Development of a Plasma Cell Target for Higher Repetition Rates in Laser-Plasma Accelerators

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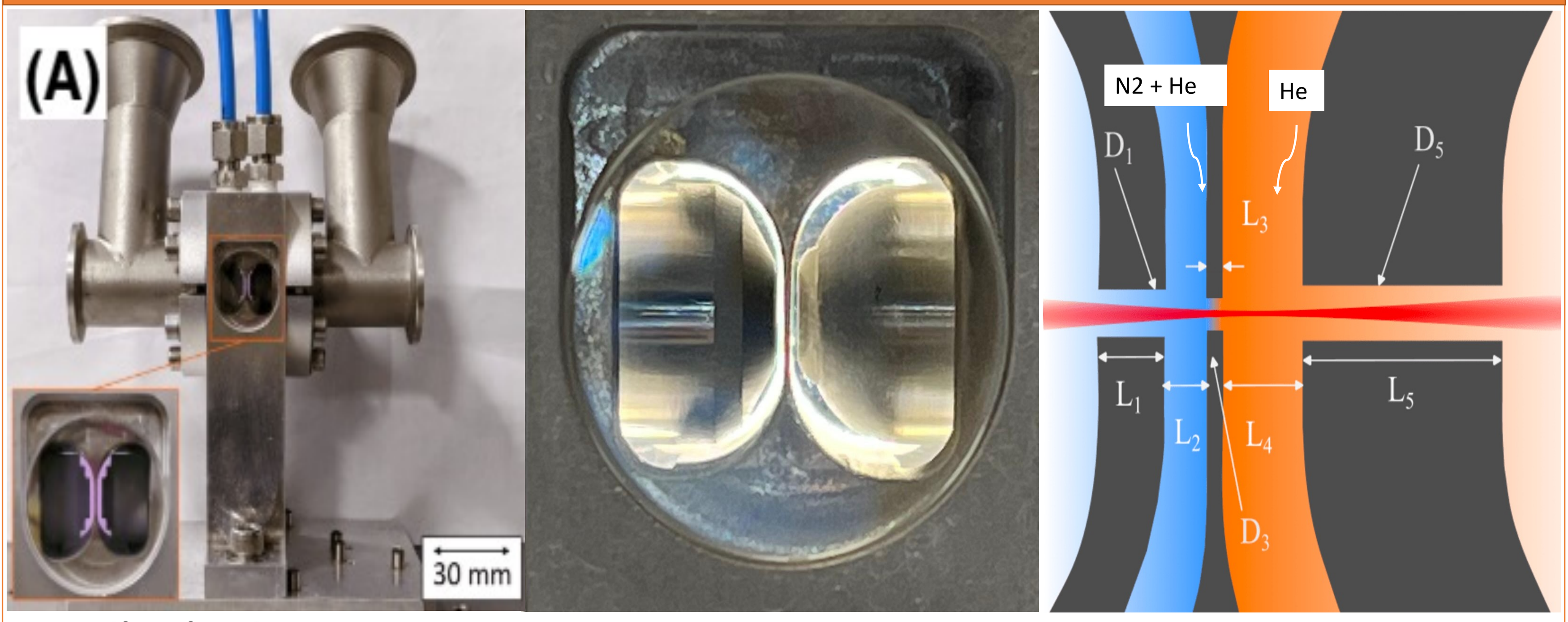
Abstract

The poster presents the development of an advanced plasma target designed for laser-plasma injectors and accelerators, specifically focusing on gas cell targets with spatial confinement of a nitrogen/helium mixture. This design ensures controlled localized ionization injection, leading to high-quality electron beam production.

We compare fluid dynamics simulations with experimental measurements to assess dopant confinement and electron density in the cell. The impact of these characterizations on beam properties is further explored through numerical optimization using the fast PIC simulations carried out with the SMILEI code using envelope approximation and azimuthal mode decomposition of the laser pulse.

