ABSTRACT
• 2D plasma potential distribution was measured in the ECRH plasmas of TJ-II for the first time in a wide area of poloidal cross-section.
• Equipotential lines are consistent with vacuum magnetic flux surfaces, 2D potential distribution is symmetric with a maximum at the plasma center.
• Plasma potential and density RMS are not fully symmetric, effect is stronger for low-density case: at the mid radius (area of the maximum density) RMS φ=15V at LFS vs ~20V at HFS, RMS δn/n=2% at LFS vs ~3% at HFS.
• TJ-II plasmas well diagnosed by HiB volunteer platform for the theoretical models for transport and turbulence in 3D devices.

BACKGROUND
• 2D mapping is aimed to validate the recent theories and GK modeling predicting the poloidal symmetry breaking for plasma potential and density turbulence [1].
• The first experiments aimed at obtain the 2D distribution of plasma potential were performed in TJ-II using Heavy Ion Beam Probe (HiB) with the variation of Cs+ probing beam plasma entrance angle and energy in the range 128-148 keV [2].
• Comprehensive study to characterize 2D structures of plasma potential and density mean-value distributions and fluctuations in TJ-II has been recently performed by varying the beam energy in a wider range 100-150 keV.

Experimental setup
TJ-II stellarator
R = 1.5 m, a = 0.22 m, B0 = 0.95 T
ECRH (two 53.2 GHz s300 kW gyrotrons)
NBI (two 600 kW H2 injectors, E=40 keV)
HiB
• Cs+ ions with energies E= up to 150 keV
• Probing beam current up to 250 µA
• 5-slit energy analyzer
• Full radial scan from LFS(p=1) to HFS (p=1) in 5-20 ms at E= 132 keV

Studied regimes:
1 (low n_e): ECRH_1+2 (470 kW), n_e = 0.5±0.07 x10^{19} m^{-3}, T_e = 1.6 keV
2 (high n_e): ECRH_1 (250 kW), n_e = 0.7±0.1 x10^{19} m^{-3}, T_e = 1.3 keV
3 (NBI): co-NBI (510kW), n_e = 0.9± 1.3 x10^{19} m^{-3}, T_e = 0.6 keV

Measurement setup
S(t, f) is PSD of selected AEs mode, fnyq is Nyquist frequency and Snyq(f)/Snyq(f) is spectral band.
The same method can be applied for the broad-band turbulence (multiband case).

OUTCOME
Plasma potential and density profiles evolution

2D distribution of plasma potential
Potential contour covers about one half of the plasma poloidal cross-section:
• the maximum of 2D potential distribution (~ 1000 V, ~ 200 V) is located at the magnetic axis
• equipotentials are consistent with vacuum magnetic flux surfaces
• 2D potential distribution is symmetric (LFS-HFS and up-down)

2D distribution of plasma potential fluctuations
• the maximum of 2D RMS distribution is located at the magnetic axis (~ 30 V, ~ 15 V) and at the edge (~ 40 V, ~ 30 V)
• equipotentials are basically consistent with vacuum magnetic flux surfaces
• 2D distribution is not fully symmetric: at the mid-radius (~ 15 V, ~ 12 V (LFS) vs ~ 20 V, ~ 15 V (HFS)

2D distribution of plasma density fluctuations
• the density perturbation has a local maximum at the centre (~ 3%, ~ 2.5%) and maxima at the edges (LFS and HFS) up to 7% and 15%
• the level of the density perturbation is asymmetric, it is lower in LFS (~ 2%, ~ 1.5%) in contrast to HFS (~ 3%, ~ 2%) near mid radius - area of the maximum density

SUMMARY
• 2D plasma potential distribution was measured in the ECRH plasmas of TJ-II for the first time in a wide area of vertical cross-section in ECRH and NBI plasmas.
• In both ECRH and NBI plasmas equipotential lines are consistent with vacuum magnetic flux surfaces, 2D potential distribution is symmetric (LFS-HFS and up-down) with local extrema at the plasma centre.
• In low-density (ne=0.5-0.8 x10^{19} m^{-3}) ECRH plasmas potential and density RMS are not fully symmetric, the effect is stronger for lower-density case: at the mid radius (area of the maximum density) broadband turbulence RMS~ 15 V at LFS versus ~20 V at HFS, RMS ne ~ 2% at LFS versus ~3% at HFS. In the NBI plasmas with the density increase the asymmetry is decreasing and finally vanishing at ne=1.2-1.3 x10^{19} m^{-3}.
• 2D distribution of the NBI-induced Alfvén eigenmodes show asymmetric structures: contrary to broadband turbulence AE-associated potential perturbation dominate in the LFS with a factor up to 1.7 respect to the HFS.

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