Start-to-end modelling for the realization and optimization of plasma-wakefield-accelerator-driven free-electron lasers

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Plasma-based acceleration
- In plasma-wakefield acceleration (PWFA), short and high-current particle beams generate large amplitude plasma waves.
- 40 GeV energy gain of electrons in meter-scale plasma modules was demonstrated experimentally [1].
- Allows for dramatic miniaturization and reduction of costs of future light sources [2,3] or particle colliders [4,5].
- Extreme wakefields ~10-100 GV/m
- Electrons accelerated to GeVs in cm/s
- Shrinking size of accelerators from km's to m's

Free-electron lasers
Free electron lasers (FELs) are deliver
- Spatially and temporally coherent radiation
- with (sub-)mm wavelengths
- pulsed in a few femtoseconds
- ultra-high brightness (~10^3 photons/(mm^2 mrad^2 0.1% b.w.))

Particle-In-Cell modelling
- Analytic description of phenomena in plasma-based accelerators not possible
- Particle-In-Cell (PIC) methods model kinetic plasma phenomena with affordable computational means
- PIC codes implicitly solve the Maxwell-Vlasov system
- Particle density is discretized with macro-particles
- Macro-particles are advanced along the characteristics of the Vlasov equation
- Fields and currents are defined on a grid

Start-to-end modelling for FLASHForward
- FLASHForward is a facility using FLASH beams at DESY for PWFA experiments
- The project aims at advancing beam-driven novel-accelerator science
- Simulations so far assumed ideal beam parameters neglecting realistic effects

This project will develop numerical methods for the first time allowing for the study and optimization of PWFA-driven FELs
- These studies are key to successful experiments at FLASHForward
- This has a transformative potential to the field of novel accelerator research
- May allow for small-lab scale high-brilliant X-ray or FEL generation

References