INSTITUTE OF PLASMA PHYSICS

NAGOYA UNIVERSITY

RESEARCH REPORT

NAGOYA, JAPAN

ON ION ACOUSTIC WAVES EXCITED NEAR AND ABOVE ION CYCLOTRON FREQUENCY IN A PLASMA*

Noriyoshi Sato+, Yoshihiko Yamashita‡,
Hiroyuki Ikezi, Nobuo Takahashi,
and Tokuhiro Obiki§

IPPJ-64 FEBRUARY 1968

Further communication about this report is to be sent to the Research Information Center, Institute of Plasma Physics, Nagoya University, Nagoya, JAPAN.

---

* This work was carried under the Collaborating Research Program at the Institute of Plasma Physics, Nagoya University, Nagoya.

+ Permanently at Department of Electronic Engineering, Tohoku University, Sendai.

‡ Permanently at Department of Physics, Okayama University, Okayama.

§ Permanently at Department of Electric Engineering, Kyoto University, Kyoto.

Abstract

Propagation and damping of ion acoustic waves excited by means of a plane grid near and above ion cyclotron frequency have the same characteristics as those below ion cyclotron frequency.

Wong, Motley and D'Angelo[1] have reported the experimental study on ion acoustic waves excited by means of a grid[2] in highly ionized plasmas produced by surface ionization and confined by a strong magnetic field. In their work, the propagation along the magnetic field is not affected by the size of the plasma column even though the wavelength (λ) is longer than the plasma radius (R) and the results agree with a plane-wave analysis. This agreement has been believed[3] to be due to the experimental conditions with f (wave frequency) $< f_{ci}$ (ion cyclotron frequency) and ρ_i (ion Larmor radius) $< R$. This note reports experimental results on propagation and damping of ion acoustic waves excited by means of a grid for $f \gtrsim f_{ci}$, $R > \rho_i$ and $\lambda > R$ in a machine similar to a Q device[4].

The plasma (about 2 cm in diameter and 130 cm long, the density $= 10^9 - 10^{10}$ cm^{-3}) is produced by surface ionization of cesium atoms on a hot tantalum plate (2300^0 k) and is confined by an axial magnetic field (2 − 3 kG). The background gas pressure is $10^{-6} \sim 10^{-5}$ Torr. Wave excitation and detection are made by using two movable grids with their planes normal to the axis. One grid is used as exciter and the other as receiver. The grids 4 cm in diameter are made of 0.2-mm-diam molybdenum wire spaced 1.5 mm apart and are biased at − 10 V with respect to the hot plate. The continuous sinusoidal signals (1 V peak to peak, 1 − 150 kc/sec) are applied to the exciting grid. The signals picked up by the receiving grid are fed to a phase-sensitive detector, together with the reference signals from the exciting source. The output is plotted on a recorder as a function of distance as shown in Fig. 2 shows the dependence of the wavelength (λ) and the damping distance (ρ) on the wave frequency (f) at $f_{ci} = 26.6$ kc/sec. The phase velocity of 1.75×10^5 cm/sec and 1.30×10^5 cm/sec are given along and against the plasma flow. ρ/λ of 0.80 and 0.61 along and against the plasma flow are independent of the wave frequency. For $f \gtrsim f_{ci}$, different behaviors are not found compared with the case of $f < f_{ci}$ and the waves decay by Landau damping. No cut-off frequency is obsearved and the waves with $\lambda > R$ and $f > f_{ci}$ propagate along the plasma column.

The results show that, in spite of Wong's apprehensions[3], even for $f \gtrsim f_{ci}$, a plane-wave analysis can be applied to ion acoustic waves excited by means of a plane grid in a plasma probuced by surface ionization and confined by an axial magnetic field. The experimental valus are about 1.5 times for the phase velocity and 2 times for δ/λ larger than those of the theoritical values for $T_e \sim T_i$ ($= 2300^0$ K), though the reason of these discrepancies is not clear. In the experiments[5,6] on the propagation of ion acoustic waves excited by means of a small coil[7] in low-pressure discharges under a weak axial magnetic field with $f \gg f_{ci}$ and $\rho_i > R$, the waves propagating down to zero frequecy have been obsearved, together with the waves with a low-frequency cut-off[7] determined by the plasma radius. Those are considered to be a principal mode[8,9] for which the phase velocity is equal to the group velocity just as in an unbounded plasma. Our results are also well understood by supposing the waves excited as the principal mode for which different behaviors are not expected near and above the ion cyclotron frequency.

