Preparations for High Transformer Ratio PWFA Experiments at PITZ.

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Abstract

In the field of plasma wakefield acceleration (PWFA) significant progress has been made throughout the recent years. However, an important issue in building plasma based accelerators that provide particle bunches suitable for user applications will be a high transformer ratio, i.e. the ratio between maximum accelerating field in the witness and maximum decelerating fields in the driving bunch. The transformer ratio for symmetrical bunches in an overdense plasma is naturally limited to 2*. Theory and simulations show that this can be exceeded using asymmetrical bunches. Experimentally this was proven in RF-structures**, but not in PWFA. To study transformer ratios above this limit in the linear regime of a plasma wake, experiments are under preparation at the Photoinjector Test Facility Zeuthen PITZ, a 25-MeV electron accelerator, that offers unique capabilities for this purpose.

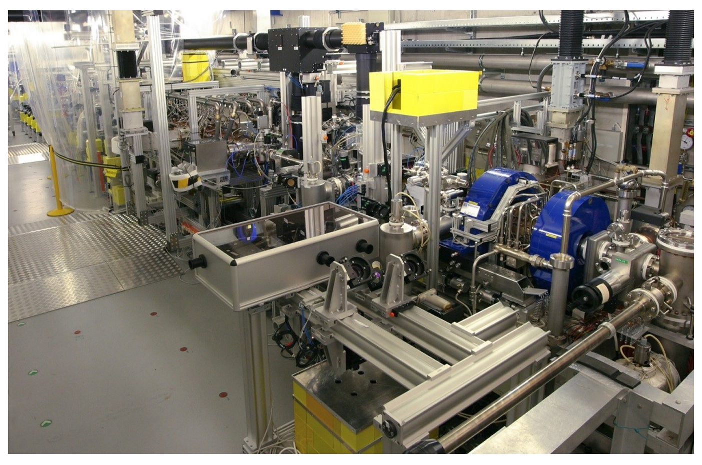
* K. L. F. Bane, P. B. Wilson and T. Weiland, AIP Conference Proceedings 127, p. 875, 1984
** C. Jing et al., Physical Review Letters 98, 144801, 2007

Beam parameters at the Photo-Injector Test facility Zeuthen

Accelerator test facility for photoinjectors of FLASH and EU-XFEL

- Bunch charge 20 pC – 5 nC
- Variable bunch length and shape (min. 1 ps rms-length)
- 1.3 GHz RF gun
- 60 MV/m at photocathode
- 6 MeV photoelectrons from gun
- Up to 25 MeV after CDS booster cavity

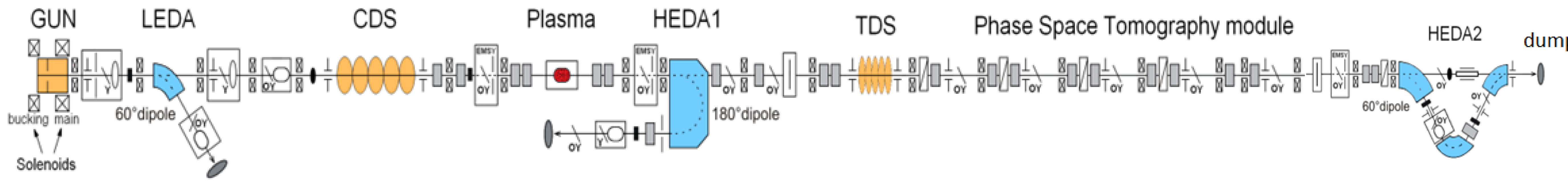
The highly flexible photocathode laser is crucial for PWFA experiments and will be further extended soon.



