FLASHForward▸▸

Future-oriented wakefield-accelerator research and development at FLASH.

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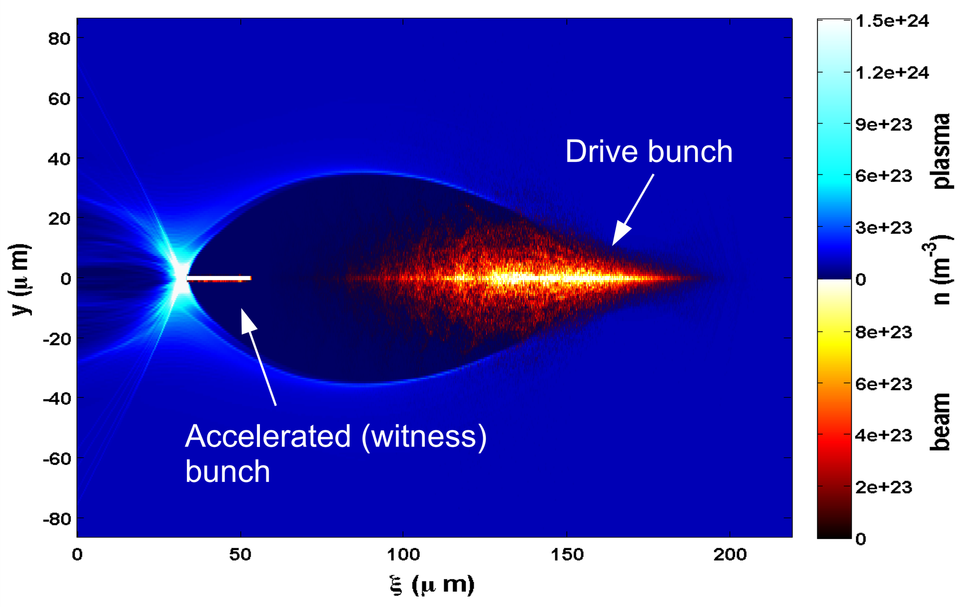
The future of particle accelerators?



Plasma and electron density obtained from a Particle-in-Cell simulation. The drive and accelerated bunches are visible.

- **Plasma wakefield acceleration** [1] is a promising technology which might revolutionise the field of particle accelerators
- Supplies accelerating gradients in the order of **10-100 GV/m** [2] – three orders of magnitude larger than in conventional radio-frequency cavities, the nowadays standard in particle accelerators
- Could lead to development of **compact** accelerators for fundamental research (particle physics, free-electron lasers) as well as for industry applications

A new facility to study beam-driven plasma acceleration, **FLASHForward**, is being prepared at DESY

How plasma acceleration works

- A **wakefield** in the plasma is excited by a bunch of charged particles (**beam-driven**) or by a laser pulse (**laser-driven**)
- Particles are **injected** into the wakefield and are **accelerated** by means of high electric fields of the wake
- Injected particles co-propagate with the wake

Particle injection types

Internal: Electrons are collected from the plasma itself

Various techniques to realise this have been proposed, e.g.:

- Density-downramp [3]
- Ionisation injection [4]
- Laser-controlled [5]

External: A prepared bunch of electrons (or protons) is injected into the plasma from the outside

Required for staged acceleration (essential for particle physics applications)

Need to assess performance of each technique

Why beam-driven?