REFERENCES

1. A.Y.Wong, R.W.Motley, and N.D'Angelo, Phys. Rev. 133, A436 (1964).

2. Y.Hatta and N.Satc, in proceedings of the Fifth International Conference on Ionization phenomena in Gases, Munich, 1961, edited by H.Maeckner (North-Holland Publishing Company, Amsterdam, 1962), p.478.

3. A.Y.Wong, Phys. of Fluids 9,1261 (1966).

4. N.Rynn and N.D'Angelo, Rev. Sci. Instr. 31, 1326 (1960).

5. P.J.Barrett and P.F.Little, Phys. Rev. Letters 14, 356 (1965)

6. F.W.Crawford and R.J.Kuhler, in Proceedings of the Seventh International Conference on Ionization Phenomena in Gases, Belgrade, 1965 (Gradjevinska Knjiga Publishing House, Belgrade, 1966).

7. P.F.Little, Nature 194, 1137 (1962).

8. B.Bertotti, A.Cavaliere, and P.Giupponi, Phys. of Fluids 9, 265 (1966).

9. H.N.Ewald, S.A.Self, and F.W.Cramford, in Proceedings of the Eighth International Conference on Ionization Phenomena in Gases. Wien, 1967 ; S.A.Self, H.N.Ewald, and F.W.Crawford, ibid.

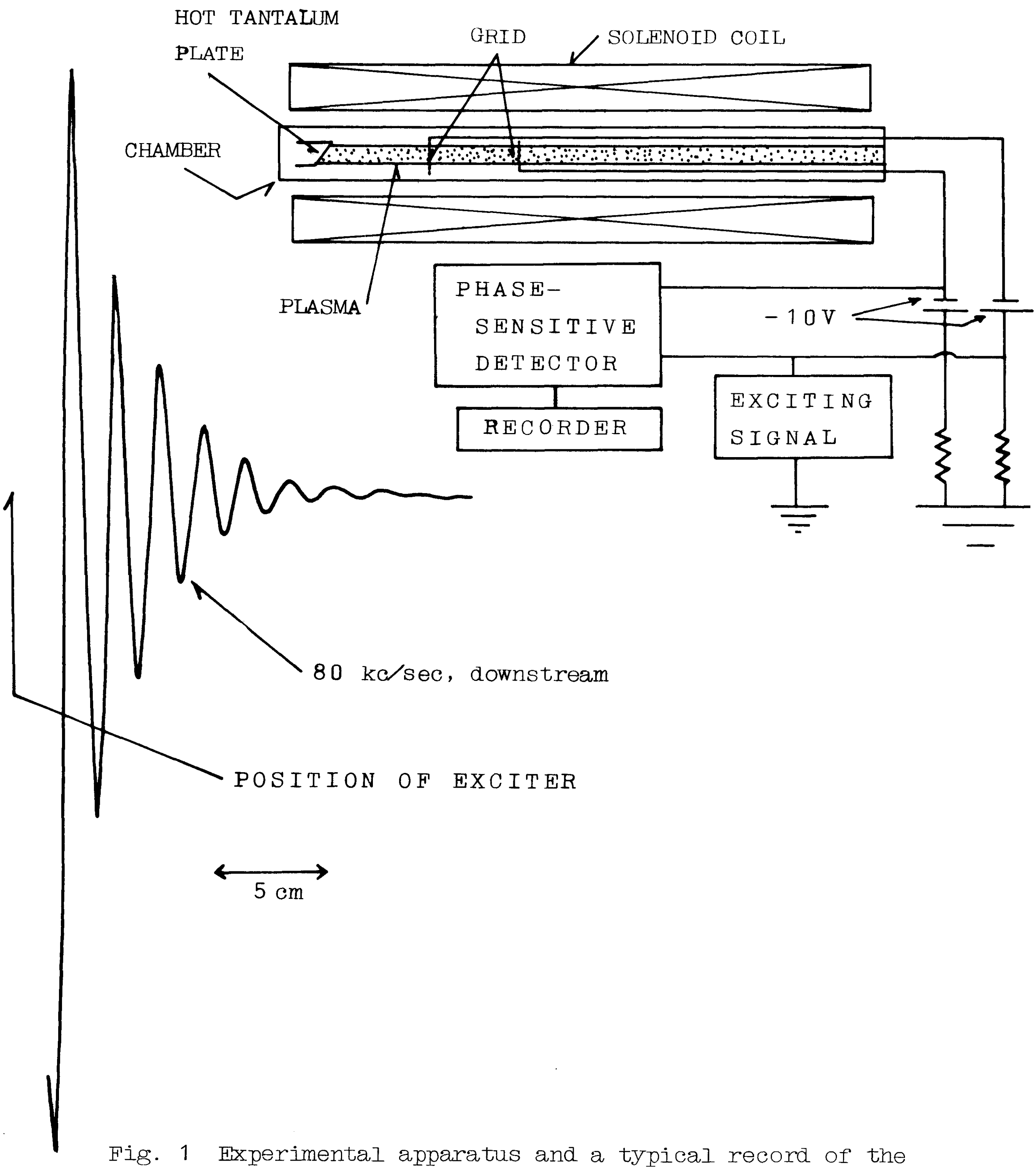

Fig. 1 Experimental apparatus and a typical record of the propagation and the damping along the plasma column.

