Effect of driver charge on wakefield characteristics in a plasma accelerator probed by femtosecond shadowgraphy

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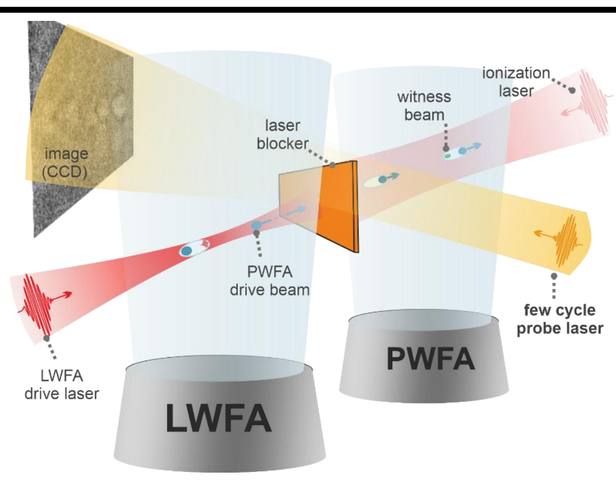
Motivation and Setup

- **PWFA**: promissing acceleration method for the generation and acceleration of **high quality electron beams**
- **LWFA beams** are intrinsically **short** and can reach high peak currents **(>10 kA)**

→ combine both in a **Hybrid LWFA driven PWFA**

- **ultrafast** (~ 10 fs FWHM) **optical pulse** for plasma probing
- **inherently synchronized** to LWFA driver laser



Hybrid Collaboration partners

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Phil. Trans. R. Soc. A **377**: 20180175 (2019)
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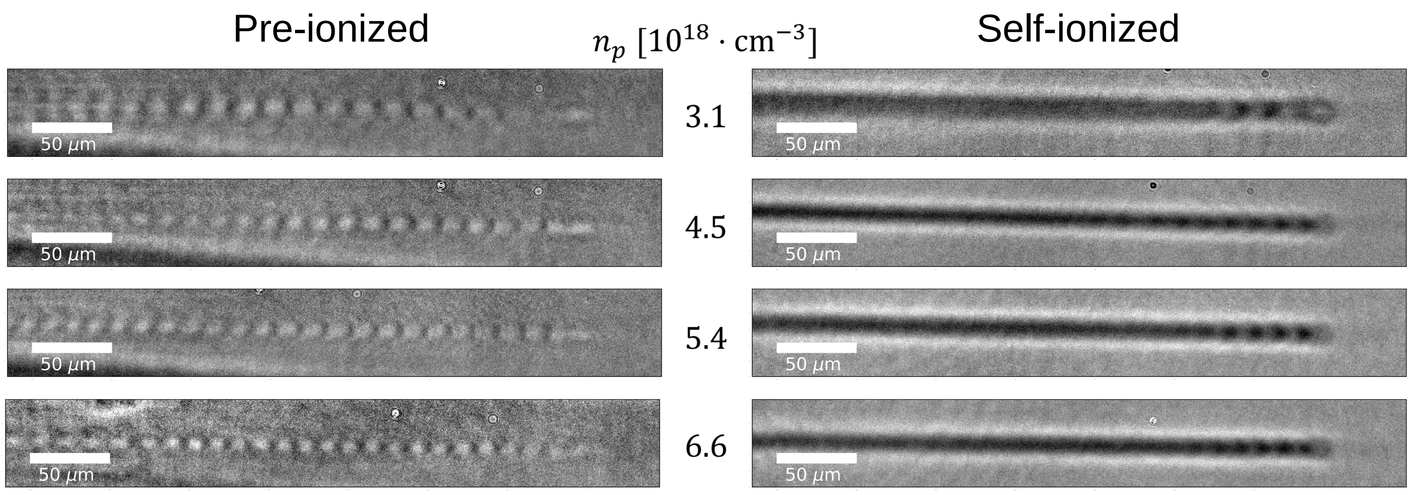
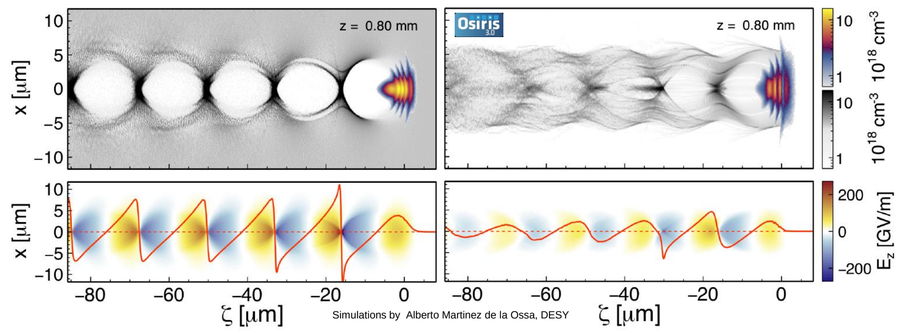
Observation of beam-driven plasma waves

