GENERATION OF MULTI-PULSE LASER WAKEFIELD DRIVERS VIA DELAY MASKS

A. Marasciulli, L. Labate, P. Tomassini, F. Baffigi, F. Brandi, L. Fulgentini, D. Palla, P. Koester, L. A. Gizzi
Intense Laser Irradiation Laboratory (ILIL), Istituto Nazionale di Ottica (CNR–INO), Via G. Moruzzi 1, Pisa, Italy
andrea.marasciulli@ino.cnr.it
contributor ID: 130 (Student poster)

Abstract

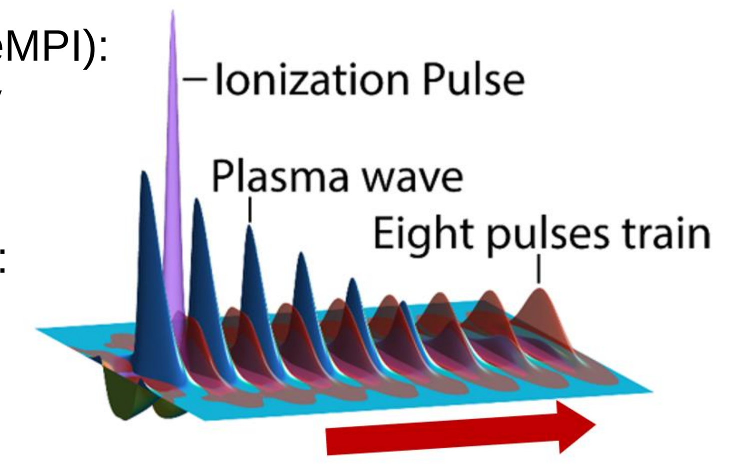
Laser-plasma accelerators are rapidly developing to produce high-quality sub-GeV electron beams capable of Free Electron Laser (FEL) operation. Their reduced size and cost with respect to conventional accelerators can widely spread the use of particle beams in medical physics and industry. Although multi-GeV electron energies were demonstrated [1], more work is needed to establish the high quality acceleration in this energy range. The Resonant Multi-Pulse Ionization (ReMPI) injection scheme [2] aims to produce FEL quality electron bunches with existing ultrashort and ultraintense laser systems, combining the advantages of the multi-pulse acceleration [3] and the two-color injection [4].

Here we report on how to produce a multi-pulse driver for the ReMPI scheme focusing the laser beams generated via wavefront division of a single ultrashort pulse by a glass delay mask, which demonstrated to have the right features to be used for ReMPI. A spatio-temporal characterization of the pulse train obtained with this method is presented. An experimental scheme to detect the effectiveness of the delay mask in triggering a resonant wake excitation, based on a density scan of the gas-jet target, was modelled and it will be discussed in detail.

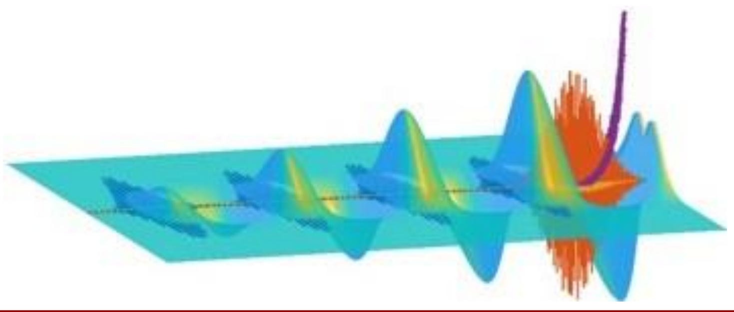
ReMPI injection scheme

Resonant Multi-Pulse Ionization injection (ReMPI): electron acceleration scheme for high-quality electron bunches

Tunable injection by a single ultrashort pulse:
- pulse train driver
- resonant wave excitation
- higher-harmonics ionization pulse
- low-emittance injection