❖ First Result from last week in PALLAS

Cell Design

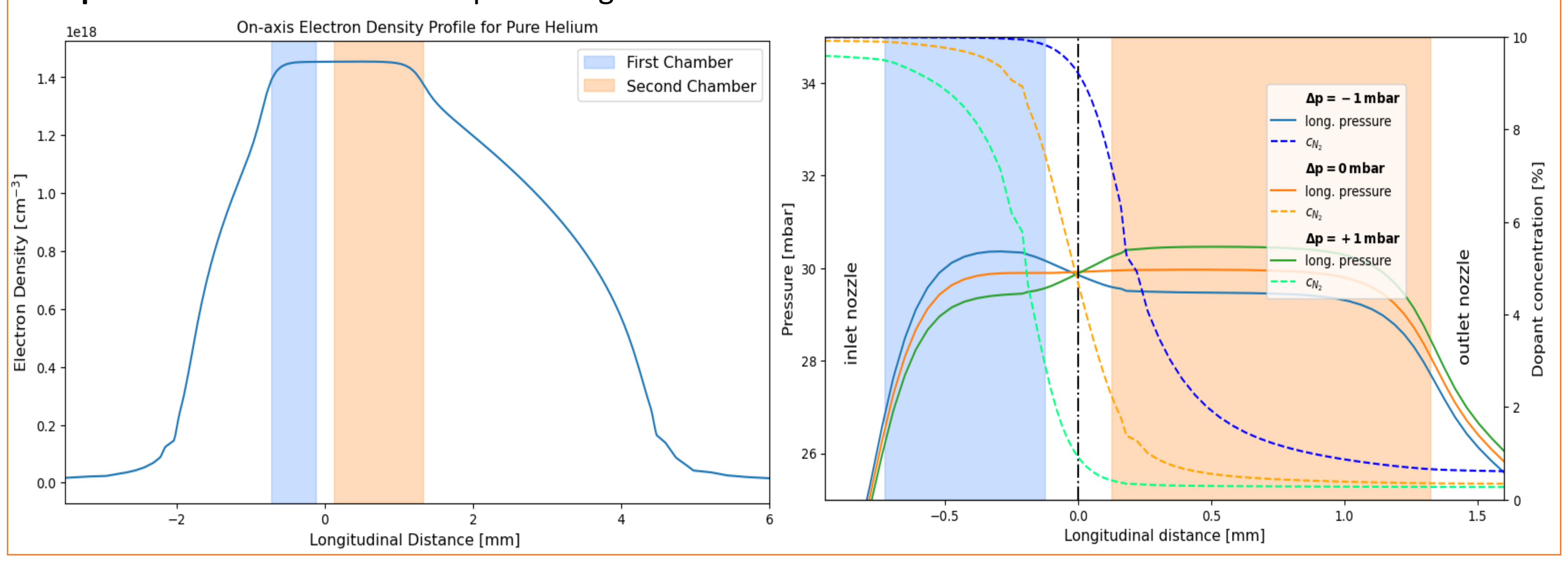


Two-Chamber Gas Target

- **First Chamber:** Ionization injection *(nitrogen–helium mixture)*
- **Second Chamber:** Acceleration *(pure helium)*

CFD Simulations

OpenFOAM simulations to quantify the electron density profile inside the cell.
Dopant localization control via pressure gradients between chambers.



