E-301 Plans for 2024

2023 FACET-II User Meeting

Robert Ariniello / Project Scientist / AARD
October 17-19, 2023
E-301 Overview

- Laser ionized plasma source in a filled chamber
- Semi-arbitrary longitudinal density profile
- Optically accessible
- Permits the use of gas jets along the plasma

PWFA capabilities in a tunable plasma that is physically and optically accessible.
E-301 Science goals

• 10 GeV scale PWFA stage (2-3 years)
  - High energy gain
  - High driver-witness efficiency
  - Low energy spread
  - Full charge transmission
  - Emittance preservation

• Detailed PWFA physics studies (2-3 years)
  - Longitudinal beam dynamics: loading, transformer ratio, efficiency
  - Transverse beam dynamics: chromatic phase mixing, hosing (E-302)

• Platform for other experiments (2-5 years)
  - High brightness beam injection (E304, E307, E31X)
  - Narrow channel electron and positron PWFA (E333)
  - Ion channel laser (E306)

Achieving E-301 science goals enables many other experiments.
E-301 Optical setup

Tandem lens can produce a near arbitrary on axis intensity profile (also have a 0.7° axicon)
Expected plasma – pre-ionized lithium

[Graph and diagrams showing plasma characteristics]
E-301 Expected plasmas

Goal is a fully ionized plasma, as wide as possible.

- Not enough laser energy to get a wide plasma in He.
- Either axicon or tandem lens produces a good H2 plasma.
- The tandem lens delivers almost three times the energy to the target – leads to a wider plasma.
- Bubble size about $\lambda_p = 150 \mu m$ (target width $195 \mu m$)
E-301 Current state - optics

- One set of tandem lens has been made
  - Tested at University of Colorado
  - Performs as expected from simulation
  - Designed for the lithium oven

Optical technique/design software validated
E-301 Recent upgrades

- Two axis mover in the compressor
  - 2D raster scan tandem lens
- Motorized rail camera
- DSHM Near and Far setup
  - Observe broadening due to refraction
E301 Plans for 2023 – Axicon only

- Measure intensity along the focus in-situ
- Ionize H2 and observe broadening of the spot
- Send single bunch through laser-ionized plasma
  - Raster scan the plasma across the electron beam
- Interested in beam ionization in H2 with laser heater
E301 Plans for 2024

- Repeat intensity/ionization measurements with the tandem lens
- Single bunch PWFA studies
  - Drive bunch depletion
  - Beam matching of the tail
- Two bunch (when available) PWFA studies
  - Clean acceleration of the witness

Understand the optical system and electron beam in order to design an optimized lens(es).
E-301 Future evolution

- Extreme beams will ionize the partially ionized plasma ramps
  - Increases emittance growth
- PWFA applications will require a high rep rate plasma source
- Elongated gas jet one potential solution

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**Beam Direction**

J.E. Shrock, Phys. Plasmas 29, 073101 (2022)
Summary

Everything is ready for initial experiments with/without beam

2023:
- Characterize optics with the S20 laser in the tunnel
- Measure plasma refraction effect
- Measure plasma width – raster scan

2024:
- Single bunch PWFA experiments
- Drive beam depletion
- Energy matching of the tail
- Two bunch PWFA – clean acceleration of the witness

E-301 collaboration:
- UCLA: C. Joshi’s group
- SLAC: FACET-II group
- Stony Brook: N. Vafaei-Najafabadi’s group
- Ecole Polytechnique: S. Corde’s group
- University of Oslo: E. Adli’s group
- University of Colorado Boulder: M. Litos group

Ready for e-beam for initial studies
Questions?

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Designed for the FACET laser

Lens A shapes intensity
Lens B shapes phase
Tested with the CU laser

Laser used for tests produces a much shorter focus. Data compared against simulation of test laser.

Lens A shapes intensity
Lens B shapes phase
# 0.7 deg axicon, energy scan H2

## Gas Parameters
- **Gas species:** H2
- **Gas density:** 5.00e16 cm\(^{-3}\)
- **Gas profile:** Filled chamber
- **Gas pressure:** 1.52 Torr

## Laser Parameters
- **Main-amp output:** 800-500mJ
- **Pulse duration:** 55fs FWHM
- **Wavelength:** 800nm
- **Beam size (w0):** 20.24mm
- **Beam profile:** Super-Gaussian

## Laser Energy
- **Energy to mask:** 304-190mJ
- **Energy after mask:** 114-71mJ
- **Energy to ionize:** 2.30-1.04mJ

## Laser refraction simulation
- Split step Fourier based code.
- Energy loss due to ionization.
- No dispersion, no self-focusing.

### LO region starts at z=100mm

<table>
<thead>
<tr>
<th>n_e (10^{16} cm^{-3})</th>
<th>FWHM: 177.6 um</th>
<th>FWHM: 170.1 um</th>
<th>FWHM: 172.9 um</th>
</tr>
</thead>
<tbody>
<tr>
<td>x (μm)</td>
<td>z=349.2 mm</td>
<td>z=602.0 mm</td>
<td>z=850.8 mm</td>
</tr>
</tbody>
</table>

Can still get something even if the laser energy is a bit on the low side.
LO8 tandem lens, density scan H2

Gas Parameters
Gas species: H2
Gas density: 1.70e16-4.50e16 cm⁻³
Gas profile: Filled chamber
Gas pressure: 0.52-1.37 Torr

Laser Parameters
Main-amp output: 800mJ
Pulse duration: 55fs FWHM
Wavelength: 800nm
Beam size (w₀): 20.24mm
Beam profile: Super-Gaussian

Laser Energy
Energy after optics: 276mJ
Energy to ionize: 6.96-20.12mJ

Laser refraction simulation
Split step Fourier based code.
Energy loss due to ionization.
No dispersion, no self-focusing.

LO region starts at z=500mm