High Quality Laser Wakefield Acceleration: Design And Implementation At ILIL-PW

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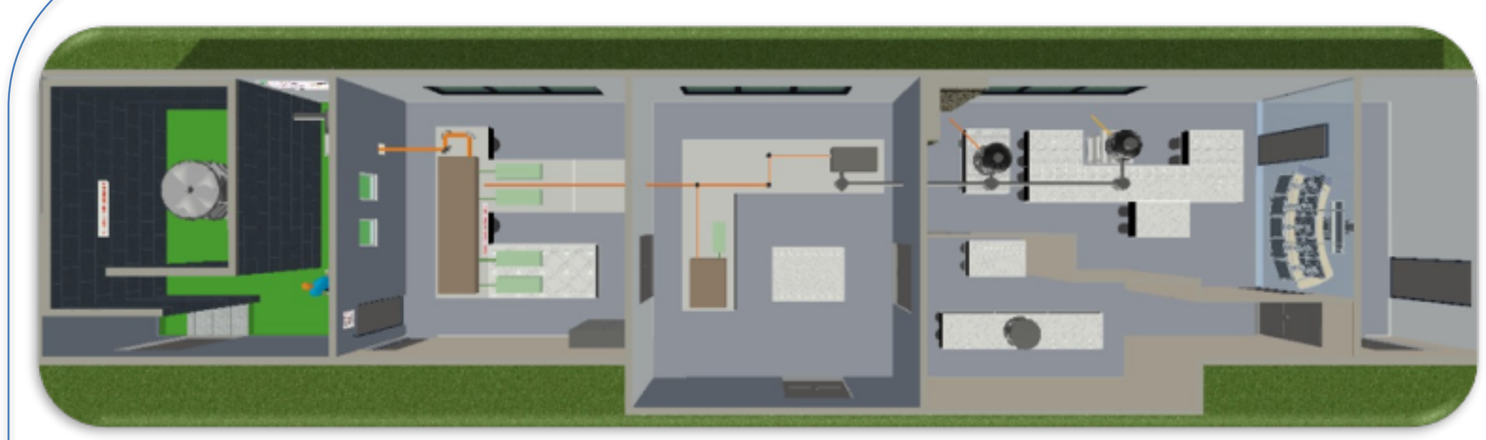
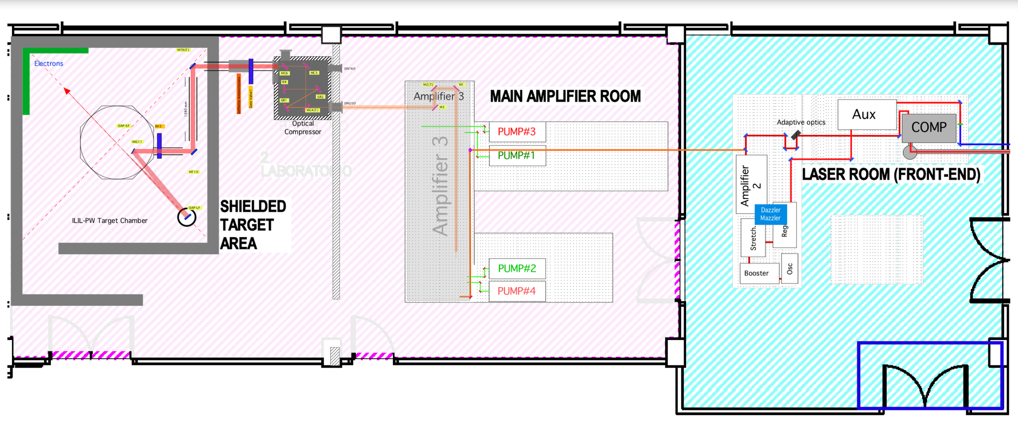
Abstract

Demonstration of high quality laser-plasma acceleration is mandatory for future development of novel plasma-based radiation sources like the EuPRAXIA H2020 project. In this context we are developing a test electron beam-line based on laser-wakefield acceleration with the aim of driving a Free Electron Laser in the X-ray domain. Our developments include design of a novel injection and acceleration scheme named ReMPI [1] to produce low energy spread, low emittance bunches, and the experimental proof-of-principle demonstration of such a scheme, including a short wavelength injection pulse and a resonant pulse train, all starting from a single Ti:Sa laser pulse. These developments take advantage of the recent upgrade of the ILIL-PW facility including the recent >100 TW scale laser upgrade and the commissioning of the new, PW scale interaction area. A preliminary set of data was already acquired following the successful commissioning of the laser system. Data include output from a range of diagnostics designed to characterize gas target, laser-gas interaction stability and electron bunch characterization. An overview will be given of the design and of the relevant ILIL-PW facility features.