Laser-driven (LWFA)

- Most common technology for plasma acceleration
- But has a number of disadvantages:
  - Low average laser power and low wall-plug efficiency → not suitable for particle physics
  - Fluctuations of laser pulse parameters → affects accelerated beam stability
  - Plasma wakefield dephasing → limits beam quality
  - Diffraction of laser pulse → limits beam energy

Beam-driven (PWFA)

- A promising alternative to laser-driven:
  - High average power
  - Higher stability of the driver
  - Larger beam energy and better quality (no diffraction, no dephasing)
- However:
  - More difficult to realise, since need a conventional accelerator
  - High-quality beams not yet demonstrated
  - Accelerated bunches not systematically analysed
- Existing accelerator infrastructure at **DESY** makes it suitable for studies of PWFA

FLASHForward facility at DESY

Overview

- FLASH is a free-electron laser (FEL) at DESY, world's first soft X-ray FEL
- Provides high-quality electron beams up to 1.25 GeV
- This gives a **unique opportunity** to study PWFA: electrons from FLASH will drive the wake in the plasma channel; injected electrons will be accelerated by this wakefield.

Physics goal – overcome current PWFA limitations

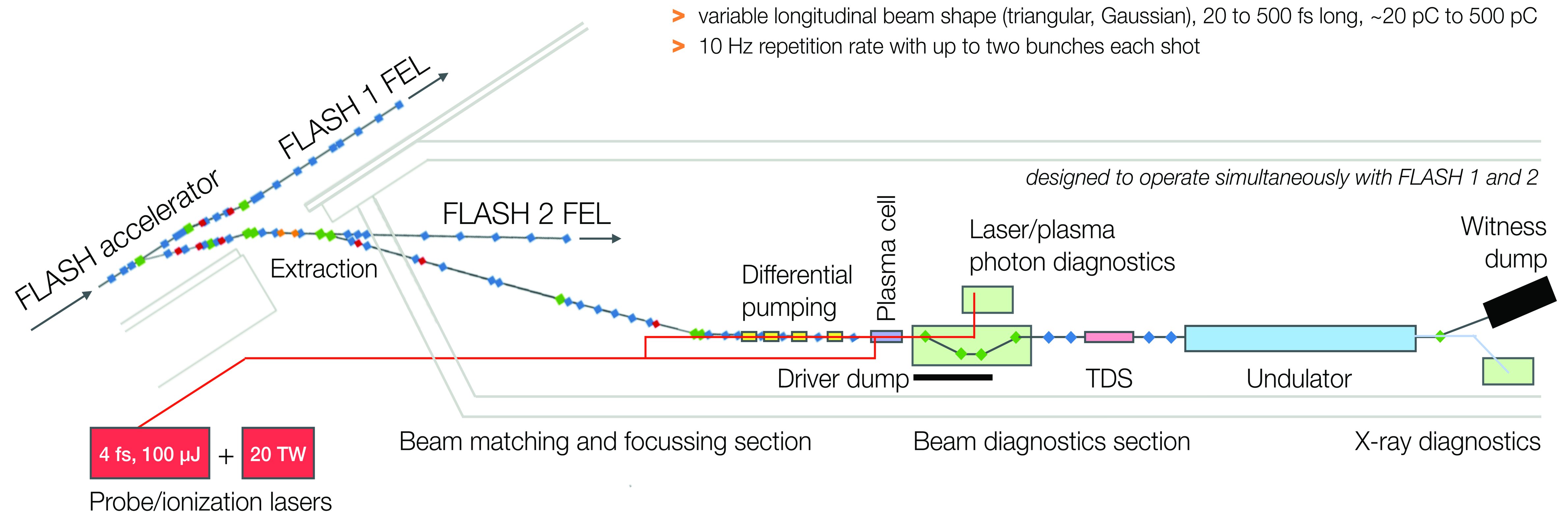
- Produce high-quality beams with beam-driven acceleration
- Systematically analyse bunch parameters (normalised projected emittance, normalised uncorrelated emittance, bunch length) for different injection techniques
- Achieve transformer ratios greater than 2 (ratio of the witness and the driver energies)
- Demonstrate for the first time an FEL driven by plasma-accelerated electron beams

Experimental setup

- Beam **extraction** and **transport** to the interaction region
- **Plasma cell** – the interaction region
- **Experimental chamber** – houses the plasma cell
- **Post-plasma diagnostics** – measures properties of accelerated and drive electron bunches
- Further beam **transport** to the **undulators** – for the FEL demonstration

