All-optical In-plasma Staging of Laser-Wakefield Accelerators Using Density Tailoring

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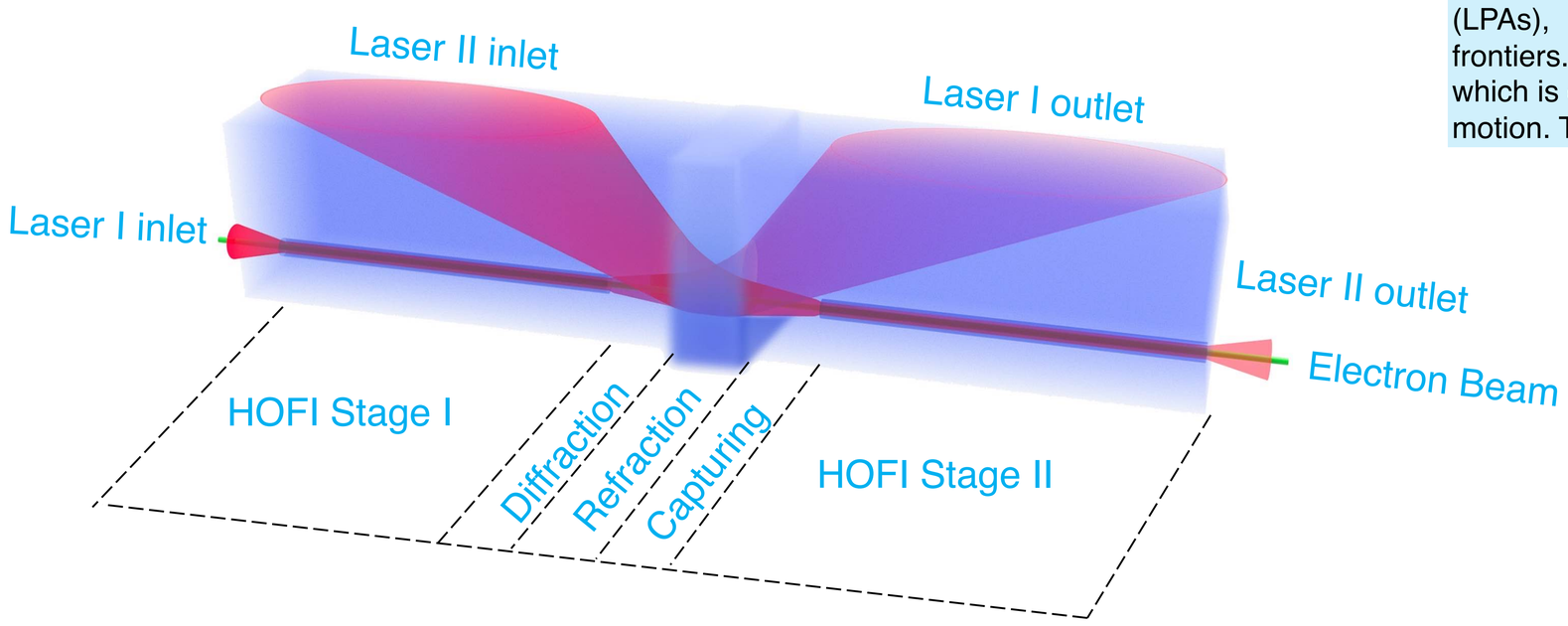
Figure: T. Hülsenbusch, DESY