PIC Simulations

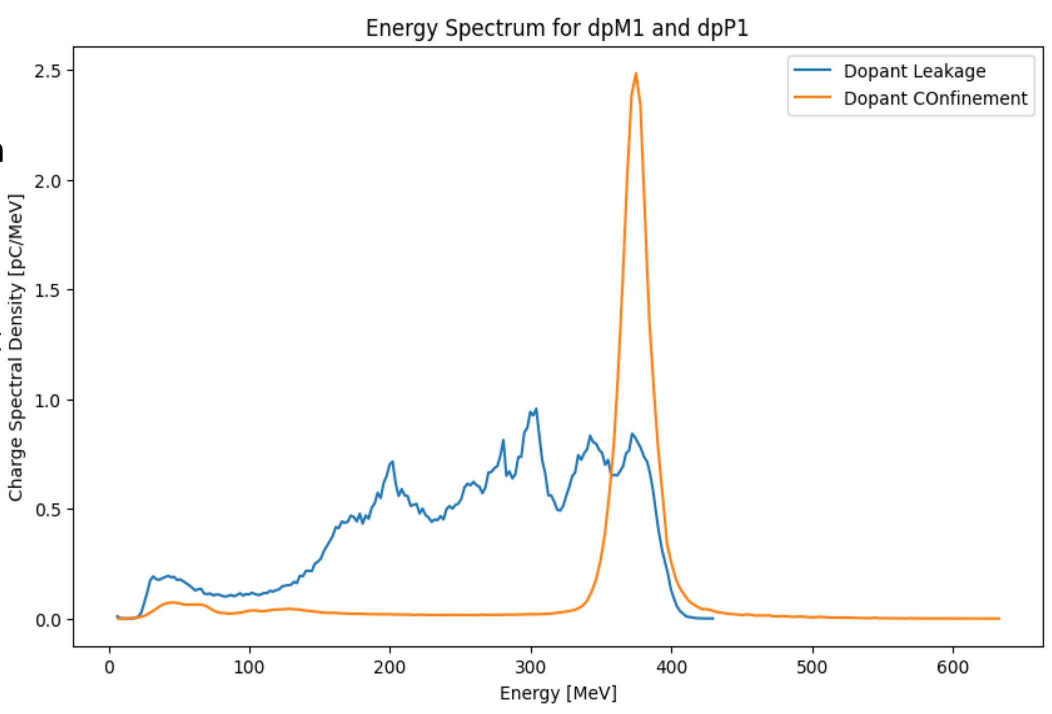
Smilei simulations:

Quantify the effect of dopant localization on the electron beam quality using SMILEI PIC Code.

- ΔP = +1 mbar → Dopant confinement
- ΔP = -1 mbar. → Dopant leakage

Optimized using: Bayesian Optimization (via xopt)

