INITIAL MEASUREMENTS OF PLASMA POTENTIAL AND FLUCTUATIONS WITH A HEAVY ION BEAM PROBE IN THE MST REVERSED FIELD PINCH

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A Heavy Ion Beam Probe is operational on the Madison Symmetric Torus; this is the first implementation of an ion beam probe on a Reversed-Field Pinch. The goals are to measure the profiles of the equilibrium plasma potential and electrostatic fluctuations. Measurements indicate a positive potential in the vicinity of r/a = 0.4, consistent with the expectation of rapid electron transport due to magnetic fluctuations. Comparison between the radial electric field and plasma flow is underway to determine the extent to which equilibrium flow is governed by ExB. Measurements of electron density fluctuations indicate a peak in the density fluctuation power spectrum at the tearing mode frequency.

The application of an HIBP on MST has posed challenges - the requirement to keep ports small to avoid introducing magnetic field perturbations led to the use of cross-over sweep systems; high plasma and ultraviolet flux led to magnetic plasma suppression; comparable toroidal and poloidal field strengths leads to highly three-dimensional ion trajectories. In addition, the measurements are influenced by the presence of magnetic fluctuations, which are much larger on a reversed-field configuration than on tokamaks and stellarators.

1 Introduction

A heavy ion beam probe (HIBP) is in operation on the Madison Symmetric Torus (MST)[1]. Designing an HIBP for MST was complicated by small ports, high plasma and ultra-violet flux through the ports, and a magnetic field that is not well known. A feature of an HIBP is its well established ability to make both equilibrium potential and fluctuating density and potential measurements in the core. In this paper we present an overview of the HIBP diagnostic on MST and report on experimental measurements of plasma potential and fluctuating density in the core.

2 Diagnostic Overview

The beam probe utilizes a singly charged beam of ions injected by a 200 keV accelerator. Four pairs of electrostatic sweep plates function as a cross-over sweep system to steer the beam through a 2" port on MST. The sweep system is designed to maximize the angular variation of probing ions at the plasma surface and, as a result, the area of plasma probed.

Plasma loading of the HIBP steering system remains the most limiting factor to system performance. The small port size restrictions on MST, and the desire to maximize the overall sample volume area, necessitate that both the primary and secondary beam line sweep plates be located close to MST and thus to the plasma. In general, ultraviolet radiation (UV) and plasma particle flux through the MST diagnostic ports are very high. Without mitigation techniques, the combination of plasma loading and UV induced secondary electron emission impedes the operation of the sweep plates. The use of permanent magnet plasma suppression structures coupled with apertures reduces the plasma flow and UV radiation into the beam lines; though reduced, UV loading is still substantial[2].

UV loading can be sufficient to change the voltage on the steering plates, particularly the primary poloidal plates closest to the plasma. The consequence is a change of the primary beam trajectory and therefore a change in the sample location. The resulting measurement may be interpreted as a fluctuation when in fact it is an instrumental effect.

3 Measurements

MST has a major radius of 1.5 m, a minor radius of 0.52 m, a 5cm thick aluminum wall, and operating parameters of 500 kA plasma current, central electron temperatures T_e 0.8 keV, and pulse length of 70 ms. The data presented in this article are from MST discharges with plasma current Ip= 380 kA (peak on axis magnetic field of approximately 0.4 T), density n_e=1.0x10^{13} cm^{-3}, reversal parameter F= -0.2 to –0.3, and a working gas of deuterium.

The evolution of the potential measured during a single discharge in the vicinity of r/a~0.4 is shown along with the instantaneous phase velocity of a core resonant m=1, n=6 tearing mode in Fig. 1. It indicates a measured positive potential consistent with the development of an outward directed, radial electric field due to a preferential loss of electrons along stochastic field lines[3, 4]. The magnitude of the measured potential in MST high current discharges (350-400 kA) is typically on the order of 1.5-1.9 kV, roughly 3-5 times the electron temperature (400 eV). Measurements in low current discharges (250-300 kA, Te ~ 300 eV)) exhibit lower potentials in the range of 0.9-1.2 kV. Rough estimates suggest that the measured potential is consistent with an ExB velocity of the same value as the measured phase velocity of the dominant m=1, n=6 core tearing mode. Visual inspection demonstrates a general trend between the measured potential and phase velocity during the periods between the sawtooth activities. The gaps in the plotted potential (noisy bands where the potential plummets) correspond to sawtooth events when UV loading, decreased signal to noise levels and changes in the magnetic field profile make it difficult for the HIBP to obtain secondary signals.

