SPECTROSCOPIC MEASUREMENTS OF NON-MAXWELLIAN AND ANISOTROPIC FEATURES OF THE ION DISTRIBUTION FUNCTION IN H-1 HELIAC

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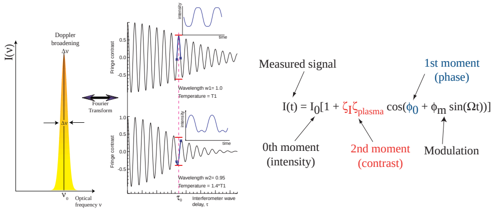
COHERENCE MEASUREMENTS WITH MOSS

The Modulated optical Solid State spectrometer (MOSS) is a fixed delay optical Fourier transform spectrometer. It can measures the light intensity, spectral width and centre frequency, by monitoring the coherence (fringe contrast and phase) at one fixed delay. The centre frequency (phase) conveys the ion flow speed, and , assuming that the distribution function is Maxwellian, a temperature can be determined from the contrast.

The measured contrast and phase is related to the lineshape by the Fourier transform:

$$\underbrace{\zeta(\tau)}_{\text{contrast}}e^{\overset{\text{phase}}{i\phi(\tau)}} = \underbrace{\Gamma(\tau)}_{\text{coherence}} = F\left(\overset{\text{lineshape (aka distribution function}}{I(\nu)}\right)$$

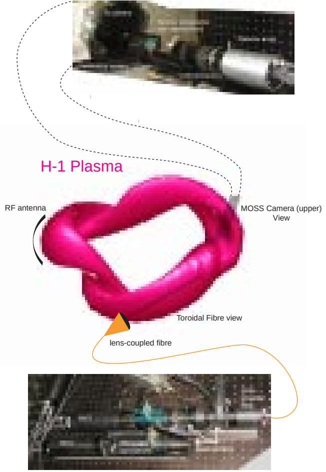
The following figures illustrate the measurement principle:



MOSS DIAGNOSTICS ON H-1

The MOSS spectrometer is a pockels cell, consisting of an electro-optic, birefringent, modulated wave-plate, polarises and an interference filter to select the line of interest [1]

MOSS CAMERA:
- Channels: 32
- Coverage: Entire plasma cross section
- Direct View.
- Waveplates can be added between shots



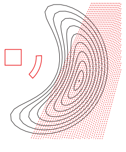
FIBRE-COUPLED SINGLE-CHANNEL Dual MOSS
The incoming light is separated into two separate waveplates, each of different delay, to check the distribution function.
- Waveplates: fixed (not changed between shots)

THE MOSS CAMERA images a poloidal cross-sectional view of the plasma, as shown below. This instrument is sensitive to the temperature and flow mostly **PERPENDICULAR** to the magnetic field.

A **FIBRE COUPLED MOSS** system views a single chord running through the entire plasma cross section, in a direction mostly **PARALLEL** to the magnetic field.

With the two diagnostics operated together, it is possible to measure the **ISOTROPY** of the distribution function, by comparing poloidal and toroidal temperatures.

LINE-INTEGRATION EFFECT



View of plasma poloidal cross section

MOSS measures the contrast weighted by light emission. The light emission profiles are always PEAKED near centre. Therefore,

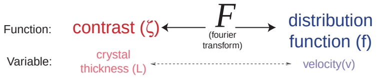
◆ Edge channels convey only edge temperature (centre is bypassed)
◆ Channels which view through the central regions of the plasma convey this more as the light emission is stronger in the centre.
◆ The details of the profile are unimportant because the contrast/temperature profiles are only weakly varying with radius

ABSTRACT

In this poster, we show recent results from coherence imaging spectroscopic systems on H-1, examining the ion distribution function in low-field (B<0.15T) Argon discharges (recall poster 580 on monday by J. Howard for further information). Strong non-Maxwellian features and anisotropic characteristics have been found. Specifically, most of the measured distribution functions can be fitted to a “two temperature” maxwellian incorporating both a hot and minority (20%) cold population.
The cold component of the distribution function has a larger proportion at the edge, which is consistent with the explaination that it is caused by charge exchange with neutrals.
The parallel ion temperature is smaller than the perpendicular component at lower background fill pressures and at higher magnetic fields, which may indicate that the heating mechanism drives the perpendicular component preferentially.

EXPERIMENT

Measurements of contrast were made with the MOSS camera at different crystal thicknesses, in order to test whether the distribution function was Maxwellian.



Function: contrast (ζ) ← F (fourier transform) → distribution function (f)
Variable: crystal thickness (L) ←------→ velocity(v)

Crystals were interchanged in between shots, so that by relying on shot-to-shot reproducibility, a spatial map of the distribution function could be made.

For a Maxwellian distribution, f(v) is a Gaussian. Therefore ζ(L) is gaussian.