$$f = \frac{\sqrt{q[C]\,E[MeV]}}{\Delta E[\backslash one]}$$



Acknowledgment

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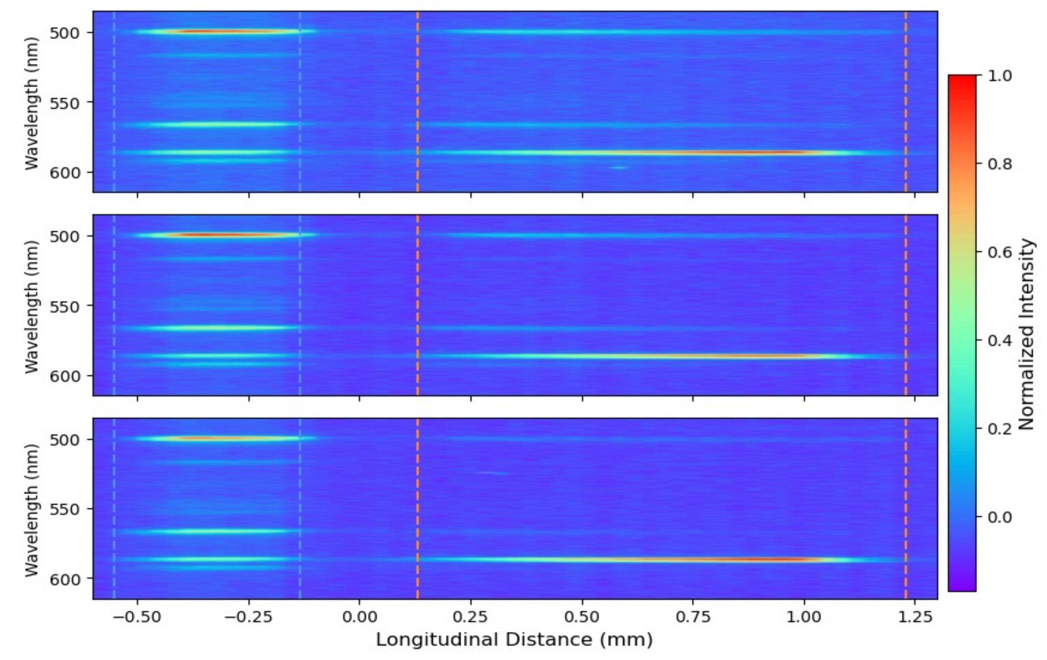
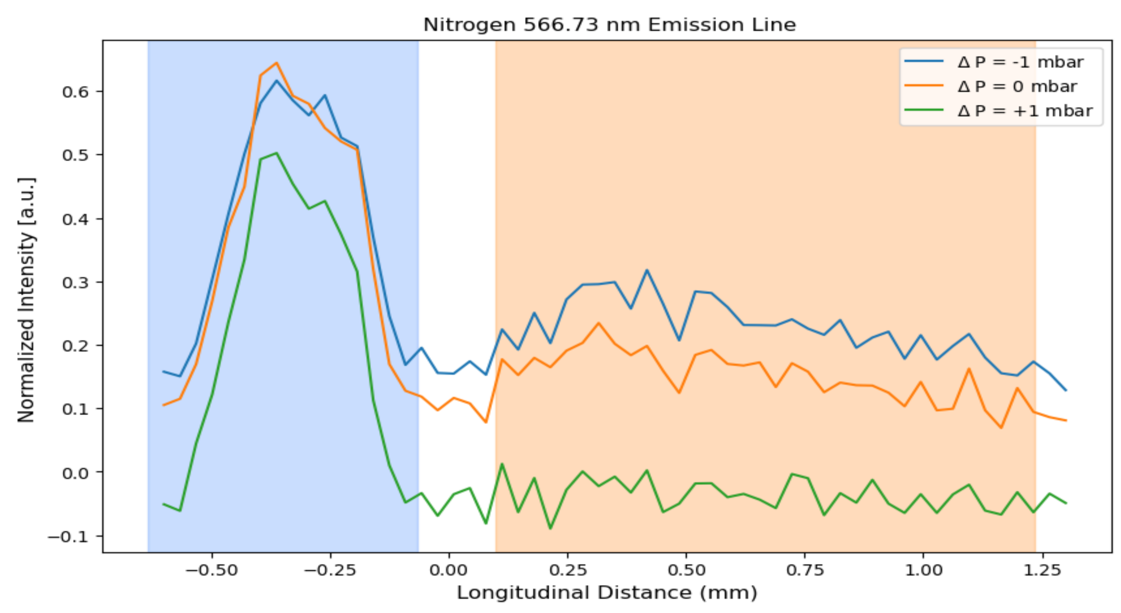
Dopant Confinement

- Experiments performed at 40 mbar with 80% nitrogen concentration.
- High dopant concentration was selected to increase the emission signal on the spectro-camera.
- Results are averaged over 20 frames, with each frame corresponding to a 10-shot accumulation on the CCD.



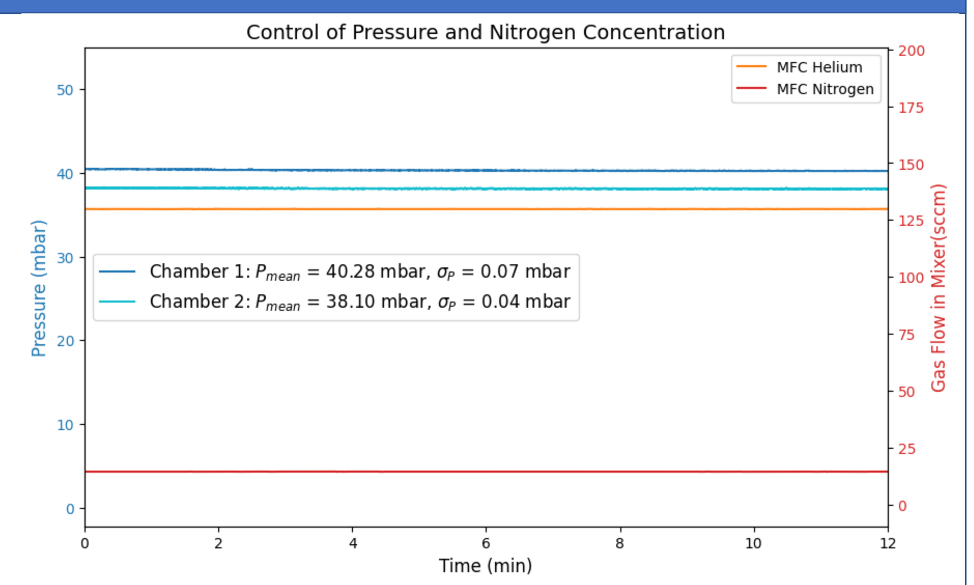
- ➢ **Dopant confinement is monitored by tracking the nitrogen emission line at 566.73 nm.**
- ➢ **Pressure gradient enables control over dopant localization.**



