Heat-Flux Measurements from Thomson-Scattering Spectra

Heat flux at $t = 2.5$ ns

$\frac{q_{TS}}{q_{fs}}$ vs. Distance from target ($\mu$m)

- $q_{TS}$
- $q_{SH} = -\kappa \nabla T_e$

R. J. Henchen
University of Rochester
Laboratory for Laser Energetics

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Thomson scattering from ion-acoustic waves (IAW’s) and electron plasma waves (EPW’s) were used to measure heat flux in coronal plasmas

- Changes in Landau damping caused by heat flux were seen in the relative amplitudes of Thomson-scattering spectra from IAW’s and EPW’s
- Local plasma conditions obtained from Thomson scattering provide an independent measurement of the heat flux using the Spitzer–Härm (SH) thermal-transport model
- The two methods of measuring the heat flux are in good agreement over the locations probed

University of Rochester
Laboratory for Laser Energetics

W. Rozmus

University of Alberta
An experiment was designed to test Spitzer–Härm thermal transport in laser produced coronal plasmas.

These experiments measured the heat flux, electron temperature, and density as a function of space in a coronal plasma.
Collective Thomson scattering can measure the heat flux and the local plasma conditions

\[ P_s \propto \left( 1 + \frac{2\omega}{\omega_1} \right) S(k, \omega) \]

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

\[ \chi_e = \int_{-\infty}^{\infty} dv \frac{4\pi e^2 n_e}{m_e k^2} \frac{k \cdot \frac{\partial f_e}{\partial v}}{\omega - k \cdot v - i\gamma} \]

\[ f_e = f_0 + f_1^{SH} \]
Changes in the electron distribution function caused by heat flux affects the scattering spectrum of Thomson scattering from EPW’s

Effect of heat flux on electron distribution function

Effect of heat flux on EPW scattering feature ($q/q_{fs} = 0.035$)

$$f_e (\text{arbitrary units})$$

$$f_0, f_{e}^{\text{SH}}$$

$$v_{\phi}/v_{te}$$

$$P_s (\text{normalized})$$

$$f_0, f_{e}^{\text{SH}} = f_0 + f_1^{\text{SH}}$$
Thomson scattering was used to measure the heat flux, electron temperature, and electron density in coronal plasmas.

Thomson scattering (TS) provides local measurements of $T_e$, $n_e$, and $q$ in a $50 \times 50 \times 50$-μm$^3$ volume.

- Probing five different locations provides values for $\nabla T_e$
- An independent measure of $q$ is obtained from $T_e$, $n_e$, and $\nabla T_e$

Thomson scattering provides two separate measurements of heat flux by probing plasma waves along the direction of the temperature gradient.
The up- and down-shifted EPW features were measured with a large signal-to-noise.
Thomson-scattering spectra obtained at five locations in the corona were used to measure heat flux.
The scattering spectra are fit to determine the electron temperature and density.
The electron temperature and density measurements are used to infer the heat flux.
The relative amplitudes of the EPW scattering features were used to measure heat flux.

EPW lineout, 1100 μm from target, $t = 2.5$ ns

- Data lineout
- $q = 0$
- $q = 0.015 q_{fs}$

$T_e = 1.1$ keV
$n_e = 1.19 \times 10^{20} \text{ cm}^{-3}$

EPW lineout, 1500 μm from target, $t = 2.5$ ns

- Data lineout
- $q = 0$
- $q = 0.043 q_{fs}$

$T_e = 1.0$ keV
$n_e = 5.2 \times 10^{19} \text{ cm}^{-3}$
The heat-flux values obtained by matching electron feature amplitudes are in good agreement with the temperature gradient measurements.
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