Optimization of ECR-breakdown and plasma discharge formation on T-10 tokamak using X-mode second harmonic of ECR.


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Status of T-10 ECH system and Plasma Diagnostics actual for submitted experiments (2008 y.)

- R=150 cm, a=30 cm
- $P_{\text{ECH}}(130\text{GHz})=1.4$ MW
  $P_{\text{ECH}}(140\text{GHz})=1.6$ MW
- Second EC harmonic, LFS injection, X-mode
- $\tau_{\text{ECH}}$ up to 0.4 s
- $\max p_{\text{RF}} \approx 0.25$ MW/cm² (C)
- $\max p_{\text{RF}} \approx 0.01$ MW/cm² (A,B)
- Steerable mirrors ($\varphi_t$, $\varphi_\theta$ - var), beam focusing

Fig.1
Interaction of linear polarized X-mode wave with the electron according to the equation of charge motion in electro-magnetic field:

$$\frac{dp}{dt} = eE + \frac{e}{c}[vH]$$
For all discharges deuterium was used as the pre-fill gas.

Time evolution of line density $n_e \cdot L$, $I_{D\alpha}$ intensity, injection RF timing.

$P_{rf} = 0.55\text{MW}$, toroidal injection angle $\alpha = 10^\circ$, initial gas pressure $P = (4.5 \pm 6) \times 10^{-3}\text{Pa}$. 
Breakdown in the central ECR zone (B=2.5 T). $P_{RF} = 0.55$ MW

Initial stage.

Fig. 5 Time evolution of line density profile
Time delay of line $I_{D\alpha}$ appearance relatively RF injection moment on the injected power level.

Similar dependence on loop voltage [2].

\[ P = 5 \times 10^{-3} \text{Pa}, \quad B_\perp = 15 \times 10^{-4} \text{T}, \quad B_T = 2.5 \text{T} \]
Quasistationary stage of discharge

- $P_{RF}=0.55\text{MW(C)} + 0.45\text{MW(A+B)}$.
- Injection angle $\alpha=20^\circ$
- $B_T=2.5\ T$ (central ECR zone)
- $B_\perp=15\times10^{-4}\text{T}$
- $P= 5\times10^{-3}\text{Pa}$.

Time evolution of:
plasma current [3],
loop voltage,
electron density $n_e$ (central chord),
$I_{D\alpha,\beta}$ intensity,
RF injection timing

Fig. 7
Dependence of current value on $B_\perp$ with initial gas pressure $5 \times 10^{-3}$ Pa, RF power 0.55 MW and magnetic field 2.5 T.

Dependence of current value and time delay of $I_{\text{Da}}$ on initial gas pressure, with RF power 0.55 MW, $B_\perp$ 15 Gs, magnetic field 2.5 T.
Fig. 10

Dependence of $I_{\text{pl}}$, $I(\text{CIII}^c)$, $I_{\text{D}\alpha}$ on RF injection toroidal angle with initial gas pressure $5\times10^{-3}$ Pa, $B_\perp$ 15 Gs, $P_{\text{RF}}$ 0.55 MW and magnetic field 2.5 T.
Fig. 11

Time evolution of plasma current, electron density $n_e$, injection RF timing.

$P=5\times10^{-3}$ Pa, $B_{\perp}=15\times10^{-4}$ T, $B_T=2.5$ T, $P_{RF}=1$ MW
Chord distribution \( I_{\text{AXUV}} \)

Fig. 12
Spectroscopic measurements of $T_e$
in EC plasma with current.

Chord profiles of lines: 5290 Å ion CVI, 647 Å ion CIII.

Profile of $T_e$ from corona equilibrium model.

Fig. 13
Conclusions

- Optimization of discharge plasma parameters with pre-ionization using X-mode second harmonic ECR was performed on T-10.
- It was shown, that breakdown starts developing in ECR–zone, which allows to localize RF-discharge in suitable area of tokamak vessel.
- Ionization rate $2\div 3\cdot 10^{21}$ electrons/sec was evaluated at the initial stage. According to this estimation all pre-filled gas is ionised during $3\div 3.2$ ms.
- Plasma equilibrium current value up to $I_{pl}=3$ kA ($P_{RF}=1$ MW) was measured. The following parameters were achieved at quasistationary stage of discharge: $n_e=5\times 10^{12} \text{ cm}^{-3}$, $T_e\geq(120\div 150)$ eV.
- Plasma-wall interaction leads to outgassing and impurities intake (appearance CIII, CVI lines).
- $T_e\approx 5\div 10$ eV was estimated without current.
- Plasma current ramp-up experiments are in plans.
References