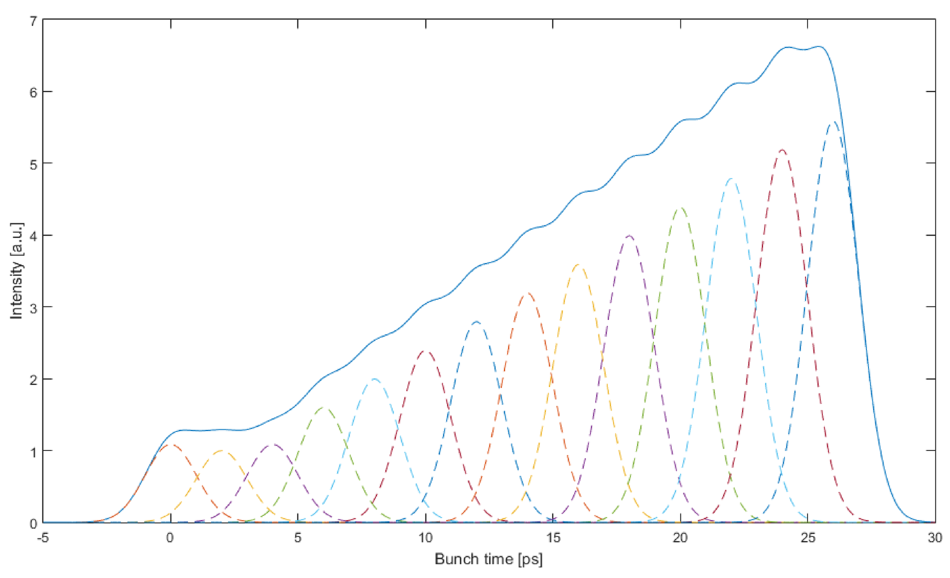
Scope of the HTR experiments at PITZ

1. Demonstration of high transformer ratio (HTR), beam-driven PWFA
2. Experimental investigation of different HTR schemes
3. Applicability of photocathode-shaped bunches
4. Advanced photocathode bunch-shaping techniques

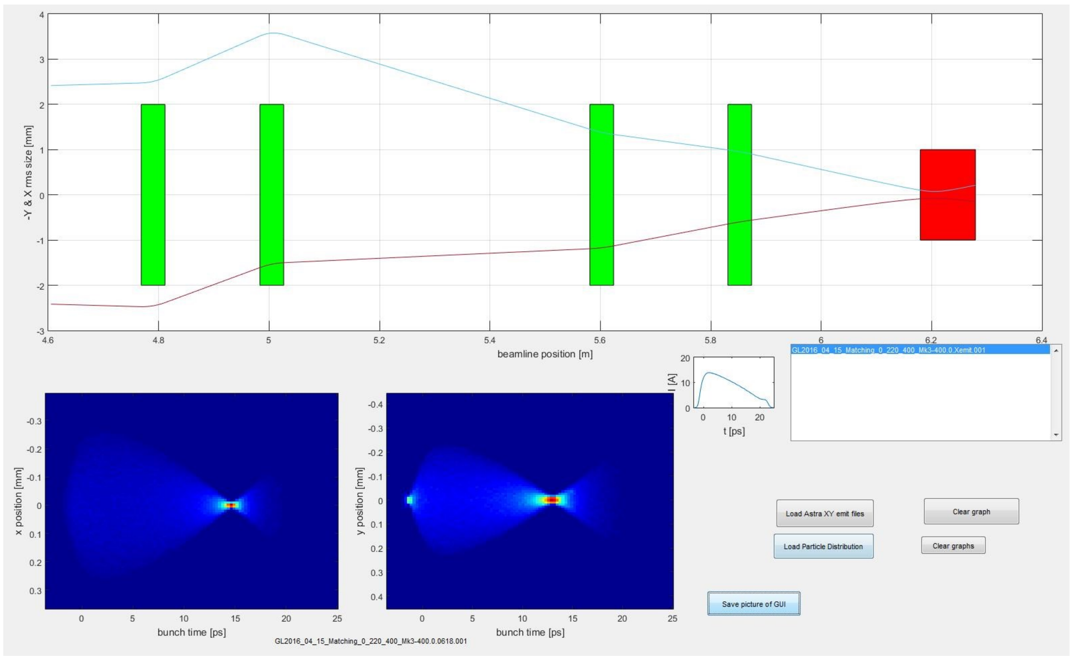
PITZ-beamline:



