Excitation of beam-driven plasma-waves in a hybrid LPWFA


Hybrid Collaboration
Motivation and Setup

- PWFA: promising concept for generation and acceleration of high quality electron beams
- PWFA blowout regimes (Lotov, 2004): e.g. strong beam regime
  - efficient energy transfer to the plasma
  - robust wakefield cavity
  - quasi linear accelerating and focusing field: promising to reach high quality witness beams
  - Driver requirements: high peak currents (> 17kA), transversal ($\sigma_r \approx c/\omega_p$) and longitudinal ($\sigma_z \approx c/\omega_p$) matching with the plasma frequency

→ LWFA is able to generate GeV class electron bunches with high peak currents (> 10 kA)

→ Using LWFA bunch to drive PWFA, could reach strong beam regime in a compact setup

Important information about PWFA process:

- **Generation** of plasma waves?
- **Structure** of these waves?
- **Interaction strength** between driver beam and plasma?

- Shorter pulse needs broader spectrum (Fourier limit)
- Using spectral broadening inside a hollow core fiber (Self phase modulation (SPM), fiber acts as mode filter)

† Ultra-short pulse (< 10 fs) deployed for probing PWFA at high density$^1$

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Plasma density dependency

More robust and visible cavities in pre-ionized than self-ionized case

Self-ionized case: good matching with expectations for fully ionized Hydrogen:

Beam is able to fully ionize Hydrogen itself
Correlation pl.-wave structure & e-spectrum

Elongation of the first cavity depending on the driver bunch properties

self-ionized regime

pre-ionized regime

Q (>25 MeV): 287.9 pC

Q (>25 MeV): 460.2 pC

Q (>25 MeV): 234.6 pC

Q (>25 MeV): 441.7 pC
Elongation of the first cavity

- Elongation is larger for shots with smaller bunch energy
  - Due to beam loading in LWFA: high charge bunches have intrinsically less energy
  - Indication for charge dependency of this elongation

- Predicted already in Lotov 2004 paper, but for a smaller transverse size

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Simulations of the correlation

- Simulation of gaussian shaped electron bunches entering pre-ionized target

100 pC

(high charge causes **elongation** of the cavities, both: relatively to the following cavities AND in general)

400 pC

Structures between cavities become smaller

700 pC

Behavior as observed in experiments:

Simulations by Alexander Debus, HZDR
Summary and Outlook

- High peak current **LWFA beam** is able to **drive plasma wave**
- Observation of a charge dependent elongation of the first cavity

→ Indication: with **LWFA beams** as drivers it is possible to **enter the strong beam regime**
→ Plasma wave **probing as diagnostic for interaction strength** (peak current) of the driver beam

See Talk:
Thomas Heinemann, **Thursday 18:00**, WG Laser-driven electron

**Thank you for your attention!**

Wednesday evening, Thomas Heinemann
Susanne Schöbel