Probing plasma temperature and density using Optical Thomson Scattering on FuZE

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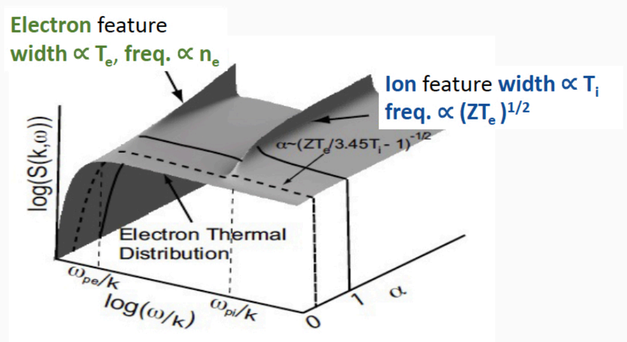
*We developed a **transportable Thomson scattering** diagnostic to **quantify plasma conditions** on experiments supported by ARPA-E. We present the first measurements from our diagnostic during its deployment in support of Zap Energy Inc.*

- *Diagnostic can **provide electron density and temperature** as shown here for the FuZE device*
- *Setup **can be transported to another facility***
- *Our team combines expertise in pulsed power, optical diagnostics and high energy density plasmas.*

Probing plasma conditions using Thomson Scattering

Thomson scattered signal of a probe laser is sensitive to the temperature and density of electrons and ions inside a plasma as well as flow velocity along one direction



Spectral density function of scattered signal[1,2] as a function of frequency and the alpha parameter, $\alpha = 1/k\lambda De$ where is the Debye length in the plasma and k the wave number.

[1]S. Ross Rev. Sci. Instr. **81**, 10D523 (2010)
[2]J. Sheffield, D. Froula, S. H. Glenzer and N. C. Luhman *Plasma Scattering of Electromagnetic Radiation: Theory and Measurement techniques* (Academic Press, 2010) p104

Our team has been funded to implement a Thomson scattering system for Inertial or magneto-inertial confinement fusion experiments. The table below shows the specifications of the diagnostic.

Plasma parameter We can resolve	$n_e > 2.10^{17}$ cm^{-3} and T_e, T_i > 100 eV
Time Resolution	Nanosecond resolution
Spatial Resolution	Collect up to 17 signals each from a localized volume (<mm^3) inside plasma
Set-up time	~1 week
Minimum time for a measurement	~2 weeks to first data

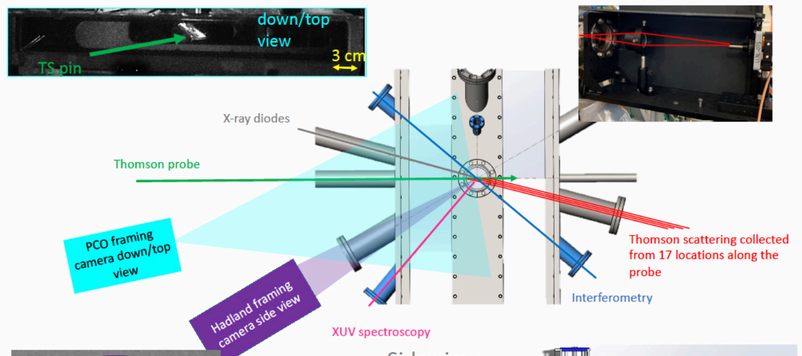
Deployment on the FuZE experiment

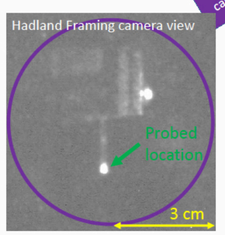
The Thomson scattering diagnostics **fits on a 4x8' table** supporting:

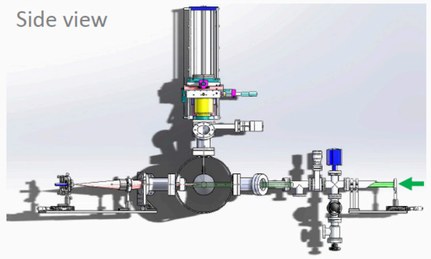
- the probe laser and periscope to reach plasma height
- the optics coupling collected light inside the spectrometer
- the time-gated camera (down to 2 ns gate)

The table can be wheeled away from the device to protect instruments from EMI

Custom flanges were designed to **allow many concurrent diagnostics**: X-ray diodes, interferometry, UV spectroscopy and optical imaging