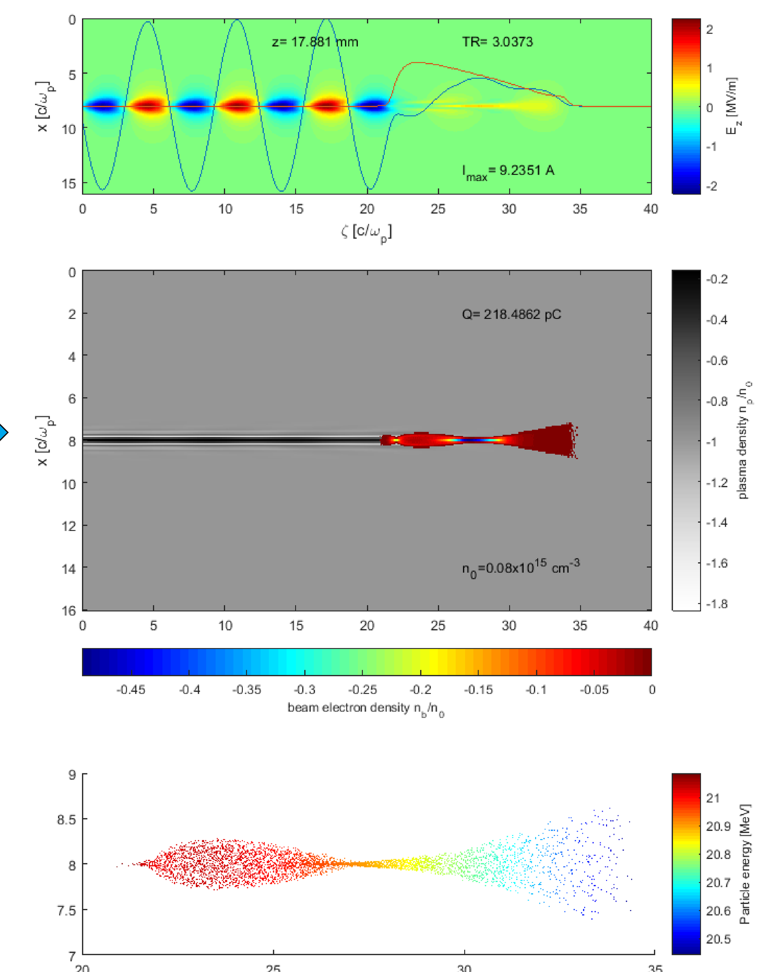
Tracking (Astra) and PWFA (HiPACE) simulations



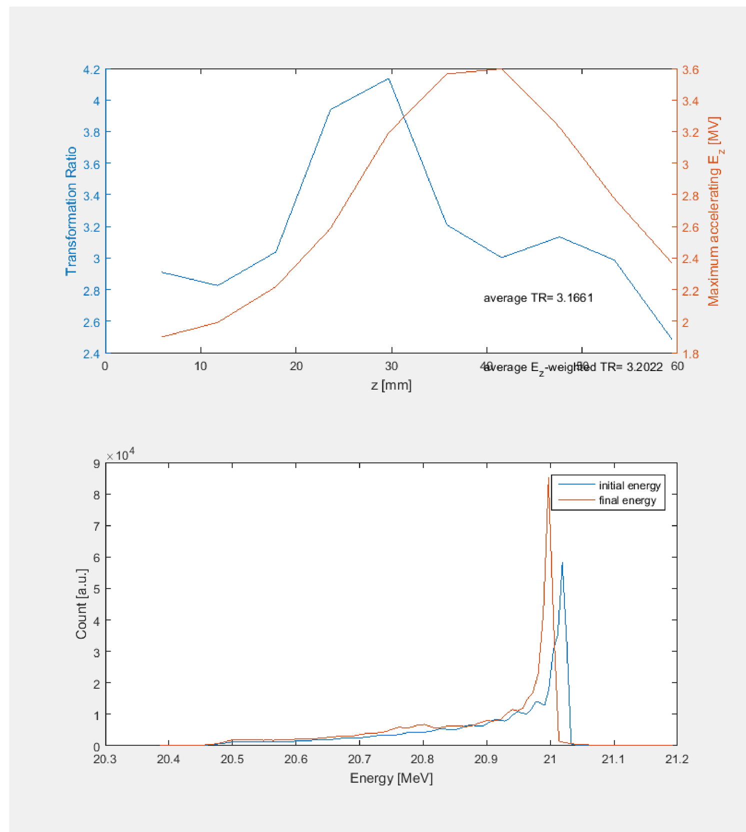
Photocathode laser pulse shape <-> Input electron bunch shape