The ILIL-PW facility

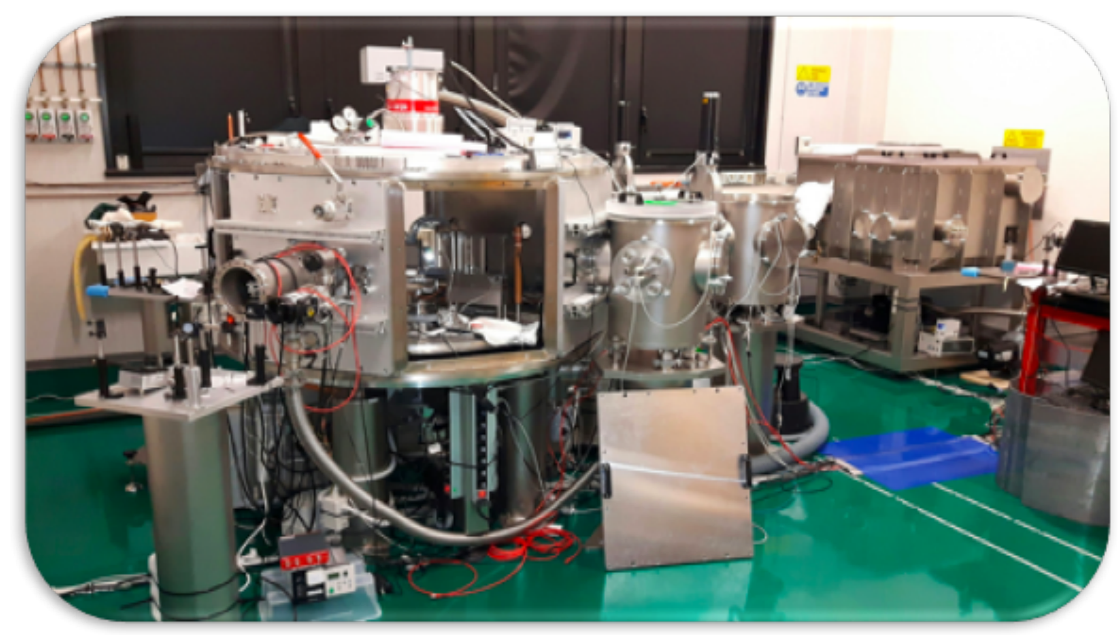




MAIN BEAM	Front-end	1st Phase	2nd Phase
Wavelength (nm)	800	800	800
Pump Energy (J)	1.8	12	24
Pulse Duration (fs)	40	30	25
Energy Before Compression (J)	0.6	4.7	7.9
Energy After Compression (J)	0.4	>3	>5
Rep. Rate (Hz)	10	1	2
Max intensity on target (W/cm^2)	2×10^{19}	2×10^{20}	$>4\times10^{20}$
Contrast@100ps	$>10^9$	$>10^9$	$>10^{10}$
Beam Diameter (mm)	36	100	100