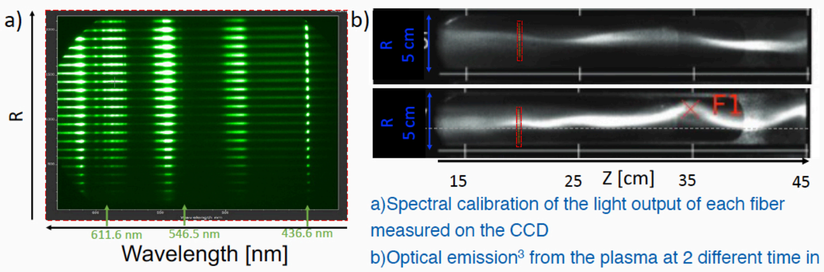






Each fiber **collects from 17 different radial location** in the plasma:

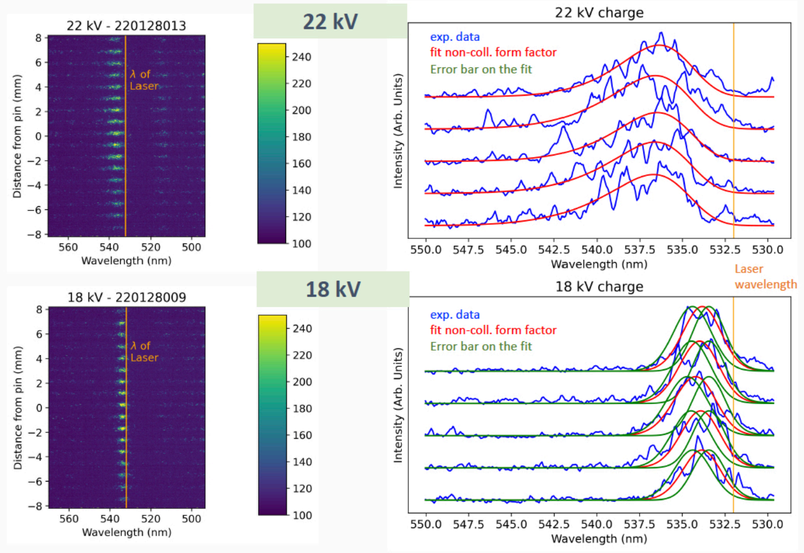
- Provides a 16 mm field of view along the laser
- helps to account for the plasma column "wiggles"



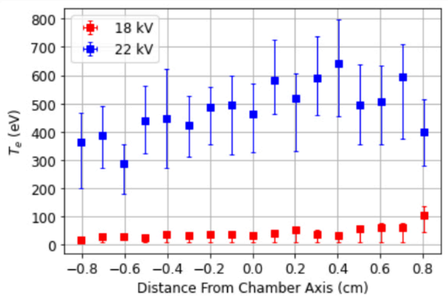
a)Spectral calibration of the light output of each fiber measured on the CCD
b)Optical emission[3] from the plasma at 2 different time in the implosion [3]Stepanov, A. D. et al. *Physics of Plasmas*, *27*(11), 2020

First Thomson scattering data

We use a **small scattering angle** to maximize the signal as well as the sensitivity. We show the **red-shifted peak** of the **EPW** for two different charge voltages reached on the FuZE device. Laser wavelength is blocked using a notch filter.



1) EPW features for all the fibers from the 22kV shots with 2) corresponding spectral lineouts. 3) EPW features for all the fibers from the 18kV shots with 4) corresponding spectral lineouts



Estimated temperature at each fiber position for 18kV and 22 kV shots

- Signal consistent with Thomson scattering
- 300 eV < T_e < 650 eV
- $n_e < 2.10^{17}$ cm^{-3}
- Estimated electron temperature increases with charge voltage
- Electron density is below diagnostic resolution

Conclusion

We successfully designed and deployed a Thomson Scattering Diagnostic suitable for High energy density experiment on FuZE.

- Preliminary **data consistent with Thomson scattering** on the FuZE device.
- Planning a second set of measurements to validate interferometry and X-ray measurements.
- Building a 2nd spectrometer/Camera assembly to **measure the electron and ion feature simultaneously**

Our team can provide optical Thomson scattering to probe n_e, T_e, or T_i at several locations along the plasma

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