Plasma Characterization for the OMEGA Laser–Plasma Interaction Platform

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A laser–plasma interaction platform was activated on OMEGA and the target plasma was characterized with Thomson scattering

- The tunable OMEGA Port 9 (TOP9) system will explore multicolor cross-beam energy transfer (CBET) mitigation strategies with a wavelength tunable (±1-nm), 351-nm UV beam
- Filamentation limited the plasma parameter space in which Thomson scattering was effective
- Imaging Thomson scattering was performed and spatially resolved measurements of plasma conditions were made
- Spatial nonuniformities in the gas-jet plasma were measured and guided the design of new gas-jet nozzles
Collaborators


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TOP9 will explore multicolor CBET mitigation strategies using a wavelength tunable (±1-nm), 351-nm UV beam

- A gas-jet and ten UV heating beams form the plasma before the interaction
  - plasma conditions were measured with Thomson scattering
- By tuning the wavelength of the TOP9 beam, the resonance between the crossed beams will be controlled
  - a N₂ + H₂ gas mix provides tuned Landau damping of ion-acoustic waves
- The transmitted beam diagnostic will measure gain in the CBET interaction with spatial and temporal resolution
The Thomson-Scattering System on OMEGA enabled simultaneous measurements of the electron, ion, and 2-D Thomson features.
Filamentation limits the effectiveness of Thomson scattering in some regimes of plasma conditions and laser parameters.
A fundamental relationship between Thomson-scattering signal to noise and electron temperature was derived using the self-focusing critical power

\[ P_L = P_c = \frac{T_e [\text{keV}]}{3 \times 10^{-8}} \left( \frac{n_c}{n_e} \right) \]

- Thomson scattering:
  \[ P \approx P_L n_e r_0^2 L \, d\Omega \]

- Signal to noise:
  \[ \frac{S}{N} = \frac{P}{\sqrt{P}} = \sqrt{P} \]
  \[ \frac{S}{N} = \sqrt{\frac{T_e [\text{keV}] r_0^2 L \Delta t \, d\Omega}{3 \times 10^2 \lambda hc}} \]
A fundamental relationship between Thomson-scattering signal to noise and electron temperature was derived using the self-focusing critical power.

\[
P_{\text{c(DPP)}} = \frac{10^{13} A}{\lambda^2} \left( \frac{n_c}{n_e} \right) \left( \frac{T_e \text{[keV]}}{3} \right) (8 f\#)^2
\]

- Thomson scattering:
  \[P \approx P_L n_e r_0^2 L \, d\Omega\]

- Signal to noise:
  \[
  \frac{S}{N} = \frac{P}{\sqrt{P}} = \sqrt{P}
  \]
  \[
  \frac{S}{N} = \sqrt{\frac{r_0^2 L \Delta t \, d\Omega}{hc}} \cdot \frac{10^{12} A}{\lambda^2} \left( \frac{n_c}{n_e} \right) \left( \frac{T_e \text{[keV]}}{3} \right) \left( \frac{8 f\#}{8} \right)^2
  \]

A 200-\(\mu\text{m}\)-diam phase plate was used to improve propagation.

Gaussian beam

200-\(\mu\text{m}\)-diam phase plate
Analysis of the ion feature shows variations in temperature across the plasma.
Large variations in density were measured across the gas-jet plasma using the electron feature.
By varying the delay on the 100-ps Thomson probe, variations in the gas-jet plasma were observed to evolve over time.

Density perturbations are caused by neutral density flow properties in the supersonic nozzle.
A new, longer-nozzle design was implemented to improve density uniformity.
Thomson-scattering data demonstrate the density uniformity provided by the long nozzle design.
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