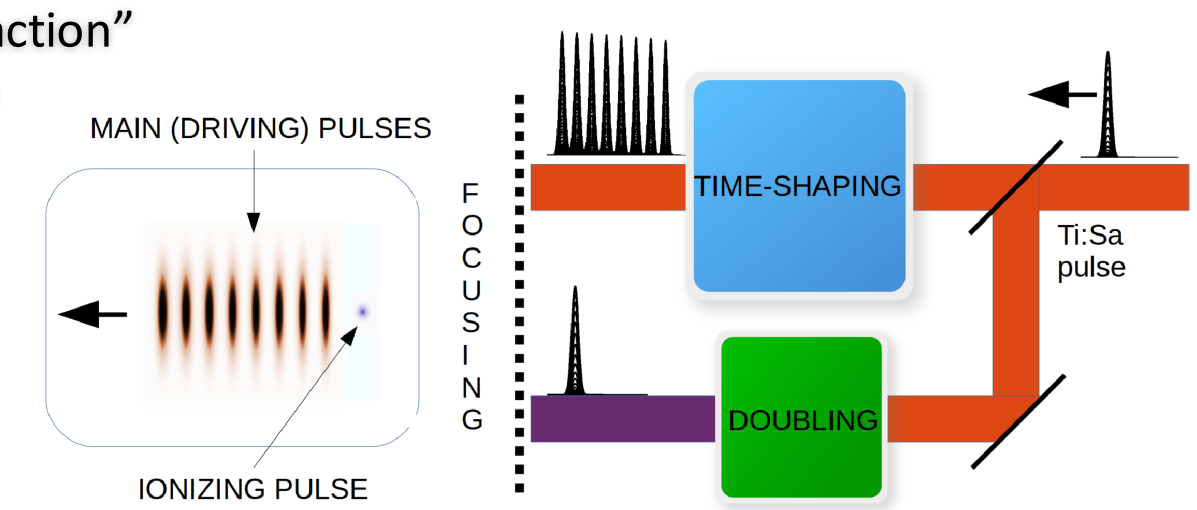
Phase 1: operational since July 2017

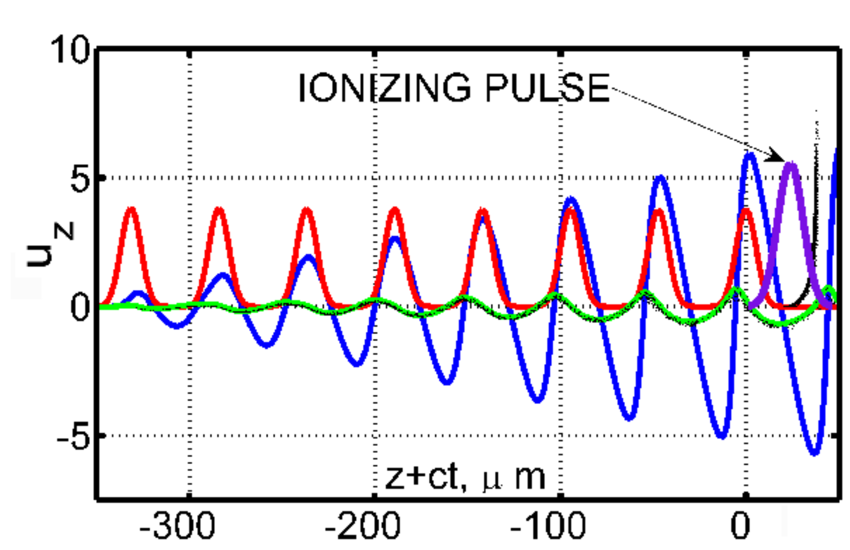
The target chamber



The Model

The Resonant Multi-Pulse Ionization injection [1,2] uses a **single (e.g Ti:Sa) 100-TW class laser system**. A minor portion of the pulse (about 100 mJ) is frequency doubled (or tripled) and tightly focuses on the target, thus acting as an "ionization-extraction" pulse that further ionize high-Z contaminants (e.g Argon, or Nitrogen). The newborn electrons are subsequently trapped by the wake driven by the main portion of the pulse shaped as a train of resonant sub-pulses. Since a resonant train of pulses can drive plasma waves with large amplitude [3], **the time-shaping procedure permits the generation of waves with amplitude large enough to trap the novel electrons,** using pulses with **peak intensities below the ionization threshold of the contaminant.**





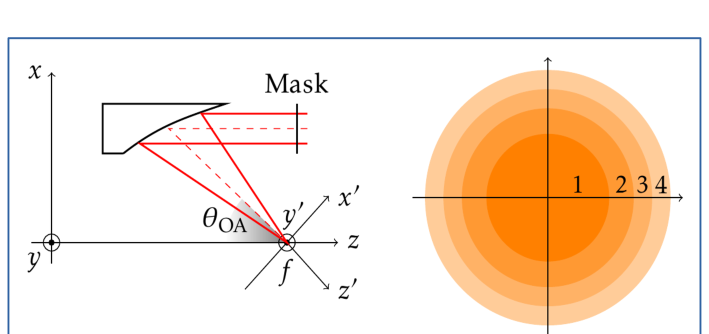
Using Argon as a contaminant species, extremely good-quality bunches **[<0.5% energy spread rms, <0.1 mm mrad of norm. emittance, 1kA of peak current]** can be generated.

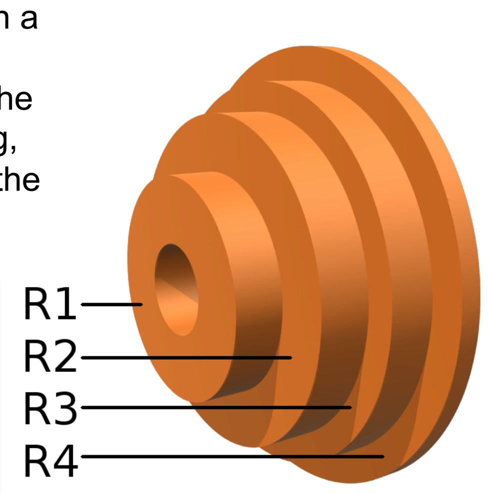
***2D cylindrical Qfluid simulation** (on-axis values). Pulses move through the left. The eight-pulses train (red lines) drives a nonlinear plasma wave (in blue the longitudinal electric field). The ionizingi pulse (purple line) extracts new particles that are suddenly trapped by the wake (the black dots represent the longitudinal phase-space of the bunch during the charging phase. [250TW , w0=45 micron, Argon, n0=5x10^17 1/cm^3]*