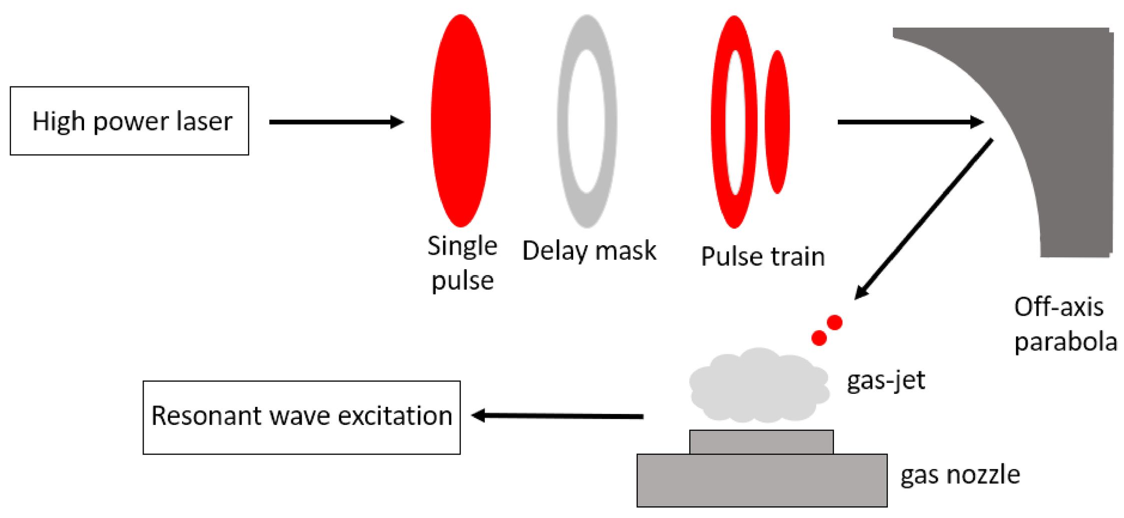
Multi-pulse driver and ionization pulse from the same Ti:Sa ultrashort pulse



Delay mask

Transparent element to generate a pulse train via wavefront division [5]

Delay control via thickness modulation



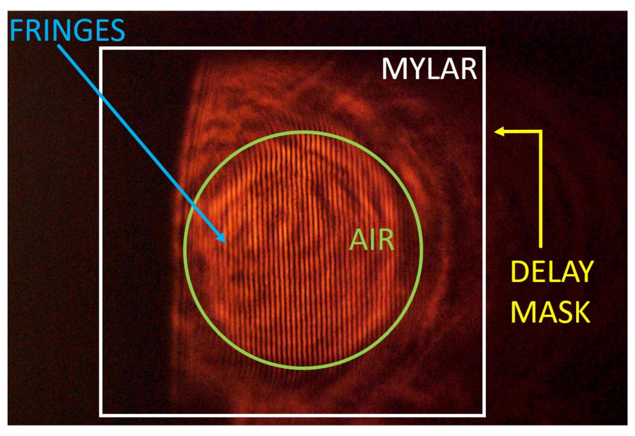
Objectives:
1. two pulses with the same peak intensity in the OAP focus
2. delay equal to the plasma wavelength

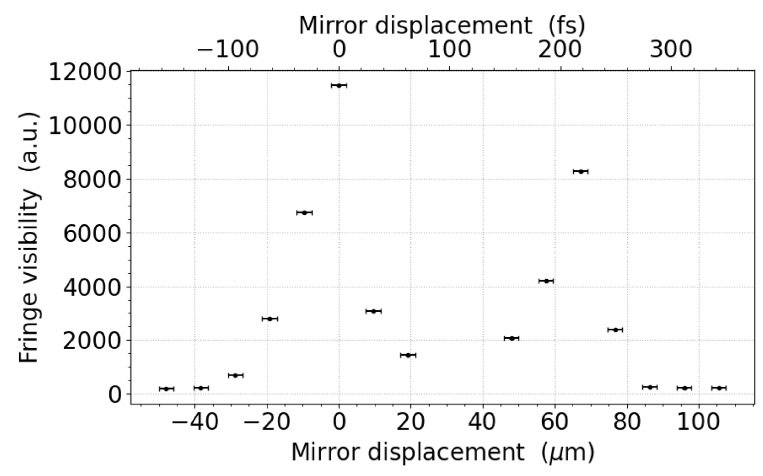
Advantages:
- flexible design
- no energy losses
- small occupied volume
- easy to use
- cheap
- only one laser needed

