Low-Frequency Oscillations of Plasma in the Gas Dynamic Trap


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Gas Dynamic Trap Device

Beam injection:
- deuterium, energy 22-25 keV,
- total power 4.5-5 MW,
- duration 5 ms, injection angle 45°

Magnetic system:
- field at the midplane: 0.3 T,
- mirror ratio: 35

Warm «target» plasma:
- hydrogen+deuterium, density $3 \cdot 10^{13} \text{ cm}^{-3}$,
- temperature up to 200 eV

Fast ions:
- deuterium, density up to $5 \cdot 10^{13} \text{ cm}^{-3}$,
- mean energy 10 keV,
Voltage applied to plasma edge to produce radial electric field and plasma rotation.

Nonlinear dissipative saturation of the $m=1$ mode.
Radial magnetic field oscillations

Two sets of magnetic coils near the fast ions turning points:
- 16 coils placed azimuthally
- 13 coils placed along the GDT axis

Registration of radial magnetic field.
Radial magnetic field oscillations

Basic stages:

0-1 ms — no oscillations with high amplitude and proper frequency;

1-2 ms — oscillations with mode m=1;

2-4 ms — oscillations with mode m=2;

>4 ms — plasma decay, frequency decreases significantly during the oscillations period

Typical signal from the azimuthal set of Mirnov probes
Radial magnetic field oscillations

Oscillations spectrum at period of 1-2 ms after injection start.

$f = 38-39$ kHz
$m = 1$
Radial magnetic field oscillations

Oscillations spectrum at period of 2-4 ms after injection start.

$f = 19$ kHz
$m = 2$
Radial magnetic field oscillations

Typical signal from the linear set of Mirnov probes

Cophased signal along the axis \( \Rightarrow \lambda_z > 1 \text{ m} \)
Linear density oscillations

Power of beam passed through the plasma at the midplane.
Ellipse axes ratio estimation (mode m=2)

\[ J = J_0 \cdot e^{-\langle nl \rangle \sigma} \Rightarrow \frac{\Delta \langle nl \rangle}{\langle nl \rangle} \approx \frac{\Delta J}{J} \approx 0.04 \]
Linear density oscillations

Oscillations spectrum obtained by 6 beams

$f = 19$ kHz
$m = 2$
Oscillation frequency

![Graph showing the relationship between oscillation frequency (f, kHz) and voltage (Ulim, V) for different values of R (R=31, R=27, R=24).]
Local plasma diamagnetism at the turning point of fast ions

Longitudinal displacement of plasma column

Fast ions energy content

$W_f = 1.5 \text{ kJ}$
Longitudinal displacement of plasma column

Dependence of magnetic field derivative from time and longitudinal coordinate

R=2

R=1.5

15 μs
Longitudinal displacement of plasma column

Dependence of magnetic field from time and longitudinal coordinate
Longitudinal displacement of plasma column

Dependence of magnetic field from time and longitudinal coordinate
Longitudinal displacement of plasma column

Dependence of magnetic field derivative from time and azimuthal angle
Longitudinal displacement of plasma column

$W_f = 1.6 \text{ kJ}$

Fast ions energy content
Longitudinal displacement of plasma column

Dependence of magnetic field from time and longitudinal coordinate
Conclusions

- Experimental data described above demonstrate agreement with the theory of vortex confinement. Oscillations observed have a flute character with only one dominating mode at each moment. Plasma rotates in the direction opposite to ambipolar rotation. Oscillations frequency has linear dependence on voltage applied to radial limiters.

- Displacement of fast ions turning point was observed experimentally. It can be explained by high beta effects.