Edge density modification with rf on TFTR and DIII-D

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Abstract. Modification of the electron density profile in front of rf antennas has been observed on TFTR and DIII-D using reflectometers installed 'in-antenna' to ensure localization to the antenna environment. The modification of the edge density gradient has two components: 1) a flattening of the gradient in the private flux zone, and 2) an increase in the edge density inside the last closed flux surface. In general, these modifications result in a significant decrease in the electron density over most of the private flux zone with a sharp rise in the density near the last closed flux surface. Data from TFTR is used to infer the dependence of this edge modification with antenna strap phasing and rf power. Initial results from DIII-D showing edge modification will also be discussed. Antenna modeling has shown that this modification in the private flux zone has only small effects on the antenna loading and launched spectrum.

INTRODUCTION

Modification of the edge electron density profile has been observed during the application of rf power on both TFTR and DIII-D. In general, these modifications can be classified into two components: 1) a flattening of the gradient in the private flux zone of the antenna, and 2) an increase in the edge density inside the last closed flux surface. The modification of the density gradient in the private flux zone of the antenna has shown a dependence on both the rf power and current strap phasing, and is toroidally localized to the antenna position. Although this modification is pronounced with high power rf, it is occurring at very low densities and so has only a minor effect on the loading. In contrast, the increase in density inside the last closed flux surface can have significant effects on the loading.

These edge density profile measurements were made using microwave reflectometers installed in or adjacent to the rf antennas (but still within the private flux zone of each antenna). The TFTR edge reflectometer is described in ref. [1]. This differential-phase reflectometer operates in the 90-118 GHz range using the extraordinary mode (x-mode) and views the plasma through a diagnostic port located in the Bay K antenna. The diagnostic port penetrates through the Faraday shield and is located at the geometric center of the antenna. The reflectometer used on DIII-D for these measurements is an AM reflectometer operating in the 33-50 GHz range using the x-mode.[2] This system originally operated on PBX-M where it observed similar decreases in the density immediately in front of the rf antenna during IBW operations.[3]

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INITIAL RESULTS FROM DIII-D

Figure 3 shows four edge density profiles from DIII-D obtained during one discharge with four different rf conditions. As shown in the inset, the first profile is obtained before rf, the second is obtained with rf on the 0° antenna, the third is obtained with rf on both antennas, and the fourth is obtained with rf on only the 285–300° antenna. The reflectometer launcher is located adjacent to the 285–300° antenna as illustrated in Fig. 4. Figure 3 shows that the rf does modify the edge density profile on DIII-D, and that the decrease in the density immediately in front of the antenna during rf is a localized phenomenon. This is demonstrated by the fact that no density decrease is observed when the 0° antenna is powered, but a clear decrease is observed when the 285–300° antenna is powered.

The most significant uncertainty in the profiles shown in Fig. 3 is due to the uncertainty in the DIII-D magnetic field. As with the TFTR data, the starting frequency can be determined very accurately. The radial position of the initial cutoff is determined by the mechanical layout of the reflectometer antenna system, shown in Fig. 4. With this antenna arrangement, the initial cutoff will occur somewhere in the region between the reflectometer antenna apertures and the surface of the wall tile. For this analysis, the initial cutoff radius is assumed to be the antenna aperture radius (2.382 m). The magnetic field profiles obtained for this data consistently put the ECR for the initial cutoff frequency up to 1 cm behind the surface of the reflectometer antennas; therefore, the magnetic field must be reduced by up to 0.5% to move the ECR out in front of the antenna block. This uncertainty in the magnetic field greatly reduces the accuracy of the absolute density at any given point, but does not significantly effect the comparison of the four profiles.

CONCLUSION

Reflectometer measurements of the edge density profile on TFTR and DIII-D have shown that the application of rf power modifies the edge density in two ways. First, it reduces the density in the region between the Faraday shield and the rf limiters (or possibly all the way in to the last closed flux surface), and second, it causes an increase in the density inside the last closed flux surface. These changes show dependence on both the antenna strap phasing, and the applied rf power. Data from DIII-D with two toroidally separated rf antennas indicate the first effect is localized to the private flux zone of the rf antenna.

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FIGURE 1. TFTR edge density profiles for monopole phasing with a power scan.

FIGURE 3. DIII-D edge density profiles showing effect of powering far away and adjacent rf antennas. Note, $\bar{n}_e$ varies by a factor of 2 during the time interval shown, leading to the significant profile differences near the separatrix.

FIGURE 2. TFTR edge density profiles for dipole phasing.

FIGURE 4. Location of DIII-D rf antenna reflectometer launcher on DIII-D.