VI Scientific Advisory Committee Meeting 2015

Recommendations and Response

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HELMHOLTZ GEMEINSCHAFT

Prioritization of scientific programme and methods

> *In view of the accumulated delay, prioritization of scientific programme and methods should be considered. Selection of injection mechanisms should be done according to complexity and merit.*

- Prioritization at FLASHForward workshop on April 5-6, 2016.

  VI internal (but FLASHForward external panel): Carl Schroeder (LBNL), Jorge Vieira (IST) Andreas Maier (UHH), Chris Behrens (DESY)

  Injection method ranking: 1. DDR (hydrodynamic), 2. DDR (laser-assisted), 3. Wakefield triggered ionization injection, 4. Beam-triggered ionization injection, 5. LWFA-based beam injection, 6. Trojan Horse

  Criteria: experimental complexity, parameter sensitivity, chances to contribute to project success.

Guided by PWFA applications in high-energy physics and photon science

Beam-quality conservation & efficiency → staging

Methods: external injection, witness and driver shaping

Tools: beam masking (scraper), FLASH beam shaping, plasma lens, plasma targets, RF-deflector

High-quality beams → plasma cathode

Methods: density down-ramp injection

Tools: plasma density diagnostics, plasma lens, plasma targets, laser shaping, temporal and emittance diagnostics

Grand future goals

> *State more clearly the grand future goals – e.g. high-repetition rate operation.*

- **FF▸▸** Phase I: Quality conservation for externally injected beams → staging.
  High-quality beams from plasma → plasma cathode.
- **FF▸▸** Phase II: Demonstrate applicability and usability (for photon science) → FEL gain.
- 2022+: Demonstrate high average-power, high repetition-rate PWFA. Utilize FLASH MHz, multi-kW capabilities.

Dependence on FACET and FLASH-2 availability

> *Dependence on FACET and FLASH-2 availability should be critically assessed and aims/schedule adjusted if necessary.*

FACET at SLAC (no further beam time at FACET, experiments non-critical for FLASHForward, will continue)

- E-210 - “Trojan Horse Plasma Wakefield Acceleration”: successful, gained valuable experience
- E-215 - “High-Quality Witness Bunch Generation and Acceleration”: got three shifts, too few for success
- E-226 - “Energy-Chirp Compensation of Electron Beams in a Plasma”: no beam time

ATF at BNL (important, but non-critical for project, will be continuing studies at FLASHForward)

- Proposal #300483 - “Energy-Chirp Compensation in Plasma”:
  helpful to study dechirping early, beam time foreseen in 2016

MaMi at U Mainz (critically important, will be continuing studies at FLASHForward)

- “Characterization of active-plasma lenses”: first beam-time received, successful, additional beam-time in August.

FLASH at DESY (critical to prepare FLASHForward operation)

- 10% of FLASH beam time is devoted to accelerator R&D (ARD)
- Obtained 7 shifts for driver/witness pair creation: very helpful, changed strategy
- Shifts for mitigation of head-to-tail correlation in PWFA driver approved for 2016 → control hosing
- FLASHForward demands to receive FLASH ARD time will increase once beam line is installed

General recommendations

- *Consider developing FLASHForward into a user facility in the future.*
  - FLASHForward will not become a user facility (in the sense that FLASH or PETRA III are user facilities).
  - Requires completely different organisational structure, has significant staff implications, may generate friction with the operation of FLASH itself as a user facility.
  - Alternative model of collaboration through the structures of the VI seems superior.
  - We will advertise this possibility and keep the collaboration open.
- *Seek links to other PWFA projects, e.g. KEK plasma acceleration.*
  - B.F. visited KEK. Closer links are very welcome. Have reached out.
  - Links to all other major PWFA projects exist.
- *Capitalize on experience of wider LWFA community for concepts, diagnostics and test experiments.*
  - Links to many of the leading LWFA projects exist.
  - Have capitalized in the past, e.g. plasma targets & plasma lens, and will continue to transfer technology and ideas.
- *Investigate stability issues regarding drive bunch and laser.*
  - Experimental stability test for laser ionization will start shortly in test lab.
  - Experimental stability test of drive beam is part of the basic scientific FLASHForward program.
  - Theoretical stability investigation will be one of the next steps.

General recommendations

- *Laser development plans should be laid out more clearly.*
  - Current laser parameters (including stability) seem sufficient for project goal. Field ionization is a threshold process.
  - Laser development will focus on monitoring & control to maximize reliability and the up-time of the laser.
  - A short (~5fs) probe beam will be derived from the main laser for use in pump-probe studies.
  - Deformable mirror is planned to be added in 2017.