We propose to use laser refraction in plasma to achieve staging



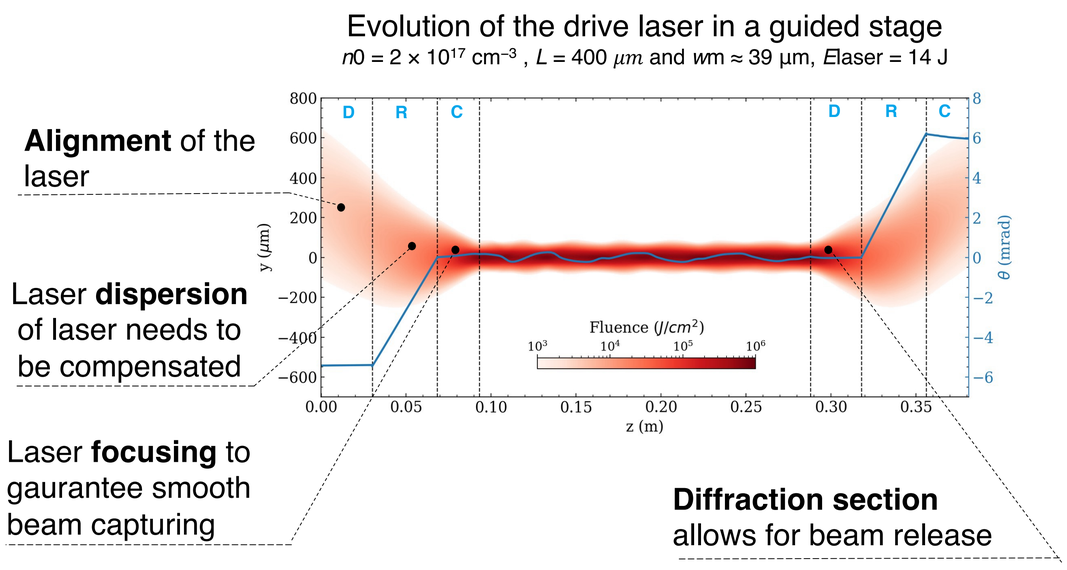
Motivation Staging consists of accelerating an electron beam through a chaing of laser plasma accelerators (LPAs), and is required to reach many-GeVs or TeV frontiers. We propose a concept of in-plasma staging, which is compact and in principle compatible with strong ion motion. This scheme is investigated with 3D simulations.

All-optical – Laser in- & out-coupling using transverse density gradient, without solid structures.

In-plasma – Witness stays in plasma in coupling region.

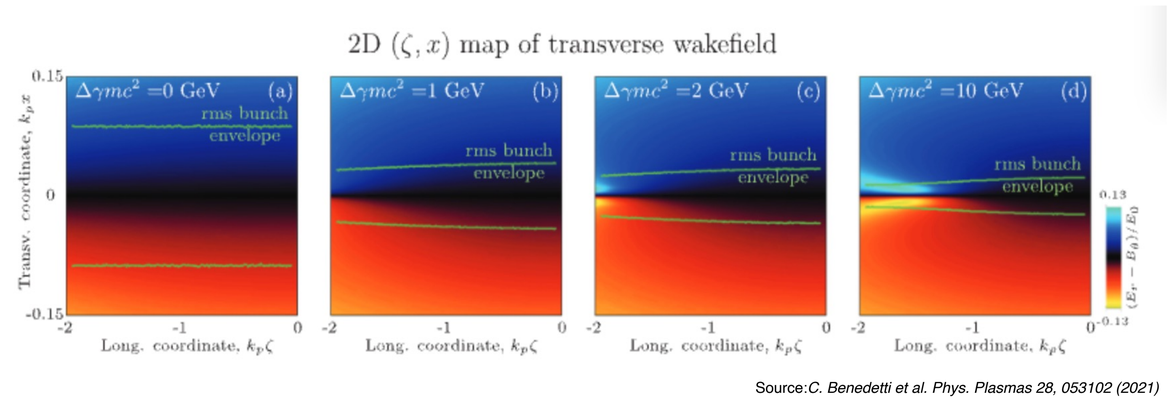
Plasma tailoring – Based on HOFI guiding scheme allowing for low density & potentially high repetition rate.

