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Effects of Resonant Magnetic Perturbations on Edge Turbulence and Profiles in DIII-D

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Abstract. It is found that resonant magnetic perturbations (RMPs) applied to the edge of DIII-D plasmas can cause changes in the average density and also in the turbulence measured by various diagnostics at the edge and scrape-off layer (SOL). Two main regimes have been explored: 1) low power and collisionality discharges, where it is seen that the RMPs affect the edge profiles across the SOL and into the core; and 2) high power, varying (low, medium and high) collisionality discharges where the average density can increase or decrease but the turbulence in the SOL always increases. In these discharges, the pedestal fluctuations can increase or decrease in narrowly localized radial regions near the top of the pedestal. When the RMP are rotated toroidally, the fluctuations change amplitude and/or location, indicating that the RMP-induced changes are toroidally localized.

RMPs are applied to the boundary of DIII-D [1] with a variety of global effects such as edge localized mode (ELM) suppression and global density increase/decrease. How the applied perturbations affect the transport and the plasma edge stability, and thus suppress the ELMs, are among the fundamental questions to be answered because of the high heat load created by the ELMs on the plasma facing components. We present fast reciprocating probe measurements of the effects of applying RMPs [2] to: 1) low power (ohmic) and 2) H-mode DIII-D discharges of diverse collisionality.

In the ohmic discharges the C-coil [1] is used to create a chain of resonant islands across the plasma edge, then at 1500 ms, the I-coil is ramped to partially ergodize the region. Field mapping using Trip3D [4] including all applied and error fields, shown in Fig. 1, predicts clear chains of resonant islands at 1200 ms that are partially destroyed by 2300 ms, as the field strength and spectrum are changed. The changes are clearly produced by the I-coil perturbation, shown in Fig. 1, where the region between ψ=0.7 and 1.0 is shown vs. poloidal angle for a fixed toroidal angle (ϕ=240 deg.) at two times; 1200 ms (or pre-I-coil) and 2300 ms (during I-coil) when the probe, trajectory shown as a vertical line, was inserted in the plasma edge. The probe does not quite reach the first large island chain at ψ~0.90

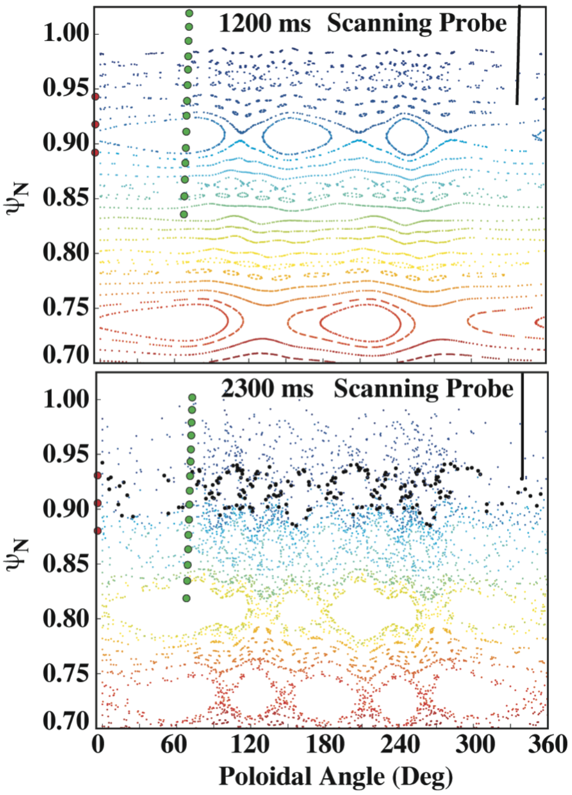

Fig. 1. Trip3D field mapping showing the vacuum field structure as a function of poloidal angle and ψ for a fixed toroidal angle. Diagnostic locations for BES (red, probe (black line) and Thomson (green) are indicated.

although it crosses other smaller structures/chains. The high spatial resolution probe measurements, shown in Fig. 2, show that the effect of islands, which appear as fine profile structure, is clearly seen in the edge plasma profiles and changes in the fluctuations as far as 4 cm inside the separatrix (R_{sep}). The probe data also show the expected degradation of the structures, becoming smoother and loosing fine structure as the edge becomes more ergodic.

The increase in I_{sat} and T_e across the last closed flux surface (LCFS) suggest increased radial transport while the changes in E_θ and V_p indicate the possible formation of quasi-steady structures, such as convective cells. Additionally, the fluctuations on the I_{sat} (mostly N_e) increase by factors of 2 across the LCFS and SOL, T_e fluctuations decrease all across and E_θ fluctuations decrease in the core and increase elsewhere. Additionally, both the density and radial velocity of the intermittent structures (most of the turbulence) increase by factors of 1.5-2, and, since they are in phase, result in increased radial turbulent flux. The flux increases at the LCFS (within errors) and SOL and decreases slightly inside the LCFS, consistent with a slight increase in average discharge density.