Layout

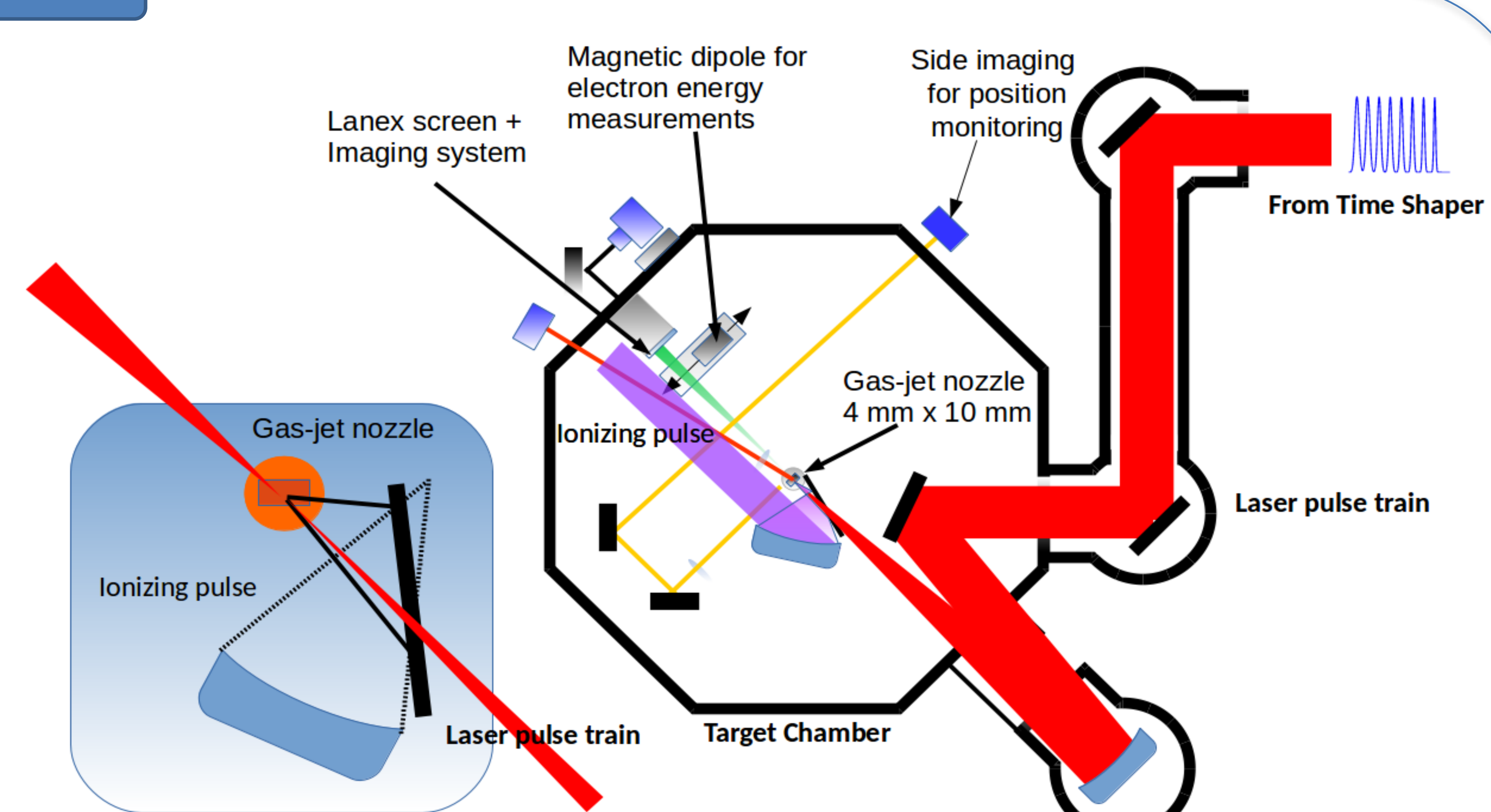
The temporal pulse shaper

The main portion of the pulse passes through a set of ring-like delay masks, each of them induces a different delay on the sub-pulse. The optimization of the masks radii is still ongoing, the goal being the generation of pulses with the same energy and minimum waist.





See poster by G. Vantaggiato et al.,



Acknowledgements

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References

[1] P. Tomassini et al, , "The Resonant Multi-Pulse Ionization injection", Acc. For pub. On PoP (Oct 2017), arXiv:1708.04957
[2] P. Tomassini et al., "High quality electron bunch production for high brilliance thomson scattering sources", SPIE proc. (2017)
[3] S. M. Hooker et al. , "Multi-pulse laser wakefield acceleration: a new route to efficient, high-repetition-rate plasma accelerators and high flux radiation sources", , J. Phys. B 47, 234003 (2014)

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