Tailored density profile permits laser coupling



Initial laser profile is iterated through Bayesian optimization: optimas

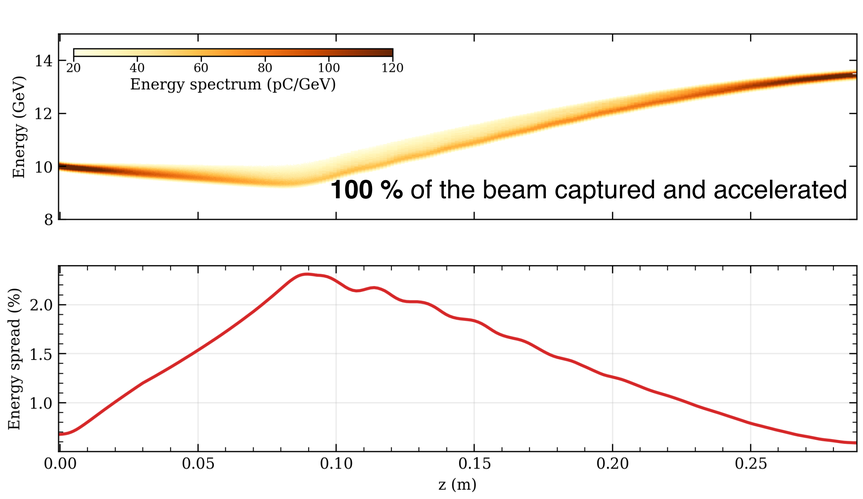
Compatible with beam matching with strong ion motion

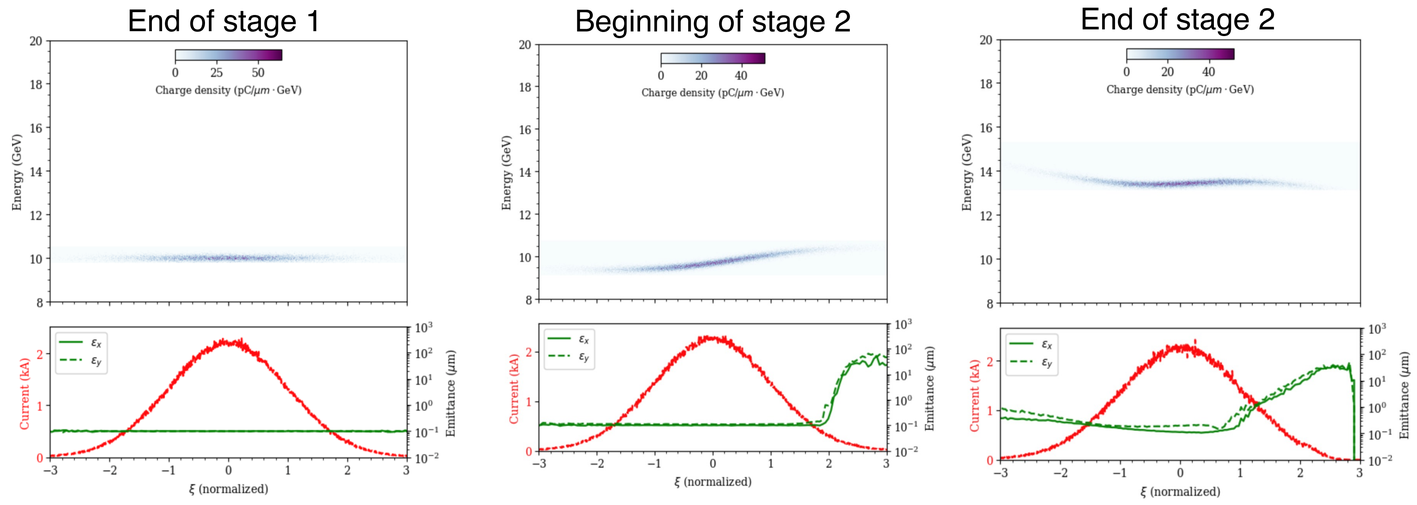


Source: *C. Benedetti et al. Phys. Plasmas 28, 053102 (2021)*

By staying in the plasma, the witness beam can be adiabatically matched to the distorted transverse field caused by ion motion.

3.5 GeV net energy gain with full beam capture from start-to-end 3D PIC simulation





Conclusion

- **3.5 GeV energy gain** achieved within 30 cm.
- **100% capture,** emittance well-preserved within majority of the beam.
- **Compatible with strong ion motion** and adiabatic matching.

Perspectives

- Main challenges are **head erosion** and **laser coupling.**
- Development of **numerical tools** for better performance.
- Next steps to improve **beam loading** and laser coupling.

References
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