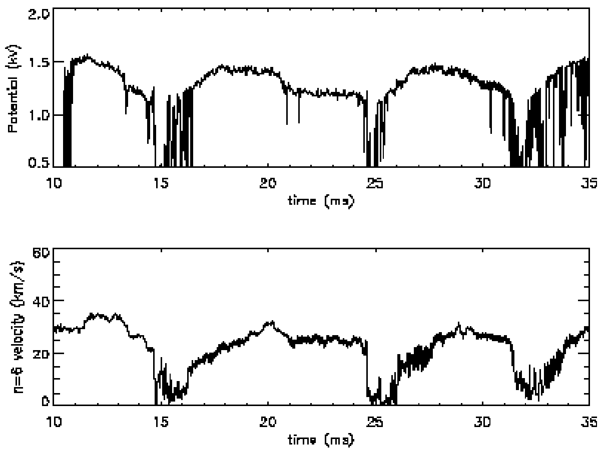

Figure 1 Measured potential at r/a~0.4 and mode velocity versus time of a 370 kA discharge. The noisy narrow bands in the potential data are a processing artifact caused by a loss of signal

Core density fluctuations have also been measured. During periods which are not influenced by power supply loading, measured fluctuations are closely coupled to low frequency MHD activity. Figure 2 illustrates the cross correlation of density fluctuation measurements made by the HIBP with magnetic fluctuations measured with pickup coils mounted on the MST vacuum vessel wall. The figure illustrates (a) the density fluctuation power spectrum, (b) the magnetic fluctuation power spectrum, (c) the coherence spectrum, and (d) the phase spectrum. The figure clearly shows that the measured density fluctuations are closely related to the core m=1, n=6,7 toroidal modes around 20 kHz. The data contain many realizations taken from the semi-quiescent periods between the sawteeth of approximately ten shots and is representative of most fluctuation data acquired. The measurements suggest that $\tilde{n} / n \sim 10\%$, though analysis is ongoing to determine if instrumental effects are a contributing factor.

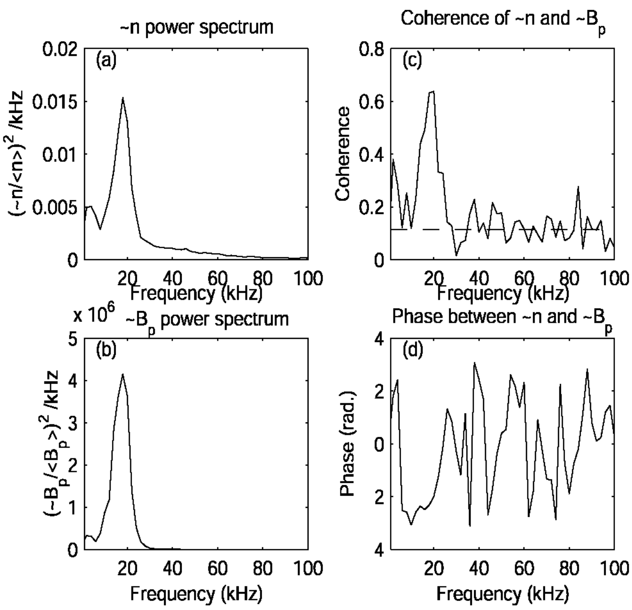

Figure 2 Spectra of (a)density fluctuations measured by the HIBP, (b)magnetic fluctuations measured by coils at the wall, (c)coherence between density and magnetic fluctuations, (d)phase angle between density and magnetic fluctuations

4 Conclusions

The potential has been measured in the core of MST and is found to be large and positive. This is consistent with the presence of magnetic stochasticity and a preferential loss of electrons. The magnitude of the potential varies temporally, by several hundred volts, with the sawtooth cycle, reaching its peak value between crashes. The magnitude of the potential is also consistent with an ExB velocity of the same value as the measured phase velocity of the dominant m=1, n=6 core tearing mode. Interior measurements of density fluctuations have been made on MST. The density fluctuations are closely coupled to low frequency MHD activity.

With the ability to make interior measurements of the potential, electric field, potential fluctuations, density fluctuations and, likely, fluctuations of magnetic vector potential, the HIBP is now part of the MST physics program to understand and improve confinement in the RFP.

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