Performances	Specified value	Test performed during OSAT 2
Pulse Duration	<25 fs	<25 fs
Output Energy	>600 mJ	611 mJ
Energy stability (3 min)	<2% RMS	0.65% RMS
Peak power	>24 TW	>24 TW
Beam pointing stability	<20 µrad RMS	3.27 µrad RMS
Temporal intensity contrast	10^{-3} @ 1 ps	2.10^{-4}
	10^{-5} @ 5 ps	2.10^{-7}
	10^{-7} @ 20 ps	4.10^{-9}
	$\leq 10^{-9}$ @ 300 ps	2.10^{-9}
	$\leq 10^{-9}$ (replica)	$9.7.10^{-10}$
Strehl ratio	≥0.7	0.85

WG 1 recommendations

cf. talk by A. Martinez de la Ossa

Plasma simulations

> *Validate simulation results with available experimental data and alternative codes, particularly for injection and beam propagation problems.*
  - Experimental data not available.
  - Benchmarking OSIRIS with HiPACE. OSIRIS benchmarked against experiments worldwide.

> *Build capability for detailed experiment modeling as opposed to the current focus on new (idealized) concepts.*
  - Full start-to-end modeling capability has been developed.

> *Make a more comprehensive study of the various injection schemes and their requirements on drive beam properties.*
  - Done.

> *Set of simulations for parameter variations to map out beam/laser stability issues.*
  - Stability studies to be performed in the future.

WG 2 recommendations

cf. talk by V. Libov

Beamline, beam dynamics and beam diagnostics

> *For broadband spectra as expected in the early stages, the beam diagnostics may have to be adapted (energy filter and/or wider spectral acceptance).*

- Charge and energy diagnostics support broadband beam (< 100 MeV to > 2.5 GeV). Diagnostics that require beam transport need energy spread on few percent level.

> *Investigate/prioritise single-shot diagnostics (for early stages with bad beam quality).*

- All diagnostics will be single shot. Development of single-shot emittance diagnostic ongoing.

> *RF-deflector should be reconsidered.*

- S-band cavity being included in design. Klystron shared with FLASH. ~10 fs resolution expected.

> *Consider synchronization turbo-pump for vacuum separation.*

- Complexity too high. Standard differential pumping design seems appropriate.

> *Consider undulator as a primary emittance diagnostic.*

- To be studied in preparation for Phase II. There will be no undulatory in Phase I.

WG 2 recommendations

cf. talk by V. Libov

Beamline, beam dynamics and beam diagnostics

> *Consider optical replica diagnostics.*
  - Complex. Implementation at FLASH did not succeed.

> *Clarify role of TADPOLE in research strategy.*
  - None.

> *Plasma-based ultrashort laser pulse generation should be considered in order to aid laser-driven injection schemes.*
  - Science case not compelling.

> *Beam arrival monitor should be considered in order to sort the data according to jitter.*
  - BAM is included in beam line (few fs resolution).
  - TR based BAM being studied for improved resolution (D. Borissenko).

WG 3 recommendations

cf. talk by L. Schaper

Plasma cell and plasma characterization

> *Stark-shift measurement is time- and space-averaged: Investigate temporal density fluctuations (e.g. triggered by exciting laser) and take into account spatial averaging of method in data analysis.*
  - Temporal averaging over ~ns (gated ICCD). Plasma dynamics on longer time scale.
  - Inclusion of spatial averaging in analysis is being worked on (L. Goldberg).

> *Stability of the plasma is very important for shot-to-shot reproducibility: Investigate this issues.*
  - To be measured at FLASHForward target test stand. High stability expected.

> *Concepts for long plasma columns should be investigated.*
  - Design for 30 cm column exists. Longer plasmas not needed nor compatible with beamline.

> *Make a more accurate evaluation of laser propagation in ionized gas over 30 cm.*
  - To be measured at FLASHForward target test stand in coming months.

> *Density profile is very important – concentrate on longitudinal density diagnostics.*
  - Raman scattering and Stark broadening diagnostics support longitudinal spatial resolution.

WG 4 recommendations

cf. talk by M. Streeter

ICS diagnostics

> *Consider a more accurate modeling of the ICS photon distribution and establish possible user interest.*

- Utilize open source ICS package by Brown et al. (LLNL).
- ICS is investigated for use as electron beam diagnostic, user interest not a high priority at the moment.

> *Use of ICS as a diagnostic should be clarified (especially jitter issues).*

- Project not relying on ICS. Assessed for detecting slice parameters.
  Challenging: requires good synchronization, stability (multi-shot technique), gamma-ray spectrometer.
- Importance reduced by adding deflecting cavity.

Betatron diagnostics

> *Betatron should be evaluated more precisely to use it as a diagnostic in the commissioning phase.*

- Evaluation ongoing. Differentiation between drive and witness difficult.

Summary

- **Recommendations by VI SAC have been invaluable for FLASHForward and the VI.**
- Helped to focus the project: reduced # of injection schemes. Shaped strategy.
- Helped to include new diagnostics, e.g. S-band TDS, and focus on single-shot capabilities.
- Helped to successfully master HGF mid-term review with best possible outcome.

Thank you for your time and effort!