Measurements of ion species separation using Thomson scattering

Presentation to
Kinetic Physics Workshop

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Summary

• Thomson scattering provides a local, time resolved measurement of plasma conditions (Te, Ne, flow)

• It can also be used to characterize ion species fractions for certain plasma regimes (small fraction of high-Z material in a low-Z plasma)

• The ion species fraction was measured for a CH laser ablated plasma

• The plasma is observed to be hydrogen rich at early times
We create a high velocity plasma flow by irradiating a CH$_2$ foil target with 10 beams from the Omega Laser.

Heater beams are on for 1 ns and deliver 5 kJ to target.

Drive Beams: 10
Spot Size: ~250 μm

Timing

Probe Beam

Heater Beams

0 ns
1 ns
2 ns
3 ns
4 ns
5 ns
6 ns
7 ns
8 ns
We create a high velocity plasma flow by irradiating a CH₂ foil target with 10 beams from the Omega Laser.

The plasma expands at high speed (> $10^7$ cm/s)

Timing

- Probe Beam
- Heater Beams

- 0 ns
- 1 ns
- 2 ns
- 3 ns
- 4 ns
- 5 ns
- 6 ns
- 7 ns
- 8 ns

CH₂ Foil

plasma

2 mm

4 mm

Thomson Scattering Volume
We create a high velocity plasma flow by irradiating a CH$_2$ foil target with 10 beams from the Omega Laser.

$2\omega$ Thomson Scattering data provides $n_e$, $T_e$, $T_i$, $v$ measurements.

Thomson scattering looks at plasma waves along the $k$-vector ($k_a$).
Collective Thomson scattering from ion-acoustic and electron-plasma waves is used to measure the plasma conditions.

Thomson scattering is the scattering of an electromagnetic wave by free electrons.

$$S(k, \omega) = \frac{2\pi}{k} \left[ 1 - \frac{\chi_e}{\varepsilon} \right]^2 f_e \left( \frac{\omega}{k} \right) + \frac{2\pi Z}{k} |\chi_e|^2 f_i \left( \frac{\omega}{k} \right)$$

Optical Laser ($\lambda_0$)
Single foil evolution is consistent with adiabatic expansion with velocities between $15 - 5 \times 10^7$ cm/s and $n_e \sim 4 \times 10^{18}$ cm$^{-3}$

The wavelength shift from the incident wavelength ($\lambda_0$) is a measure of the flow velocity.

The wavelength shift between the peaks is a measure of the electron density.

$V \sim 5 \times 10^7$ cm/s

$V \sim 1.5 \times 10^8$ cm/s

$n_e \sim 3 \times 10^{18}$ cm$^{-3}$

$n_e \sim 4 \times 10^{18}$ cm$^{-3}$
Scattering from the electron feature is used to measure the electron temperature and density.

- $T_e = 100$ eV, $n_e = 5.6 \times 10^{18}$ cm$^{-3}$
- $T_e = 75$ eV, $n_e = 6.6 \times 10^{18}$ cm$^{-3}$
- $T_e = 125$ eV
These measurements are only possible because $n_e$ and $T_e$ are constrained by the electron feature.
An increased Hydrogen percentage is measured in the Thomson scattering volume at early times.

The ion feature can be used to measure the ion species fraction and ion temperature.

- $t = 3.0$ ns
- C/H ~ 0.08
- $T_i = 60$ eV

- $t = 8.0$ ns
- C/H = 0.33
- $T_i = 30$ eV

The electron temperature and density are measured using the electron feature.
Summary and future work

• Thomson scattering provides a local, time resolved measurement of plasma conditions ($T_e$, $N_e$, flow)

• It can also be used to characterize ion species fractions for certain plasma regimes (small fraction of high-Z material in a low-Z plasma)

• The ion species fraction was measured for a CH laser ablated plasma

• The plasma is observed to be hydrogen rich at early times

• This technique can also be used to characterize interpenetrating flows which will be discussed by S. Le Pape in the next talk