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Report



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## ION CYCLOTRON INSTABILITIES IN THE PHOENIX APPARATUS

by

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ABSTRACT

Instabilities which are associated with bursts of electrostatic oscillations at, or near, the ion cyclotron frequency and its harmonics are present in the PHOENIX machines both in the simple mirror and in the quadrupole magnetic well configurations. In both cases the instability is accompanied by energy spreading of the initially monoenergetic ion energy distribution though the effect is less marked in the latter. The fields have been resolved into those generated by azimuthal and axial currents and the frequency spectrum of each component has been measured. In the simple mirror the strongest signals are generated by m = 1 azimuthal currents which show characteristic frequency sweeps starting at the ion cyclotron frequency corresponding to the centre of the machine and falling by some 10% in the duration of a burst. In the magnetic well the signals are predominantly due to axial currents and the harmonic structure varies with density. At a density of $10^9$ $cm^{-3}$ the signals occur at harmonics of the central ion cyclotron frequency (normally 25 MHz) and a frequency some 3 MHz higher, the fundamental being strongest. As the density is increased the second harmonics increase in intensity until they predominate. Further increase in density brings a sudden change to strong even harmonics and very much weaker odd harmonics. At the highest densities reached ($5 \times 10^9$ $cm^{-3}$) bursts at a frequency about 4 MHz lower than the third harmonic appear and are accompanied by a progressive redistribution in plasma density. The results are discussed in the light of present theories.

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## INTRODUCTION

The PHOENIX apparatus[1] consists of a magnetic mirror trap which is filled by Lorentz ionization of a 20 keV $H^0$ beam. PHOENIX IA is a simple mirror and PHOENIX II incorporates a quadrupole magnetic field winding which, when energised, converts the initial simple mirror into a magnetic well. The magnetic fields can be maintained for periods of time of some seconds and, in the measurements described here the field at the centre of the apparatus was 16 kG giving a fundamental ion cyclotron frequency of 24 MHz. The equilibrium particle density is of the order of $10^8$ particles $cm^{-3}$ in the simple mirror, being limited by the flute instability, and of the order of $10^9$ particles $cm^{-3}$ in the case of the magnetic well, the limit being charge exchange with the background gas. In both configurations micro-instabilities, which are characterised by RF activity at or near the ion cyclotron frequency and its harmonics, have been observed. The activity is accompanied by energy spreading[2,3] of the initially monoenergetic ion energy distribution, though the effect is less marked in the magnetic well. Observations of the external electric field of the activity have been made using two kinds of RF probe - the ordinary electrostatic probes which measure a component of the electric field at the probes and loop aerials (crown probes[4]) which are sensitive to currents in the plasma. Measurements on the simple mirror and magnetic well cases are dealt with separately.

## RF ACTIVITY IN SIMPLE MIRROR GEOMETRY

Using two loop aerials in the mid-plane sensitive to $\theta$ currents and $Z$ currents one obtains typically the RF signals shown in Fig.1. The duration of the bursts of activity

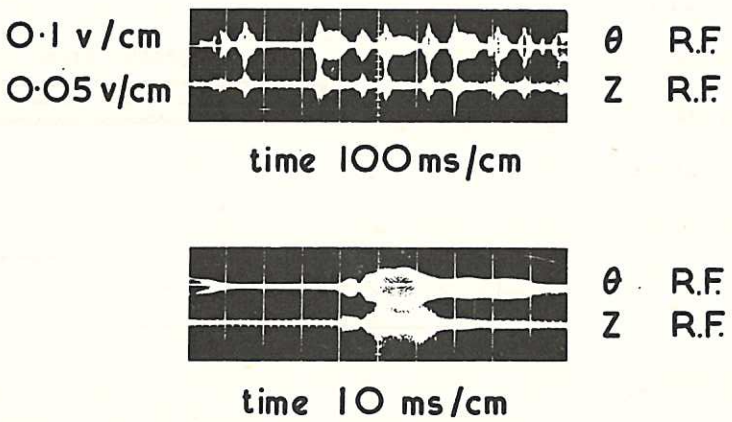


Fig.1 R F emission from PHOENIX I A (CLM-R69)

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