# Laboratoire d'Optique Appliquée

Palaiseau - FRANCE http://loa.ensta.fr









# High average gradient in a laser-gated multistage plasma wakefield accelerator

A. Knetsch<sup>1</sup>, I.A. Andriyash<sup>1</sup>, M. Gilljohann<sup>1</sup>,1 O. Kononenko<sup>1</sup>, A. Matheron<sup>1</sup>, Y. Mankovska<sup>1</sup>, P. San Miguel Claveria<sup>1</sup>, V. Zakharova<sup>1</sup>, E. Adli<sup>2</sup>, and S. Corde<sup>1</sup>

<sup>1</sup>LOA, ENSTA Paris, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, 91762 Palaiseau, France

<sup>2</sup>Department of physics, University of Oslo, N-0316 Oslo, Norway

Manuscript, see: https://arxiv.org/abs/2210.02263

# Single-stage PWFAs improve continuously



- Continuos single-stage progress on critical goals such as high accelerating gradient, matching, efficiency, energy-spread conservation, depletion
- Collider applications need orders of magnitude higher energy gains

#### Multiple stages as path to TeV energies



Source: A. Seryi,, et al. PAC09, Vancouver, BC (2009).

- A series of several subsequent PWFA stages as a path forward to reach TeV energies
- Defining parameter: Average accelerating gradient
- Plasma accelerators are inherently small, intra-stage can be a major contributor to decreased average gradient.

#### Multiple stages as path to TeV energies



Source: A. Seryi,, et al. PAC09, Vancouver, BC (2009).

- A series of several subsequent PWFA stages as a path forward to reach TeV energies
- Defining parameter: Average accelerating gradient
- Plasma accelerators are inherently small, intra-stage can be a major contributor to decreased average gradient.

#### Some core components (strongly simplified)



11-10-2022 | 20th Advanced Accelerator Concepts Workshop (AAC'22)

#### Step 1: Set all beams on same axis



#### Step 2: Gate in wakefield accelerator



# Step 3: Apply delays, replenish driver



#### Optimized spacing between beams



## Optimized spacing between beams



#### Evaluating expected accelerator length



11-10-2022 | 20th Advanced Accelerator Concepts Workshop (AAC'22)

## Introduction into different orbits: The beam reservoir



11-10-2022 | 20th Advanced Accelerator Concepts Workshop (AAC'22)

#### Introduction into different orbits: The plasma stages



#### Introduction into different orbits: Drive-beams



## Introduction into different orbits: The trailing beam



#### Development of longitudinal phase spaces



#### Results: Average gradient



## What about other parameters ?

- Efficiency:  $\eta = \frac{\Delta W_{tra.}Q_{tra.}}{2W_{res.}Q_{res.}} \approx 10.6 \%$ 
  - Improve by reducing charge of plasma lens driver,
  - improve with better beam loading
- Matching:

•

- Matched spot size on every stage

$$\sigma_r^m = \sqrt{\sqrt{\frac{2}{\gamma}} \frac{\epsilon_{\mathrm{n}}}{k_{\mathrm{p}}}}.$$

- High-energy range is close to 2f-2f imaging

$$f=rac{2\gamma}{k_{
m p}^2 L_{
m lens}} \propto rac{\gamma}{L_{
m lens} n_{
m e}}$$

Either density or lens length can be increased to control focusing





# Thank you for your attention

Questions ? Comments ?



11-10-2022 | 20th Advanced Accelerator Concepts Workshop (AAC'22)