We conclude that: 1) the applied island structures affect the edge parameters, fluctuations and transport, and 2) the observations compare qualitatively well to vacuum calculations using TRIP3D field mapping codes in plasmas with low edge collisionality, edge T_e and low rotation.

The low power discharges (with low rotation and expected high field penetration) make the important point of demonstrating that the applied magnetic perturbations affect ***both*** the SOL and LCFS region and affect fluctuations and transport. However, the case may be different at high power with rotating plasmas and other collisionalities, and we need to bridge both cases.

In high power H-mode discharges the I-coil is turned on after the discharge is well developed to suppress ELMs and measurements of probes and other diagnostics [such as beam emission spectroscopy (BES)] are made at various points in the edge/SOL and changes in the profiles and fluctuations [3] are compared. We find that fluctuations can be affected (enhanced or reduced) in narrow (1-2 cm) regions in the pedestal and in the scrape-off layer (SOL). The changes in the profiles and fluctuations are dependent on the structure of the applied fields that can be varied in both intensity and mode number.

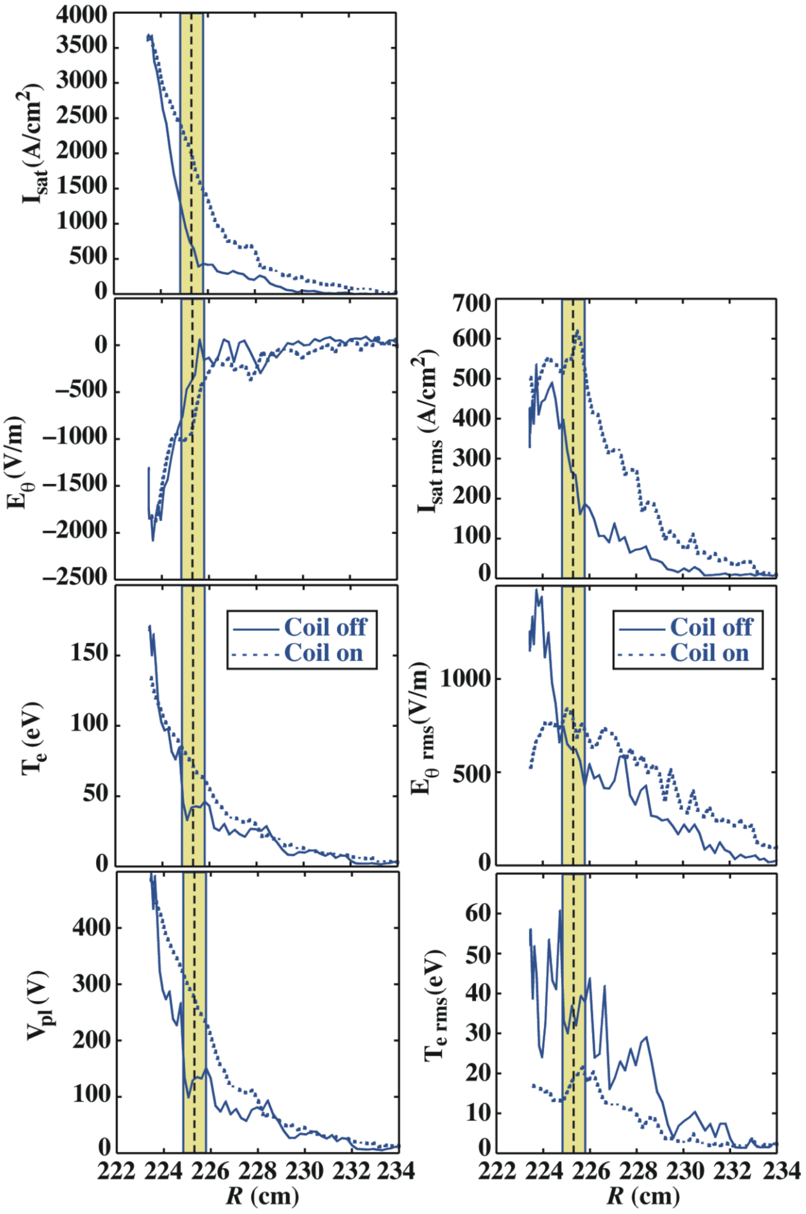

Fig. 2. Left, the steady state profiles of averaged I_{sat}, E_{pol}, T_e, V_{pl} and, right, rms levels of I_{sat}, E_{pol}, and T_e before (solid) and after (dashed) the magnetic perturbation is applied. The vertical dashed line indicates the EFIT separatrix and the shaded area indicates the uncertainty.

