ATF Plasma Sources for Wakefield Electron Acceleration


ATF User's Meeting
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Plasma Density Requirements for Plasma Acceleration Experiments at ATF

\[ \omega_p = \sqrt{\frac{4\pi n_e e^2}{m_e}} \]. Plasma frequency

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Plasma Density</th>
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<tbody>
<tr>
<td>Multibunch Resonant PWFA (P. Muggly, et. al.)</td>
<td>(4 \cdot 10^{19} \text{ cm}^{-3})</td>
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<tr>
<td>STELLA-LW (Wayne Kimura, et. al)</td>
<td>(10^{16}-10^{17} \text{ cm}^{-3})</td>
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Plasma Sources at ATF

- Ablative discharge capillary
- Gas-filled capillary
- Gas jet
Ablative capillary can produce plasma with densities: $10^{14} - 10^{17}$ cm$^{-3}$.

The plasma is “made” out of material ablated from the walls of the capillary.

Capillary lifetime is limited.
Plasma Sources: gas-filled discharge capillary

- Plasma concentration: $10^{15} - 10^{18}$ cm$^{-3}$
- Additional density control
- Wide range of available plasma densities
- Simple electrical scheme
- Clean plasma
Plasma Sources: Gas Jet

- Gas concentration: $4 \cdot 10^{19} \text{cm}^{-3}$ (at back pressure: 10 psi, 30 μs gate)
- Gas jet can be used for LWFA or as a target for ion generation experiment
Diagnostics: Stark broadening of atomic hydrogen lines

\[ N_e = C(N_e, T) \cdot \Delta \lambda^{3/2} \]

where \( C(N_e, T) \) is a week function of \( N_e \) and \( T \).

- If the electron temperature is known the accuracy of the plasma density measurements can be 10-20%.
- Balmer \( \alpha \) (656.3 nm) and Balmer \( \beta \) (486.11 nm) are most convenient for observation hydrogen lines.
Dependence of plasma density upon time delay

(a) ablative capillary

(b) gas-filled capillary

- $n_e \text{ cm}^{-3}$
- delay, ns

- $10^{15}$
- $10^{16}$
- $10^{17}$

- Hα
- Hβ

- inserted fiber
- lens collection system
Dependence of the plasma density upon pressure (hybrid capillary)
Frequency domain holography allows to detect transient changes in plasma density. (N. H Maltis et. al. Proceedings AAC06)
Summary

• Plasma sources:
  Ablative capillary; (10^{15}-10^{17} \text{ cm}^{-3})
  Gas-filled capillary; (10^{16}-10^{18} \text{ cm}^{-3})
  Gas jet (0..>10^{19} \text{ cm}^{-3})

• Plasma Diagnostics:
  Stark Broadening Measurements
  Frequency Domain Holography (to be implemented)