Heat-Flux Measurements in Laser-Produced Plasmas Using Thomson Scattering from Electron Plasma Waves

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Heat flux at t = 2 ns

\[ \dot{q}_{SH} = -k \nabla T_e \]

3\( \omega \) drive beams
(2 ns, \( 1.3 \times 10^{14} \) W/cm\(^2\))

TS collection

Heat flux at t = 2 ns

Heat flux at t = 2 ns

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Thomson scattering from ion-acoustic waves (IAW’s) and electron plasma waves (EPW’s) were used to measure the 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.
- Heat-flux measurements indicate the SH model is not valid and nonlocal effects are present.
- Fokker–Planck simulations recover values obtained from measuring changes in Thomson-scattering spectra from EPW’s resulting from heat flux.
Collaborators

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Changes in the electron distribution function caused by heat flux affect the Thomson-scattering spectrum from EPW’s.
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 $50 \times 50 \times 50$-$\mu$m$^3$ volume.

Probing five different locations provides values for $\nabla T_e$.

$q_{SH}$ was determined by measuring $T_e, n_e,$ and $\nabla T_e$.

Thomson scattering provides two separate measurements of heat flux by probing plasma waves along the direction of the temperature gradient.
Thomson-scattering spectra obtained at five locations in the corona were used to measure the 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.
The two methods of measuring heat flux are not consistent

Heat flux at $t = 2\text{ns}$

$$q_{TS}$$

$$q_{SH} = -\kappa \nabla T_e$$
Measurements of the mean free path and temperature scale suggest that classic thermal transport (SH) is not valid.

The SH model breaks down at $v_\phi = 4v_{Te}$ when $\lambda_{ei}/L_T = 0.004$. 
Heat-flux values from Fokker–Planck simulations* are obtained using measured plasma profiles

Electron temperature and density profiles in Fokker–Planck simulations

Heat flux from Fokker–Planck simulations

Heat-flux values from Fokker–Planck simulations* are obtained using measured plasma profiles (continued)

Heat-flux values from Fokker–Planck simulations agree with measured values from non-Maxwellian electron distribution functions

Electron temperature and density profiles in Fokker–Planck simulations

Heat flux at $t = 2$ ns

Thomson scattering from ion-acoustic waves (IAW’s) and electron plasma waves (EPW’s) were used to measure the 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. Heat-flux measurements indicate the SH model is not valid and nonlocal effects are present. Fokker–Planck simulations recover values obtained from measuring changes in Thomson-scattering spectra from EPW’s resulting from heat flux.