We compare two high power, medium collisionality (ν~1), odd parity external magnetic perturbation, otherwise identical discharges. The only difference is that the RMP is rotated toroidally by 60 deg. The average density drops slightly when the RMP is applied. SOL profiles and fluctuations show similar behavior as that reported for the low power ones, i.e. slightly broader profiles and increased fluctuations and intermittent transport in the SOL [2], but the probes cannot reach the top of the pedestal. Therefore, BES is used to evaluate the density fluctuations, and their spatial localization, in a zone straddling the top of the pedestal and the LCFS. It is found that: 1) fluctuations in the pedestal change in a narrow region when the RMP is applied, 2) the fluctuations mostly decrease for $0.90 < \rho < 1.05$ for the 0 deg. phase (115467) and mostly increase for $0.92 < \rho < 1.05$ the 60 deg phase (115470) as shown in Fig. 3. Trip3D mapping (not shown), although showing a shift of the separatrix between both topologies, ***cannot*** explain the fluctuation amplitude changes. The conclusion is that the fluctuation changes are toroidally localized.

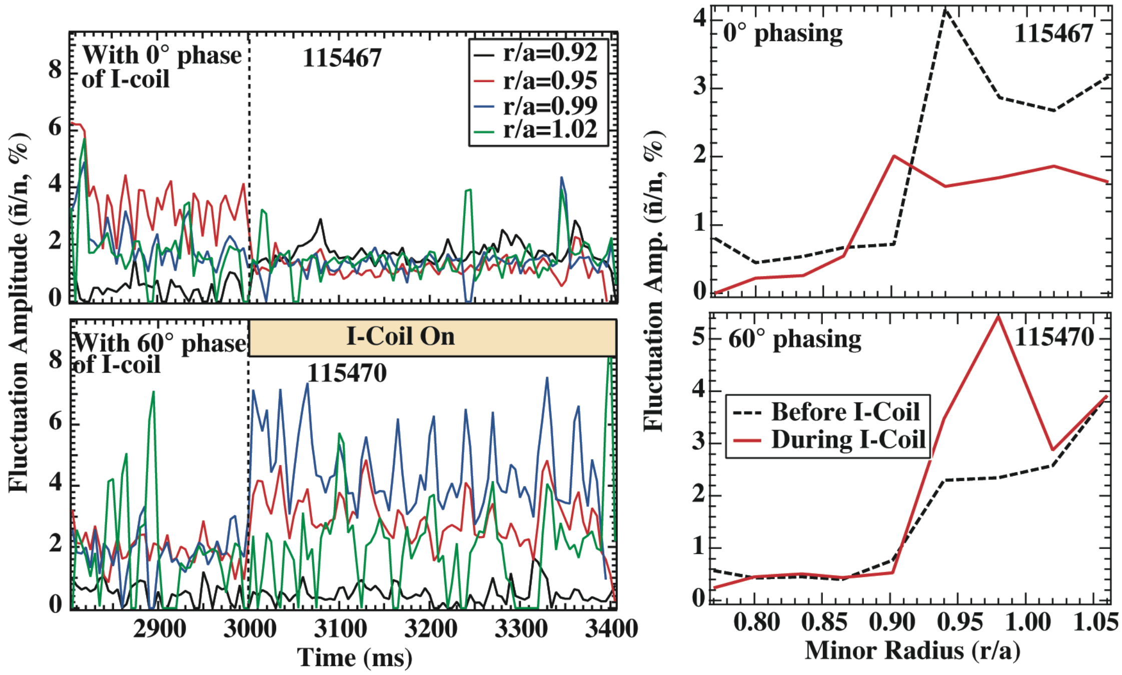

Fig. 3. Left, normalized density fluctuation levels from BES channels 11-15, spanning the pedestal and bandpass filtered from 10 to 150 kHz; right, radial profiles. Discharges 115467/70 are identical, odd parity RMP with 115470 rotated by 60 deg toroidally.

Therefore we conclude that: 1) applied RMPs can affect the static profiles by creating island or ergodic structures, 2) RMPs can affect the fluctuations in narrow regions in the pedestal and across the SOL, 3) the perturbations seem to be toroidally localized and 4) these changes seem to occur in various manifestations across a wide variety of discharges (high and low power, low, medium, and high collisionality) discharges.

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