Experimental investigation of hosing instability mitigation.

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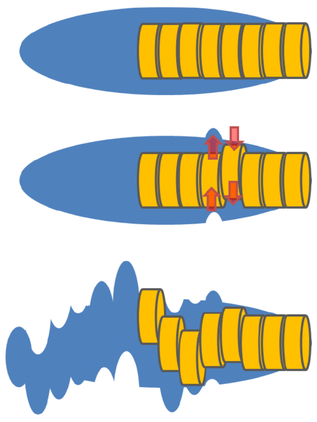
Abstract

Beam-driven plasma wakefield accelerators (PWFAs) allow for high gradient acceleration of electron beams and hence are promising candidates for compact and cost-efficient drivers of applications demanding high brightness beams.
One of the main challenges in these accelerators is to control beam-plasma instabilities with rapid growth rates which are induced by the strong transverse components of the wakefields. The hosing instability, a growing transverse oscillation of the beam centroid caused by inhomogeneities in the focusing wakefields, was predicted to set severe limits on the possible acceleration distance in PWFAs.
Several methods have been proposed to damp or even suppress the growth of the particle deflections in the affected beam and thus prevent beam-break-up.
Here, we present preparations and simulation studies aiming at the experimental investigation of hosing suppression mechanisms at the PITZ facility.

Motivation

The Beam Hosing Instability

- Transverse asymmetric beam-plasma instability
- Transverse inhomogeneities lead to slice-centroid oscillations
- Resonant betatron oscillations of slice-centroids lead to growth of amplitudes along bunch & plasma
- Beam-breakup if amplitudes get to large
- Severely limits acceleration distance in PWFA



D. Whittum *et al.*, Phys. Rev. Lett. **67**, 8 (1991)
M. Lampe *et al.*, Phys. Fluids B **5**, 1888 (1993)

Mitigation of the Hosing Instability

Methods to damp beam cetroid oscillations

- Goal: Decoherence of slice betatron oscillations
- Acquired and initial correlated energy spread
- Uncorrelated energy spread
- Inhomogeneous focusing along bunch
  - Operate in quasi-nonlinear regime
  - Large transverse bunch size at plasma entrance
  - Ion motion
- Reduce hosing seed