Particle tracking to the plasma cell position with Astra



Typical simulation of beam plasma interaction with HiPACE

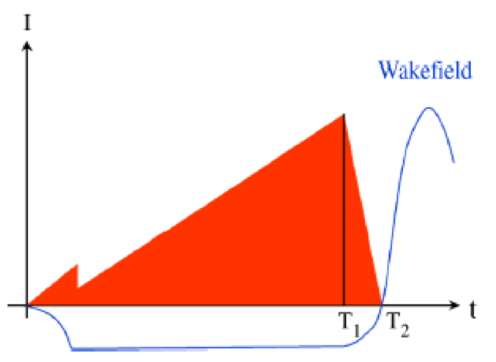


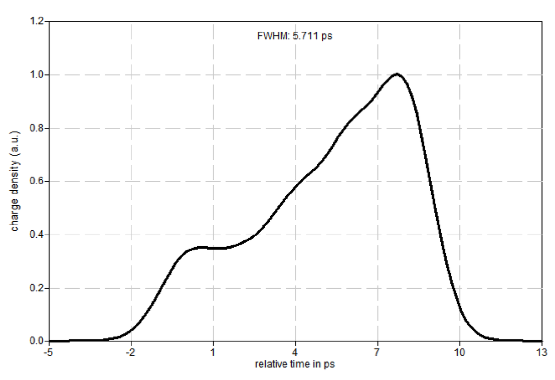
Preliminary results and further steps:

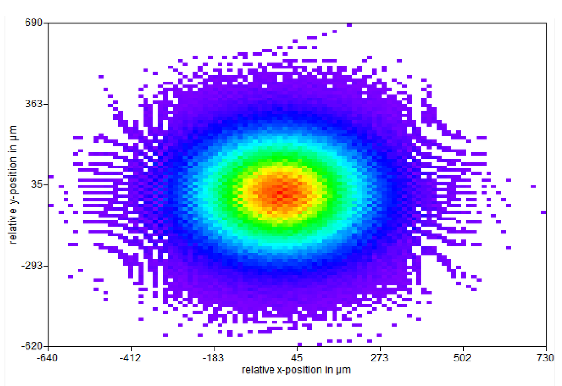
- ❑ High transformer ratios observed (right and bottom right plots)
- ❑ Uneven focusing and even self-modulation degrade driver
- ❑ Moderate field strengths
- ❑ Shorter drive beams/different charges not much better

- Idealised bunches (tr.v. Gaussian, exact laser shape)
  → scan parameters in idealised case for better understanding

- Simulate different bunch shapes (e.g. double triangle, sinusoidal, quadratic, etc.)