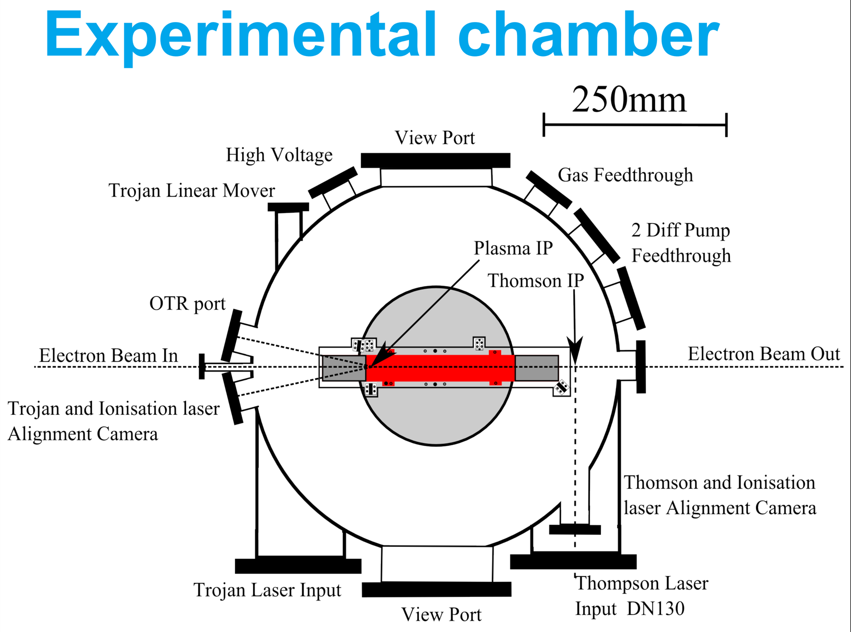
Driver-beam parameters

- FEL quality, ≤1.25 GeV, 0.1% energy spread, 1 μm transverse emittance
- variable longitudinal beam shape (triangular, Gaussian), 20 to 500 fs long, ~20 pC to 500 pC
- 10 Hz repetition rate with up to two bunches each shot



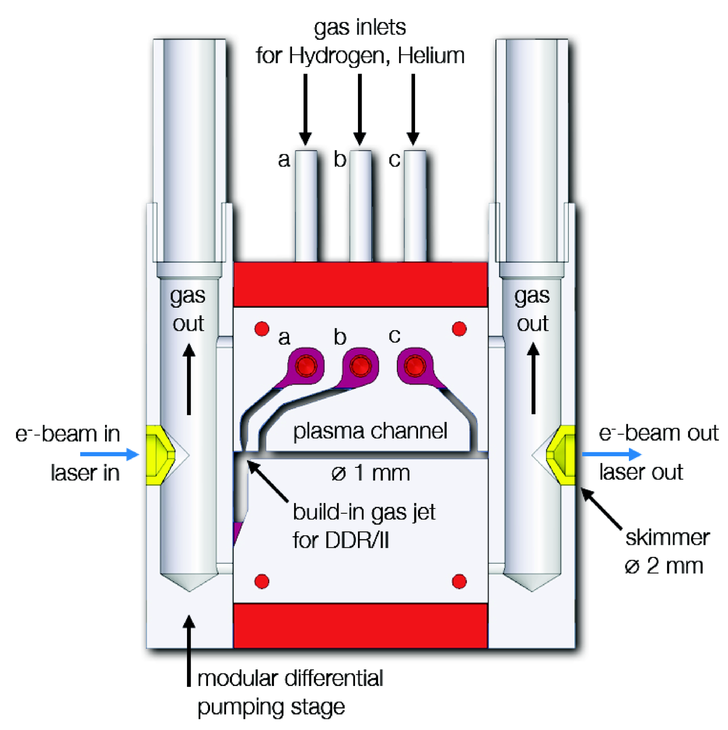
Conceptual design in progress, to be concluded in Dec. 2013
Experiments to start early 2016, run for 4 years+