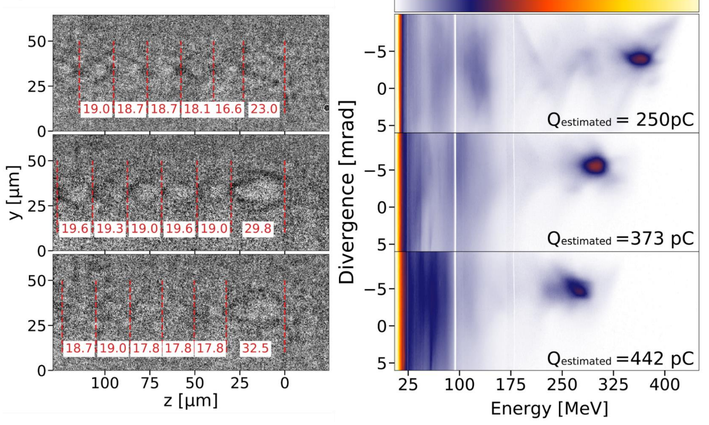




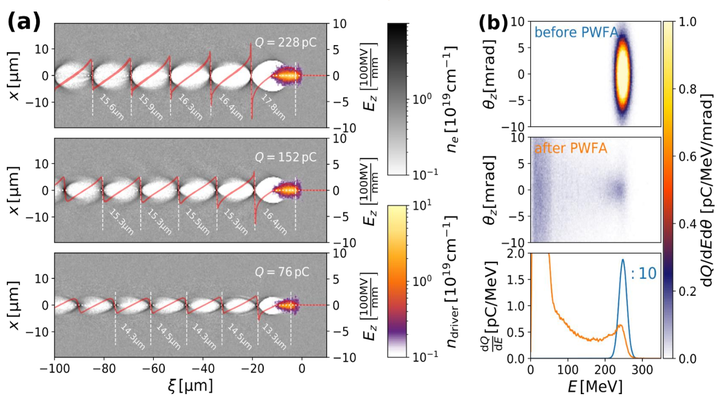
- **pre-ionized**: up to **25 cavities**, stable wakefield
- **self-ionized**: quick **smearing out** of the cavities, maximum **9** cavities visible
- **narrow plasma channel** in self-ionized case
- confirmed by simulations