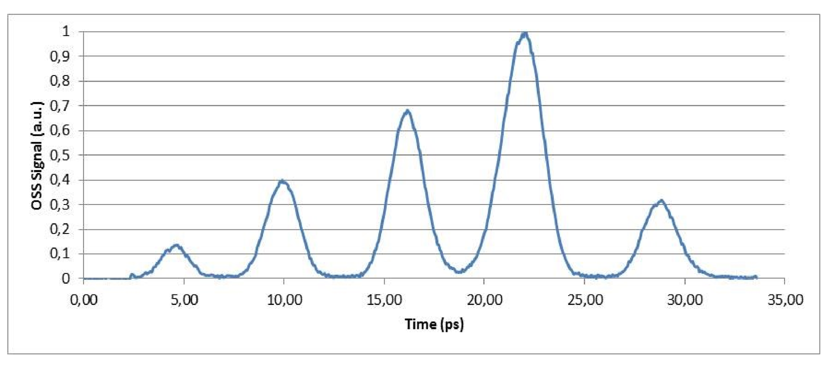


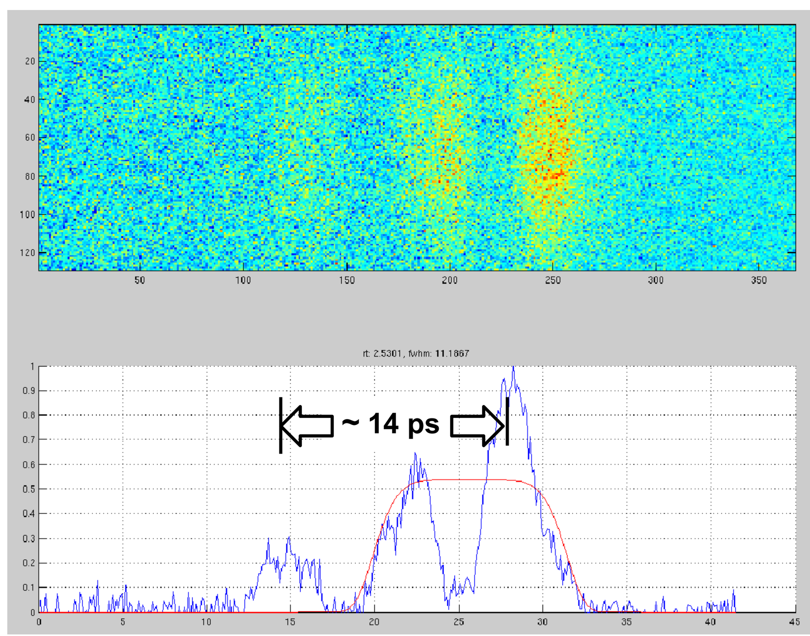




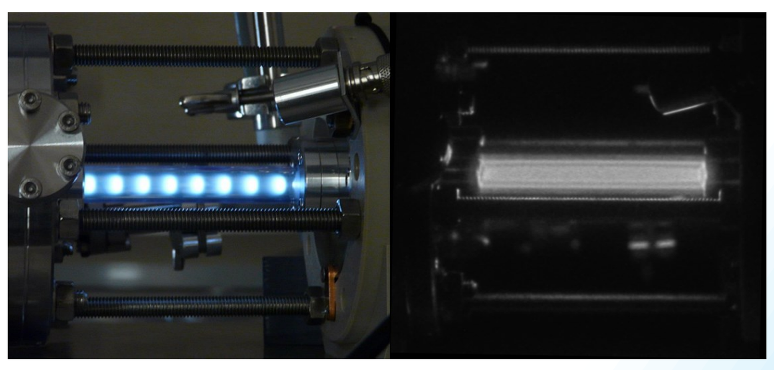
Preparatory Studies

- Versatility of photocathode laser was proven in various experiments (see cross-correlator measurement in bottom picture)
- Transport of asymmetric bunches through PITZ beamline was confirmed (see TDS measurement in right picture)





Gas discharge plasma



- Plasma cell for electron densities of 10^{14} – 10^{15} cm^{-3}
- 200 A – 600 A discharge current
- 10 cm plasma length
- Max. 3 kV discharge voltage
- Discharge gas Argon
- 0.04 – 2 mbar gas pressure
- Density measurements ongoing