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WAVE GENERATION IN THE ST TOKAMAK NEAR THE ION CYCLOTRON FREQUENCY AND ITS SECOND HARMONIC

by

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ABSTRACT

Wave generation in the vicinity of the ion cyclotron frequency and its second harmonic is currently under investigation in the ST tokamak. A novel coil exhibits considerable loading and magnetic probes indicate that the loading attributable to the plasma is due to waves propagating along the plasma torus.

We have begun Phase I of our program to heat the ST tokamak plasma with rf energy in the vicinity of the ion cyclotron frequency. The goal of this program is to supplement the heating produced ohmically by the discharge current in order to produce a higher plasma energy regime in the ST tokamak and to test the feasibility of incorporating this type of rf heating into a fusion device.

Phase I is a test phase during which we wish to determine:

1. If the coil can be placed inside the vacuum vessel in the presence of the hot tokamak plasma.
2. Wave loading of the coil
3. If waves propagate around the torus and, if so, which modes dominate.
4. Heating effects at modest powers.

The results of this phase will be used to design the system to be used in Phase II when we plan to put several megawatts of energy into the plasma waves.

In this paper, I will discuss our initial experimental results obtained at relatively low rf powers ($\lesssim$ 500 W). The heating observations at higher powers will be presented elsewhere.[1]

The coil designed for Phase I is a single, half-turn loop which enters through a port at the top of the vacuum vessel, then parallels the inner wall of the vessel, and finally exits at a port at the bottom of the vessel. The entire loop lies in a minor cross section and in the shadow of the plasma limiter. It is encapsulated in ceramic and is electrostatically shielded. Externally, the coil is terminated with capacitors at both ends to give a resonant circuit.[2] The rf power is

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delivered at one of the capacitors.

We chose to place the coil structure inside the vessel since this arrangement should be the simplest to adapt to a fusion device. This structure has been in use for several months and we have observed no deterioration of its performance due to plasma bombardment.

The rf current distribution produced by this coil is ideal for testing the wave propagation of essentially all wavenumbers parallel to the plasma column and favors m = 0 and m = 1 mode numbers around the minor cross-section. Thus, the plasma is allowed to choose the normal modes it wishes to propagate.

Coil loading is measured two ways:

(1) Effective parallel resistance - $R_{\parallel} = V_{rf}^2/2\,P_{rf}$, and

(2) Effective series resistance - $R_s = 2\,P_{rf}/I_{rf}^2$.

P_{rf} is the measured power delivered to the resonant system, V_{rf} is the peak voltage at the capacitor, and I_{rf} is the peak current in the loop. We find agreement between the two measurements.

R_s is observed to increase as $\Omega \equiv \omega/\omega_{cio}$ (ω_{cio} = ion cyclotron frequency at the center of the vessel) is increased towards unity, to decrease back to its base level (corresponding to circuit losses) when $\Omega \sim 1.15$ where the resonance plane is at a smaller major radius than the coil (cyclotron waves are completely cutoff), and to remain at its base level until Ω is sufficiently large to allow the fast modes of the plasma to propagate. Maximum values of R_s are a few ohms in approximate agreement with the cylindrical theory[3] (an applicable toroidal theory is not available). This loading pattern leaves little doubt that propagating eigenmodes are being generated in the plasma for both the slow (ion cyclotron) and fast wave ranges.

Magnetic probes located at the top of the vessel and 86 cm and 257 cm away from the coil show that propagating waves are definitely associated with the observed loading. These waves are attenuated as they propagate along the plasma column; the damping length is of the order of 1 m. However, this value must be taken as a minimum length for the attenuation by the plasma since the stainless steel vessel may be contributing to the wave damping.

Finally, this preliminary probe data exhibits a strong dependence on the location of the resonance plane in the plasma. Whereas the loading of the coil is large for $.85 \lesssim \Omega \lesssim 1.15$, the wave amplitude decreases by about an order of magnitude when $\Omega \gtrsim 1$ as compared to its value for $\Omega \lesssim 1$. This behavior suggests that the ion cyclotron waves are effectively contained between the resonance plane and the inner vessel boundary; when the resonance plane is at a smaller major radius than that for the probe, a diminished wave signal is observed.

MASTER

We are continuing these probe studies to better understand the wave-resonance plane interaction. It should then be possible to develop a suitable model for the toroidal wave theory. Also, we plan to measure the wave numbers of the dominant modes to compare to this theory and to insure a proper coil design for Phase II.

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