Driver dependend wakefield formation

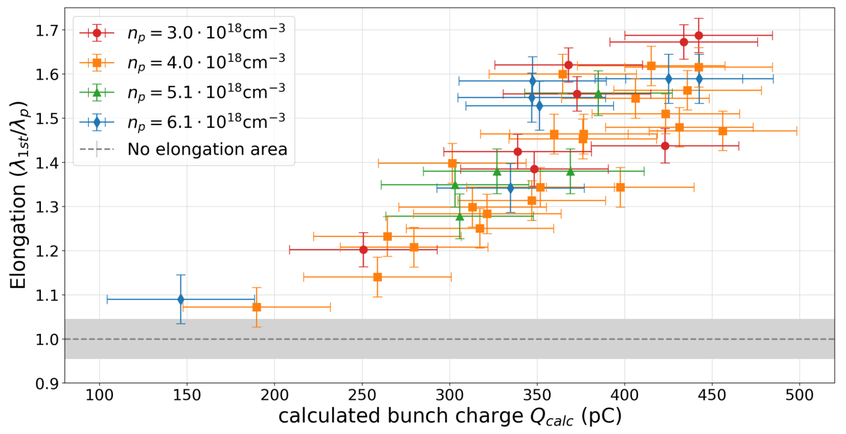
Experimental data



Simulation



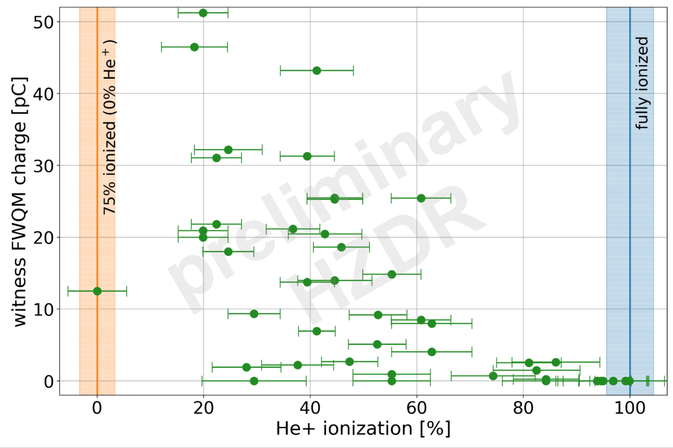
→ **elongation increases with increasing driver charge**

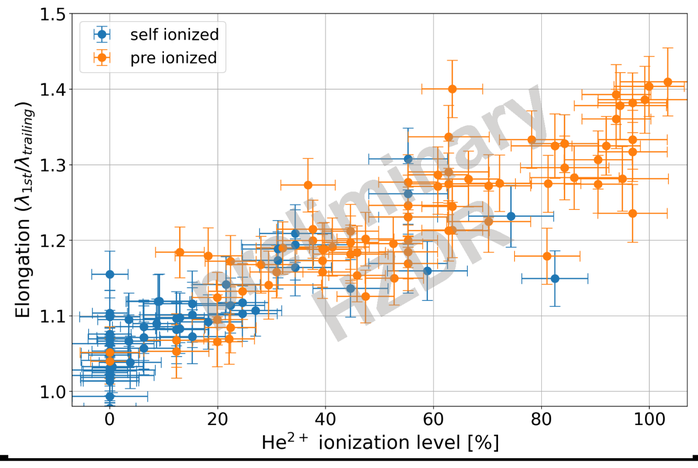


- observation: **first cavity** is **elongated** with respect the nominal plasma wavelength
- **elongation increases** with **decreasing remaining energy** which is coupled to **the initial charge** via **beamloading** in the LWFA stage
- **consistent** over various plasma densities: clear **correlation** between **elongation** of the first cavity and **initial charge** of the driver beam
- simulations confirm the **charge dependend elongation**
- **elongation** changes during **propagation** through the target as the **driver charge decreases** (due to deceleration) → **depletion measurement** possible

Driver dependend ionization

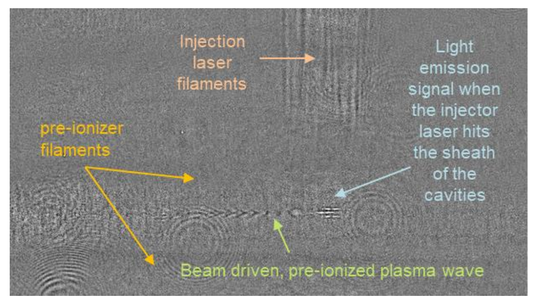
- Trojan Horse experiment: 50:50 H_2 – He mixture
  → details at Poster Patrick Ufer
- Pre-ionizer supposed to **ionize H_2** and **1st level He**
- shot to shot **jitter** of the **linear plasma wavelength** → **jitter** in the **ionization level of He+**
- **ionization correlates** with on shot **elongation**: **driver bunch** most likely to **cause** the **ionization**
- fully ionized ≙ no charge left for witness → **correlation**





Conclusions

- **LWFA beam** is strong enough to **fully ionize Hydrogen and first level** of **Helium** plus **partially He+**
- observation of an **elongation** of the first cavity depending on the **driver charge**
- **Ultrafast optical probing** technique provides a **new insight revealing subtle details** of the generated plasma wave structure and its dynamics and is **a powerful tool** to assist spatio-temporal problems in advanced injection schemes.



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