System Control

– Pressure evolution in Chambers 1 and 2
– Mass Flow Controllers (MFCs) for He and N_2 in the mixer
→ Real-time control of dopant concentration.
→ Achieved: c_{N2} = 10.06% . Std = 0.01%

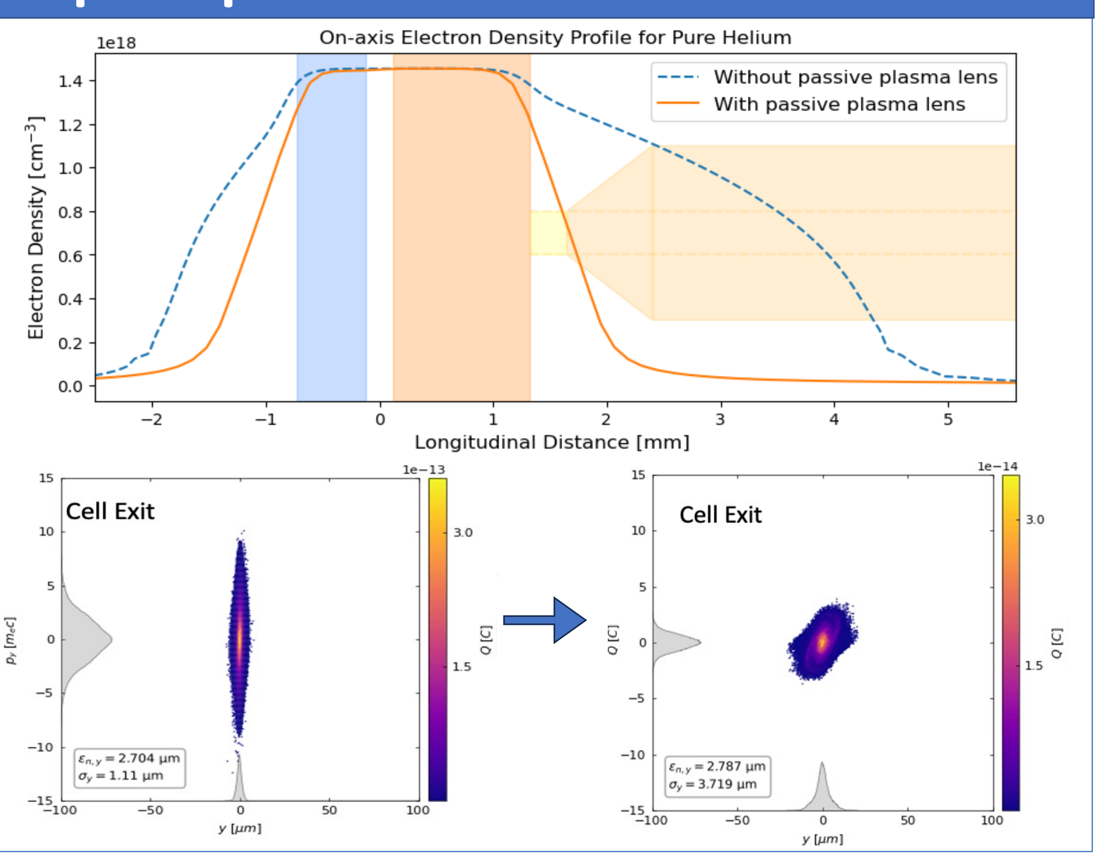
Stable operation over several minutes with precise tuning of nitrogen concentration (c_{N_2}) and pressure.



Outramp Optimization

We integrated a passive plasma lens at the outramp to reduce beam divergence through adiabatic transverse focusing in a beam driven regime.

➢ This ultimately **reduced the divergence by a factor of 2** and **the energy spread.**



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