However, in some instances, a gaussian fits the data poorly. Here a “two temperature” Maxwellian was fitted:

$$\zeta = e^{-\frac{L^2}{w^2}} \quad \text{Single Gaussian}$$

$$\zeta = (1-\alpha)e^{-\frac{L^2}{w_1^{\,2}}} + \alpha e^{-\frac{L^2}{w_2^{\,2}}} \quad \text{Double Gaussian (two temperatures)}$$

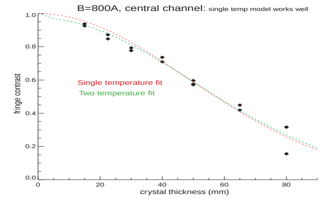
The “characteristic widths” can are converted to temperatures, according to:

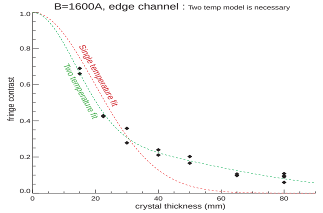
$$T_i = \frac{\lambda^2 m_i^{\,2} c^2}{B^2 k_B} w^{-2}$$

Therefore,
*** HOT IONS ==> SMALL LENGTH SCALE**
*** COLD IONS ==> LARGE LENGTH SCALE**

Most of the data show a “Tail” in the coherence curve ζ(L), implying the existence of a cold component.

The applicability of each model is shown by the following data:





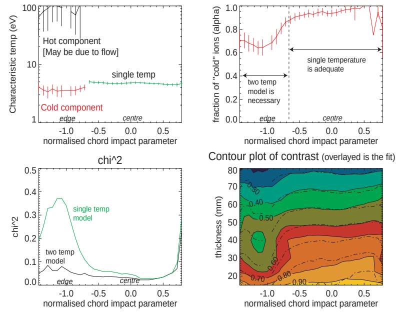
NON-MAXWELLIAN FEATURES

Shown below are a series graphs showing profiles of temperature, the chisq (residual error) of the fit to each model and the contrast. The applicability a single or double gaussian fit can be judged by:

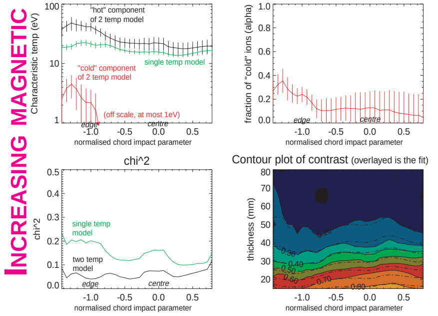
- Looking at the fraction of cold/hot ions “alpha” (close to 1 or 0 implies that a single temperature description is adequate)
- Examining the chi-squared residual. When the chi^2 for a two-temperature model is not much better than that of a one-temperature model, a single temperature is all that is necessary to characterise the distribution. Note that the chi^2 does not go to zero because of the scatter in the data (shot-to-shot reproducibility)

INCREASING MAGNETIC FIELD

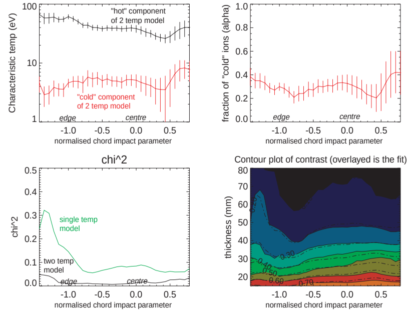
B=800A @ t=7.2ms: single and double temp behaviours



B=1200A,fl=3 @ t=7.2: two temp model works best
(although a single temp model may be adequate in central regions)



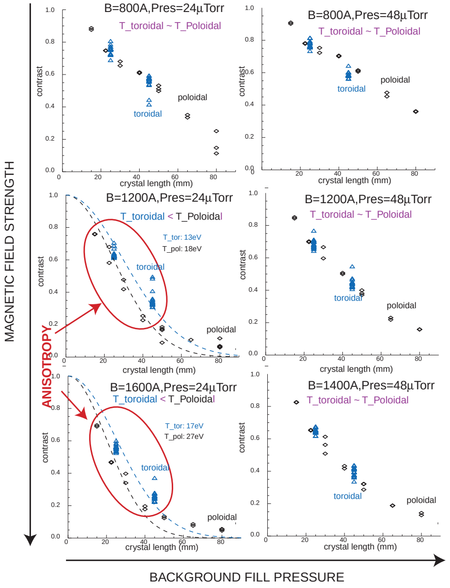
B=1600A@ t=7.2ms: two temp model is necessary



ANISOTROPY

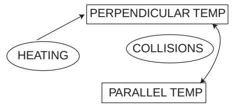
The isotropy of the distribution function is measured by comparing the contrast curves (temperatures) from the toroidal viewing MOSS with a spatial average of the polidal viewing MOSS.

Shown below is the contrast as a function of crystal thickness, at different plasma conditions (filling pressure and magnetic field). The distribution is isotropic where the blue points lie amongst the black ones, however, at high field and low pressure, an anisotropy is detected, and fits to a single temperature model are indicated.



INTERPRETATION

ANISOTROPY



- Parallel and perpendicular temperatures will equilibrate at higher collisionality (pressure).
- The existence of anisotropy implies a heating mechanism which dominantly drives the perpendicular component.

TWO-TEMPERATURE DISTRIBUTION

- Charge-exchange collisions may effect the ions, because of the large background of neutrals in H-1. This will drain some of the energy from ions, creating a “cold” component. This effect should be more pronounced at the edge, where there is an influx of neutrals. Measurements show a larger cold component at the edge.

ACKNOWLEDGEMENTS

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