T. Mehrling *et al.*, Phys. Rev. Lett. **118**, 174801 (2017)
A. Martinez de la Ossa *et al.*, Phys. Rev. Lett. **121**, 064803 (2018)
T. Mehrling *et al.*, Phys. Rev. Lett. **121**, 264802 (2018)
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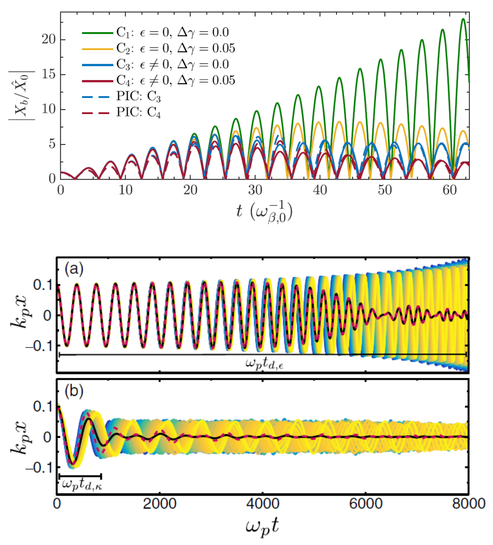
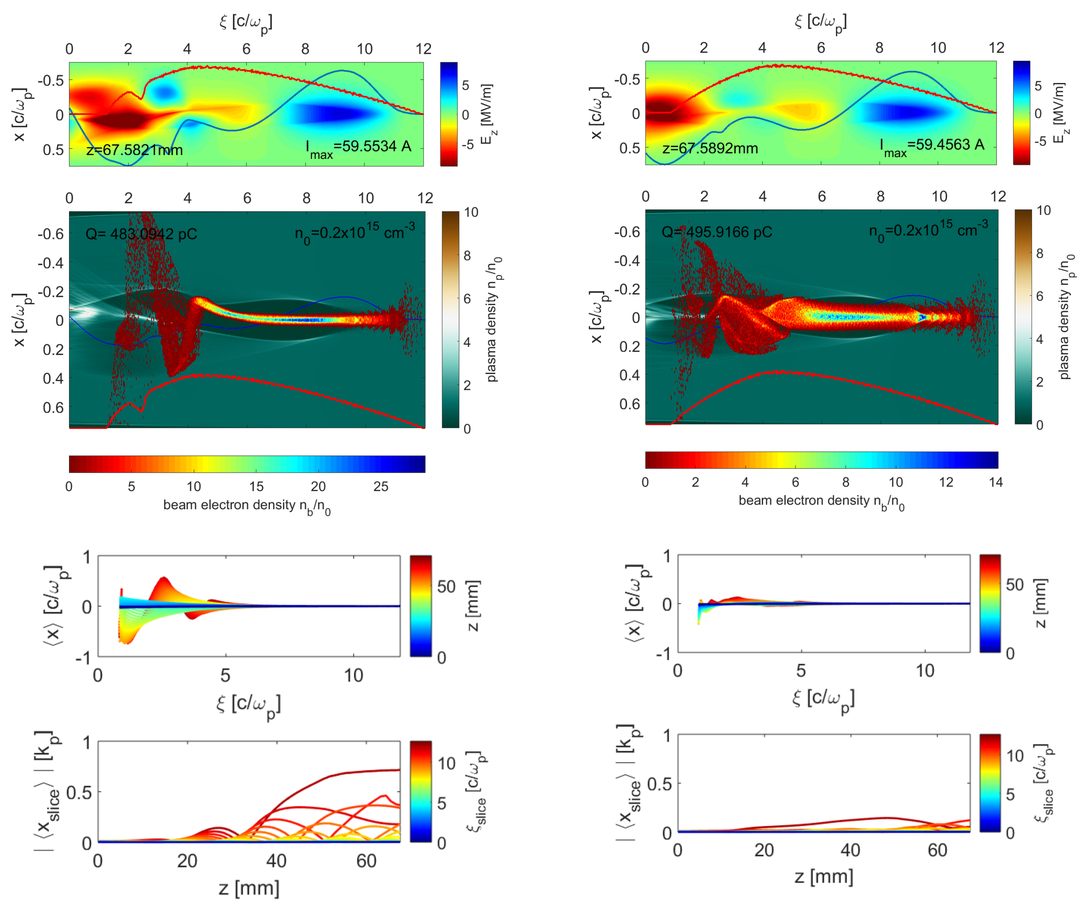
T. Mehrling *et al.*, Phys. Rev. Accel. Beams **22**, 031302 (2019)



First experimental results

- First hosing signatures observed in experiments
- Tuning of hosing seed (longitudinal bunch tilt) achieved in experiment
- 20 cm long discharge plasma set up (for higher no. of growth lengths ↔ 10 cm)

Preliminary simulation results



Analysis ongoing

- Hosing simulated for PITZ case for various parameters
- Longitudinally triangular bunches ($L_b \approx \lambda_p$) showed highest susceptibility to HI for PITZ parameters
- Different seed strengths (initial bunch tilts) allow to influence hosing
- Induce different corr. Energy spreads and different initial beam sizes to mitigate hosing
  - → Hosing mitigation via initial tr.v. bunch size increase seems to work for PITZ parameters
  - → Self-modulation instability occurs if bunch size too big → blurs hosing signature

Outlook

- Parameters for clear hosing mitigation at PITZ under investigation
- New photocathode laser for triangular bunches under commissioning

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

PITZ Photo Injector Test Facility Zeuthen