Data Analysis for Temperature Measurement of Dense Plasma

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Introduction

It is essential to have a thorough grasp of the energy exchange process between the ion and electron subsystems to fully comprehend dense plasmas. It is absolutely crucial in laboratory investigations, where the energy is typically stored in the electron subsystem, which eventually reaches local thermal equilibrium by settling into equilibrium with the ions. It has been difficult to directly detect the ion temperature in dense plasmas, which makes it difficult to estimate the time. We can fully understand the equilibration process and compare it to commonly used theoretical models by simultaneously measuring the electron temperature. My work is concentrated on measuring the width of the ion distribution curve and derivation of temperature from the measured width.

Research

A two-temperature model has the following structure is commonly used to describe the interaction between electrons and ions:

$$C_e \frac{dT_e}{dt} = -g_{ei}(T_e - T_i) + S(t)$$

$$C_i \frac{dT_i}{dt} = g_{ei}(T_e - T_i).$$

The solutions of the above two equations can be demonstrated in fig 1.

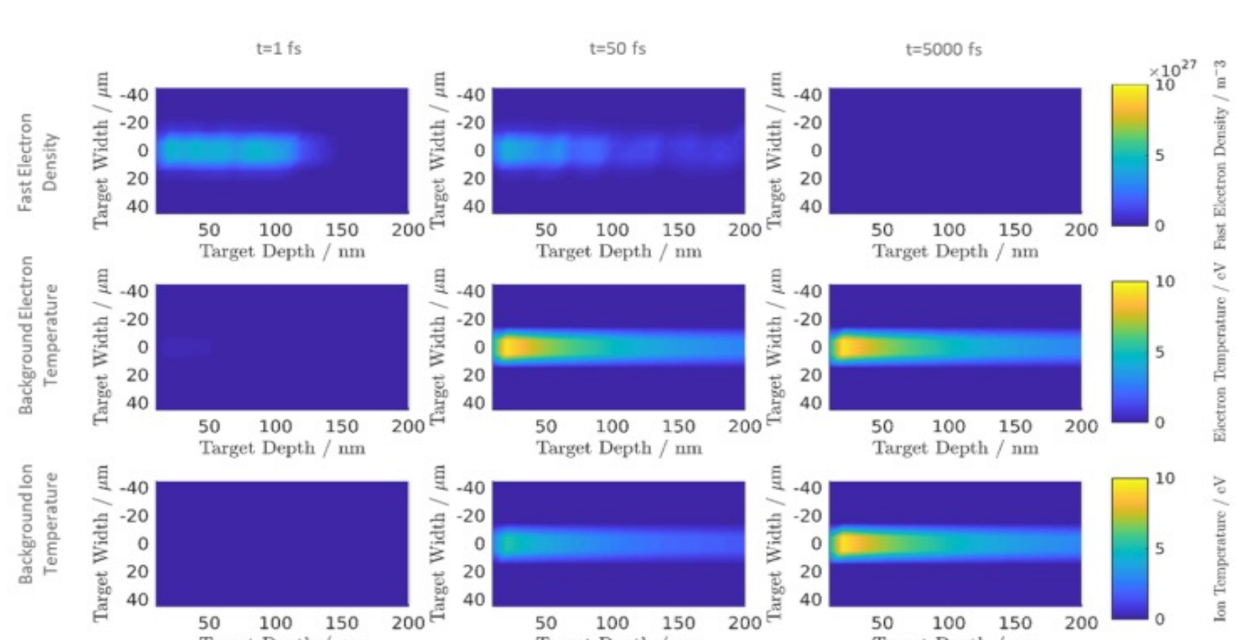
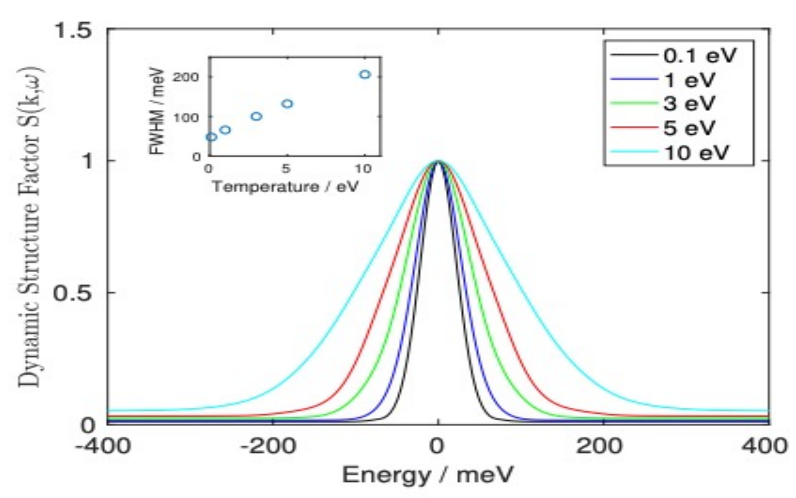