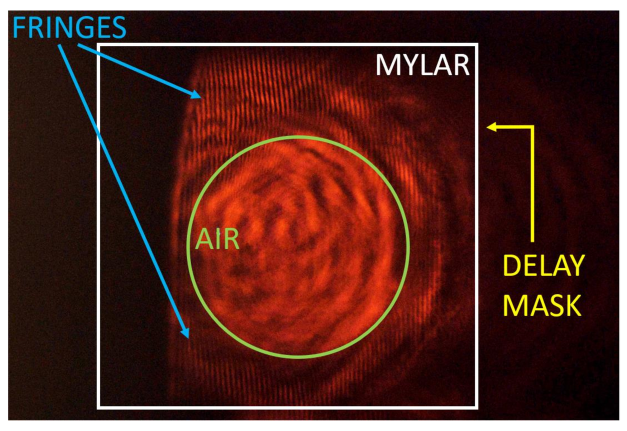
Pulse train measurement

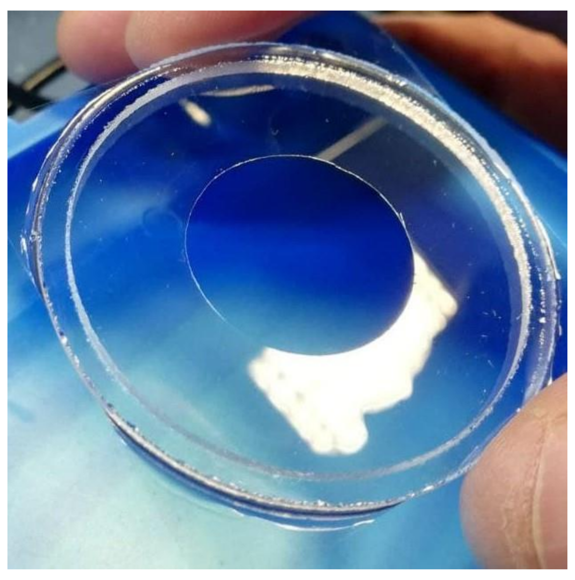
Spatio-temporal characterization of the pulse train generated by a 2-pulses delay mask before and after the OAP focusing.

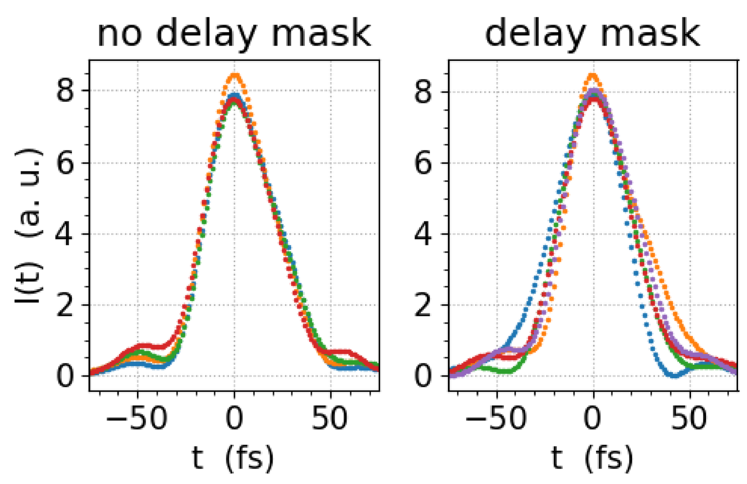
Results:
- Clearly visible temporal and spatial separation
- Negligible pulse stretching
- Expected peak intensity
- Non-invasive diffraction