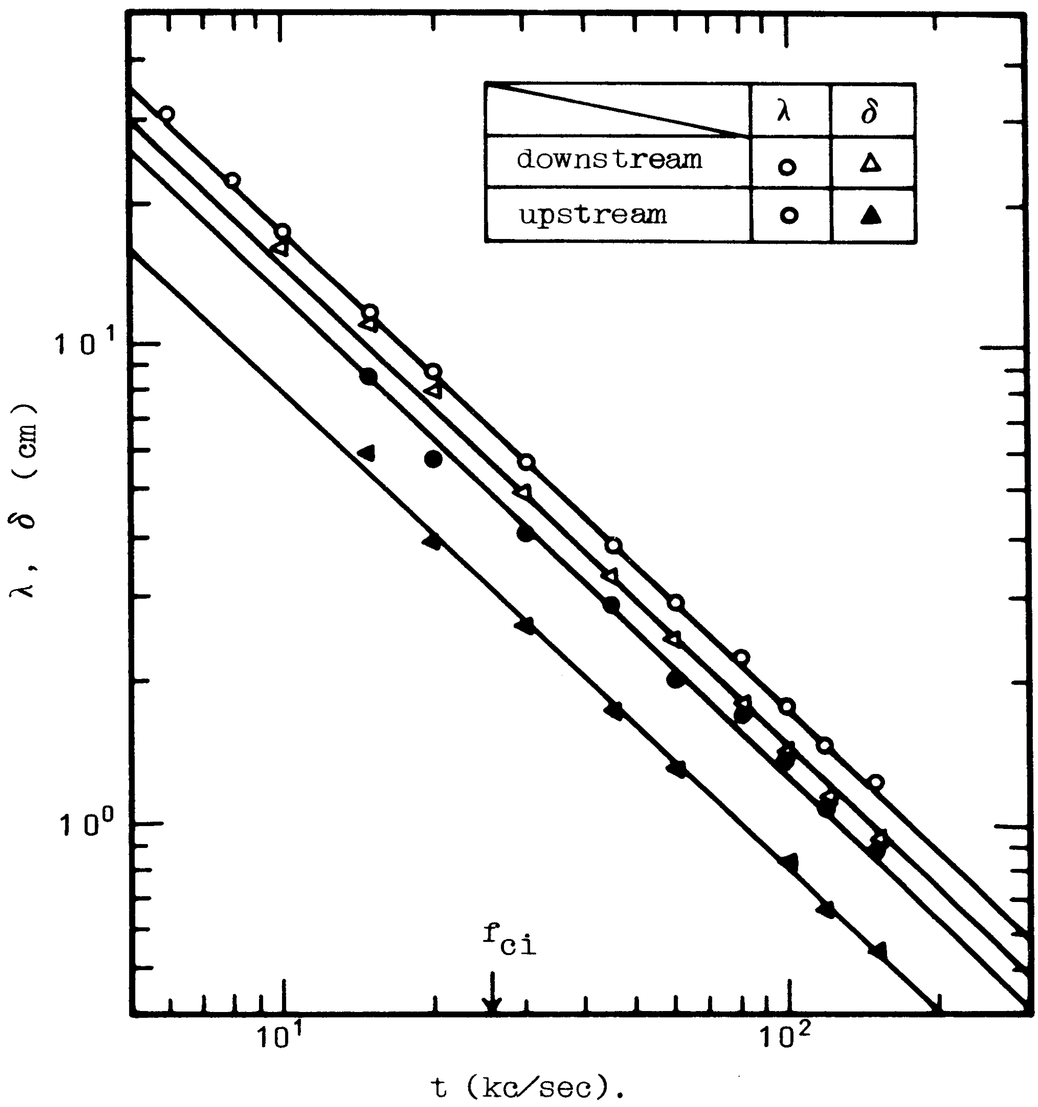

Fig. 2 The wavelength (λ) and the damping distance (δ) as a function of the wave frequency (f) at f_{ci} = 26.6 kc/sec.