Fig 1 The figures demonstrate an energy cascade from fast electrons to background electrons that takes place over a time scale of tens of femtoseconds. The energy is then transferred on a picosecond timescale from the background electrons to the ions. (Reference: Measuring the Electron-Ion Equilibration in Dense Plasmas-LCLS Proposal)

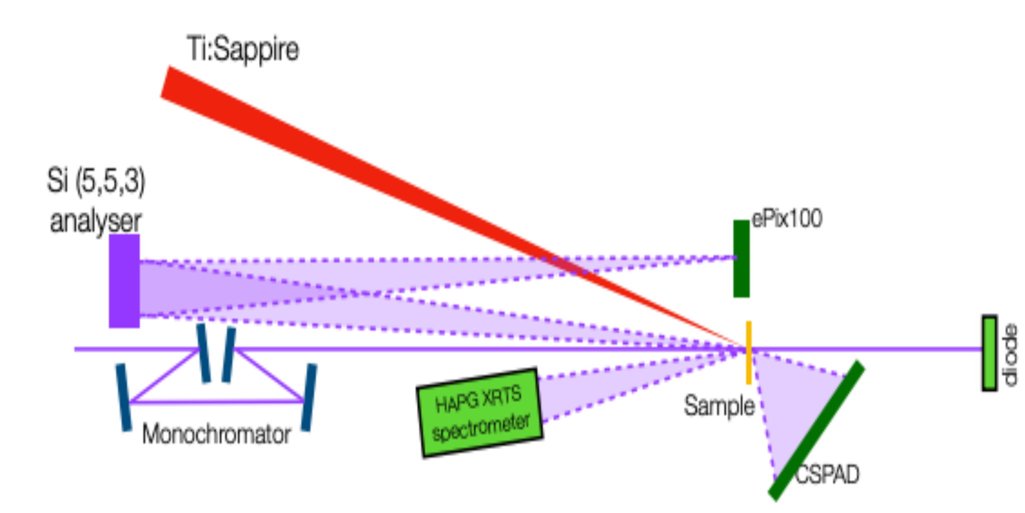
Doppler broadening and change in width with change in temperature



- Fig 2 The above figure shows the prediction curve of dynamic structure factor of ions (left hand side) and angularly resolved scattering curve(right hand side). The temperature range is 0.1-10 eV. The initial X-ray energy is assumed to be 7.4 keV.
- We display a simulation of the ion Thomson scattering peak of Au between 0.1 and 10 eV in temperature. As can be observed, the Doppler broadening requires a spectral resolution of at least 100 meV.

(Reference: Measuring the Electron-Ion Equilibration in Dense Plasmas-LCLS Proposal)

Experimental Set-up



- Fig 3-The Au or Ag target, with a thickness of around 50 nm, is the target of a short pulse Ti:Sapphire laser focussed to a 100 micron spot.
- We only require about 100 mJ of laser energy to heat these targets to 10 eV–100 eV using relatively low laser intensities (10^{14}–10^{16} W/cm^2).
- A 400 nm frequency doubled beam would be ideal to enhance laser coupling to the target, although it is not essential.

Results and Discussions (based on the energy values from the experiment)