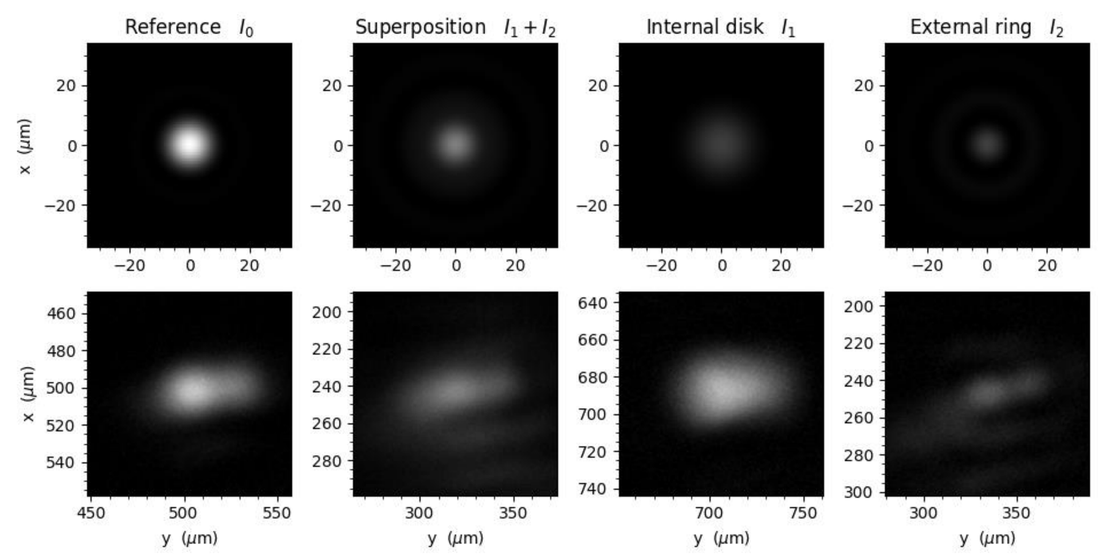


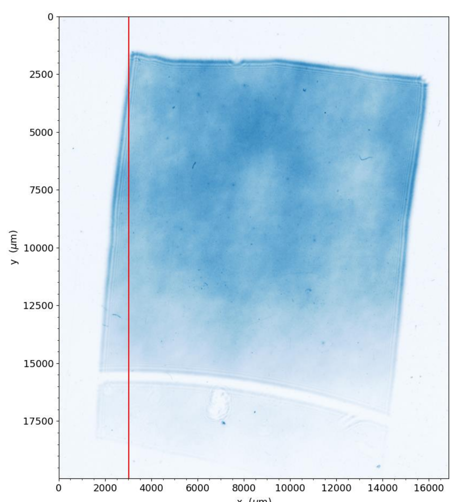


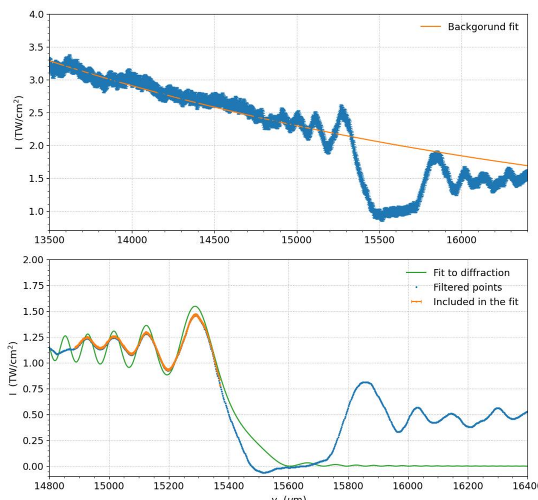








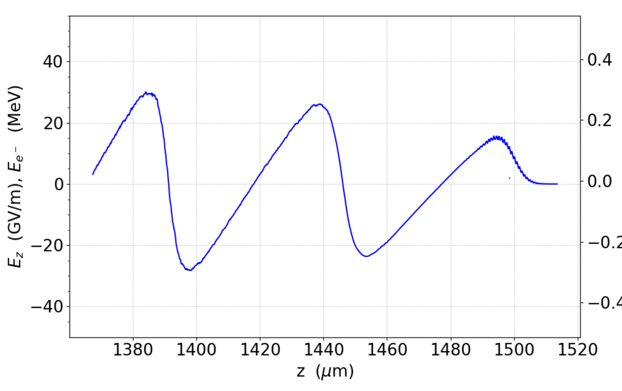




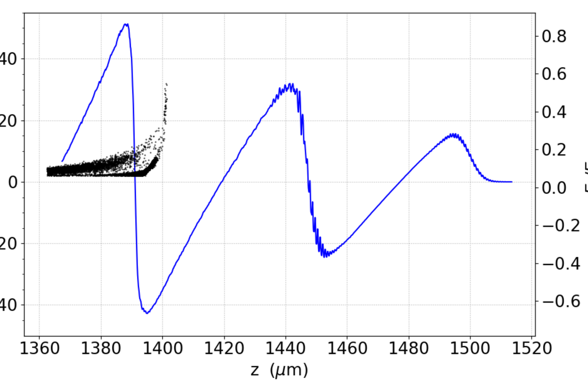
Detection of the resonant excitation

Simulated plasma wave excitation at $n_e = 4{\cdot}10^{17}\ e^-/cm^3$ by the single and the multi-pulse driver

