasibility and the detailed shape of the scraper (pyramidal vs step-like), its thickness, the relation between realistic FLASH beams and scraper width for the generation of tailored double-bunches, and the impact of coherent synchrotron radiation (CSR) effects.
This work is done in collaboration with WG1 - double-bunch beams obtained from start-to-end simulations including the scraper are used in particle-in-cell codes to assess the suitability of the generated beam distributions.

Coherent synchrotron radiation effects. Studies on characterisation and minimisation of the impact of CSR effects are advancing. Two measurement shifts of 12 hours each were performed on November 26 and 27 with the goal of refining the measurement of the beam slice properties at FLASH. In particular, a multi-quadrupole scan was performed to determine slice resolved emittance and centroid offsets for the minimum-energy-spread setting and for a compressed beam of ~200 fs duration. In addition, several measurements were taken with the CRISP transition radiation spectrometer in order to cross-check the results from the LOLA transverse-deflecting cavity. Finally, a compression scan was performed with the goal of assessing the quality of FLASH start-to-end simulations. The data is being analysed.

WG3: Plasma sources

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

LWFA setup

In the last quarter of 2016, the majority of the work in WG3 concentrated on the FLASHForward test and preparation laboratory. This culminated just before the Christmas break in the first acceleration of electrons at FLASHForward via laser wakefield acceleration (LWFA) using the 25TW FLASHForward system. The generated electron beams originated from wave breaking and showed the expected properties (cf. Figure 2). The purpose of this LWFA setup is the reliable creation of electron beams for the development of components, such as the transition-radiation spectrometer, for the beam-driven-wakefield setup at FLASH, where prototyping is difficult to perform.

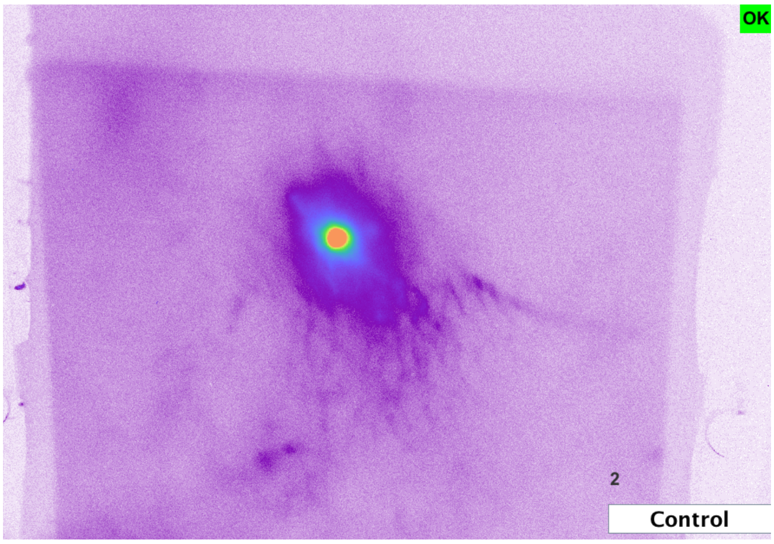

Figure 2. False-color signal of one of the first electron beams accelerated at FLASHForward on Dec 22, 2016. Screen shot of the control system of the first fluorescence screen for beam profile monitoring downstream of the LWFA plasma cell.

Plasma target tests

The experimental setup for FLASHForward plasma-target tests, for the cross-calibration of the electron density measurement via Stark broadening, and for benchmark experiments for the developed code on fragmentation dynamics of molecular gases has been refined. Data taking for all of these experiments is imminent.

Active plasma lenses.

A plasma lens characterisation campaign was executed at the MaMi microtron accelerator in Mainz, Germany, in November 2016 using an electron beam of 855 MeV. One of the goals was to evaluate the magnetic field quality of active plasma lenses, important for beam quality preservation. For this purpose, beam emittance was measured as a function of the discharge current and without the plasma lens in operation. Additionally, a transverse offset scan was performed as a direct measurement of the field gradient. The data analysis is ongoing.

WG4: Photon sources

Coordinators: t.b.d. (DESY), Carl Schroeder (LBNL)

Following the departure of Matthew Streeter, work in this area is paused awaiting the appointment of a new WG4 coordinator from the Hamburg groups. It is planned that this position will be filled soon.