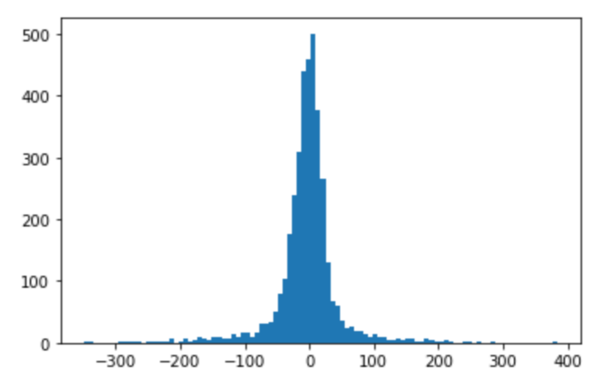


Fig 4

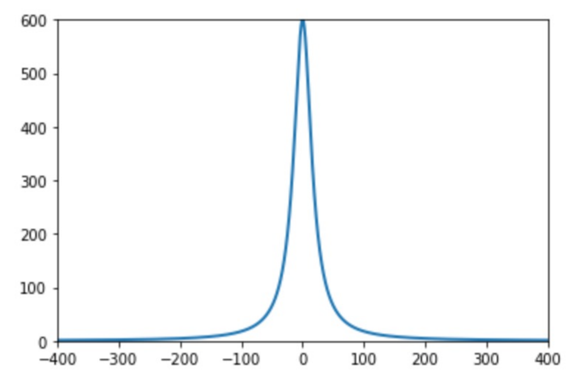


Fig 5

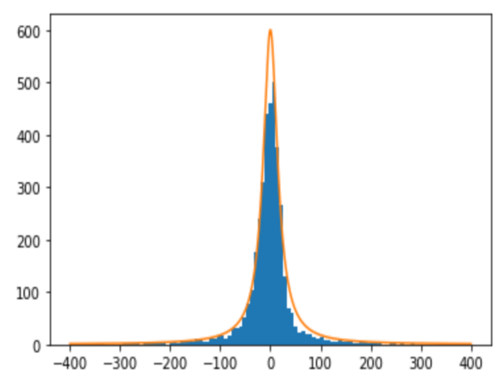


Fig 6

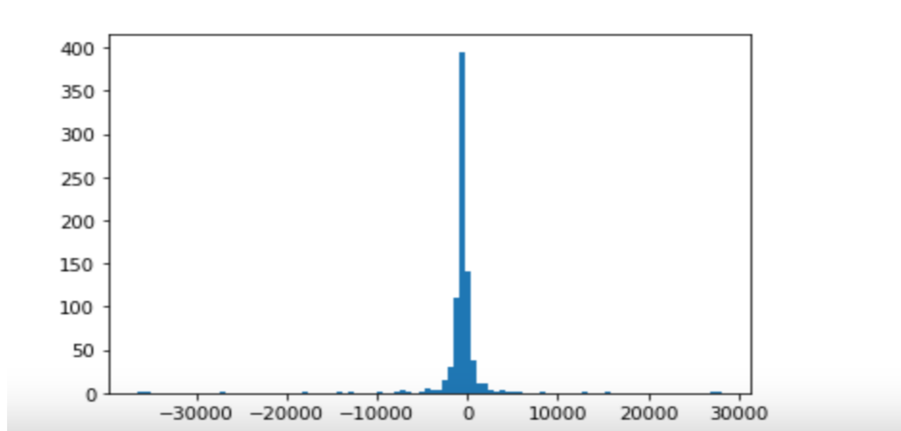


Fig 7

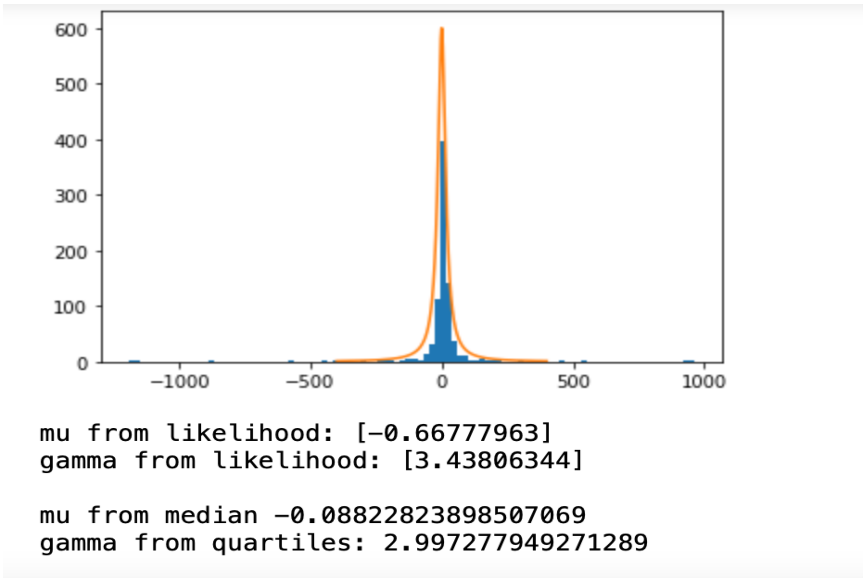


Fig 8

The x-axis denotes the data counts and the y-axis depicts the number of bins for graphs (Fig 4-Fig 8).
Fig 4 depicts the histogram based on the data provided by the experiment.
Fig 5 depicts the Lorentz distribution curve based on the data provided by the experiment.
Fig 6 shows the histogram is not fit inside the Lorentz distribution curve.
Fig 7 Histogram graph after changing the values for mu and gamma (for proper fit).
Fig 8 shows the histogram is fit inside the Lorentz distribution curve (which will give us the value for width).

Conclusion

High-resolution meV scattering will be used to measure the development of Ti from the broadening of the Rayleigh peak. The expansion of the Compton peak will provide information about Te's evolution. We observe that the angularly-resolved scattering data, albeit model dependent, will reveal information on the ion-ion potential and consequently the ionization percentage when the ion temperature is provided by the meV scattering and the density is restricted to solid.

Acknowledgements

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