Single pulse driver



2-pulses driver

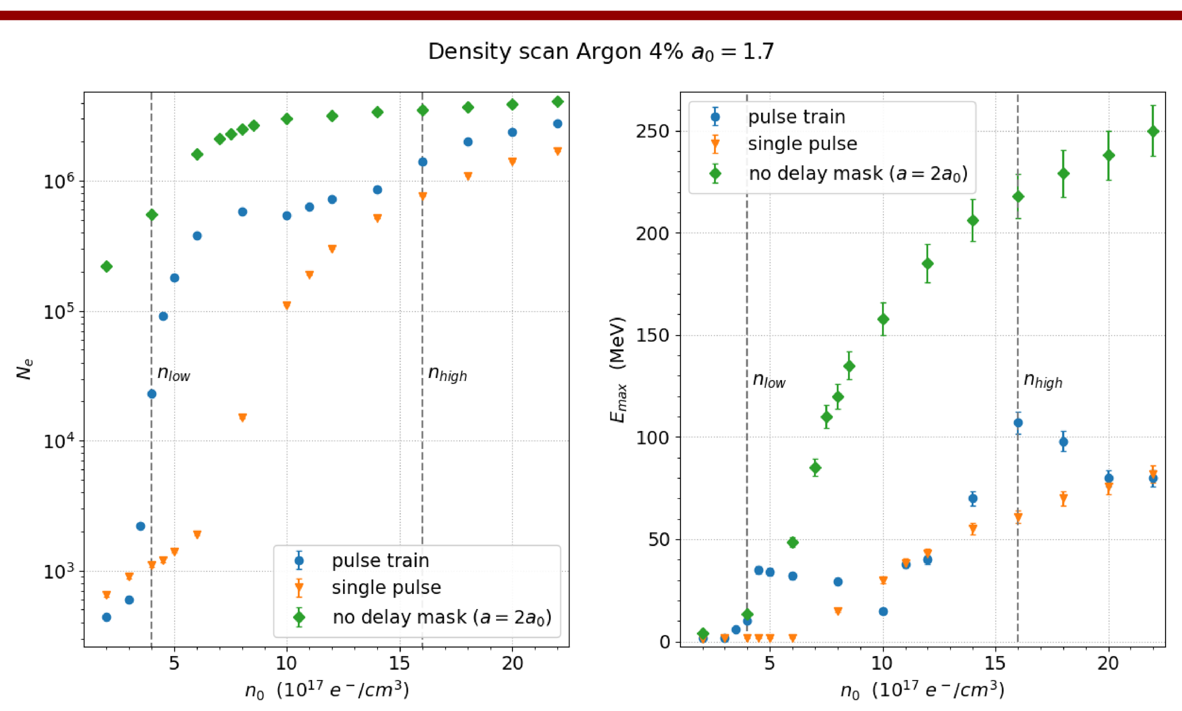


Density scan for a mixture of 96% He and 4% Ar for the 100 TW pulse train with $a_0 = 1.7$ without the ionization pulse

Search for the trapping from only the second plasma wave and comparison with respect to a single pulse

Delay between pulses of 52.4 μm matched for $4{\cdot}10^{17}\ e^-/cm^3$

Delay = $2\lambda_p$ for $16{\cdot}10^{17}\ e^-/cm^3$



Conclusions

Pulse train by a delay mask:
- Temporal and spatial profile with desired features
- Non-invasive diffraction
- Negligible pulse stretching
- Complete separation of the two pulses
- High sensitivity to the input beam shape

Simple experimental setup to detect the resonant wave excitation

ACKNOWLEDGEMENT - This poster presentation has received support from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730

References

[1] A. J. Gonsalves et al., Petawatt Laser Guiding and Electron Beam Acceleration to 8 GeV in a Laser-Heated Capillary Discharge Waveguide, PhysRevLett.122.084801 (2019)
[2] P. Tomassini et al., The resonant multi-pulse ionization injection, Physics of Plasmas 24, 103120 (2017)
[3] S. Dalla, M. Lontano, Large amplitude plasma wave excitation by means of sequences of short laser pulses, Phys. Rev. E, VOLUME 49, NUMBER 3 (1994)
[4] L.-L. Yu et al., Two-Color Laser-Ionization Injection, PRL 112, 125001 (2014)
[5] G. Vantaggiato et al., Modelling of pulse train generation for resonant laser wakefield acceleration using a delay mask, Nucl. Instr. and Methods in Phys. Res. A 909, 114-117 (2018)