Experimental chamber



- Stringent vacuum requirements at FLASH (10^{-9} mbar) call for a careful design of the interaction region
- Capability to move the plasma cell in 6D in an ultra-high vacuum
- Alignment and diagnostics of the incoming electron and laser beams
- Possibility to study laser-controlled injection (laser ports)

Plasma cell



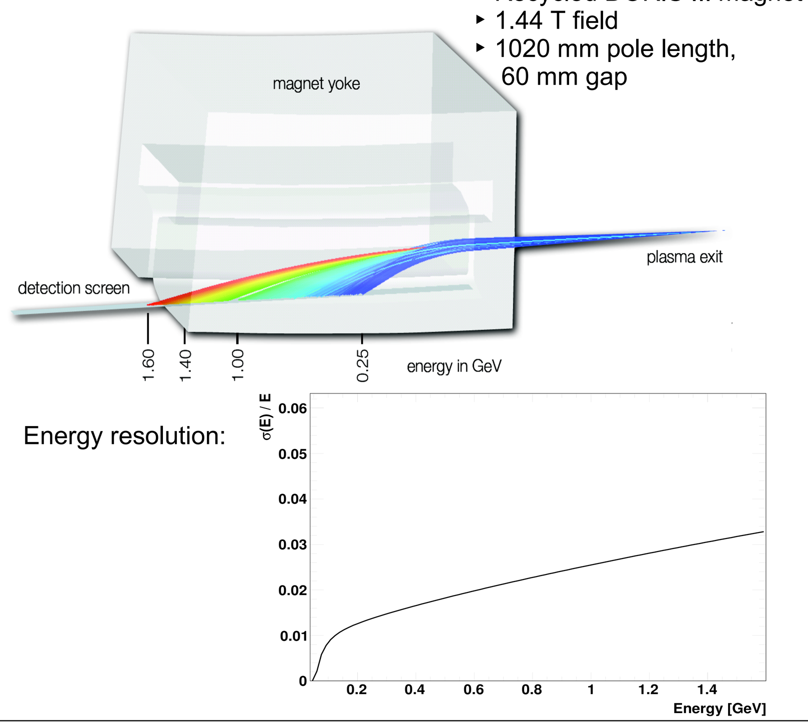
- The novel design allows stable, tailored plasma density profiles
- Plasma creation by laser or discharge possible
- Differential pumping needed to mitigate gas release into vacuum

Diagnostics

- Need to characterise both the drive and the accelerated beam:
  - Broadband GeV-electron spectrometer
  - BPMs
  - Quadrupoles and screens for beam profile and emittance (multi-shot)
  - Transition-radiation spectrometer for longitudinal bunch shape
  - X-ray CCD for beam-size in plasma
  - Undulator

Example: drive beam spectrometer

- Recycled DORIS III magnet
- 1.44 T field
- 1020 mm pole length, 60 mm gap



Summary

- **FLASHForward** is a PWFA facility being prepared at DESY
- High-quality electron beams of ~1 GeV from the free-electron laser FLASH will be utilised to drive the wake in the plasma
- Various injection techniques will be studied, such as:
  - Density-downramp
  - Ionisation injection
  - External injection
- A first demonstration of an FEL driven by electron beams from PWFA is foreseen

References

[1] T. Tajima, J. M. Dawson, Phys. Rev. Lett. **43**, 267
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[3] S. Bulanov *et al.*, Phys. Rev. **E58**, R5257 (1998), J. Grebenyuk, poster at this workshop
[4] A. Martinez de la Ossa *et al.*, paper in preparation
[5] B. Hidding *et al.*, Phys. Rev. Lett. **108**, 035001 (2012)

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