PHYSICAL REVIEW LETTERS

VOLUME 10 | 15 MARCH 1963 | NUMBER 6

RESONANCE DENSITIES IN A CYLINDRICAL PLASMA COLUMN

Adam Dattner
Royal Institute of Technology, Stockholm, Sweden
(Received 12 February 1963)

Interaction between an electromagnetic wave and a cylindrical plasma can give rise to a resonance spectrum with a series of peaks at which the wave is strongly scattered. Such spectra have been reported by Romell[1] and Dattner[2] and later reproduced by several workers. The original theory by Herlofson[3] predicts only one resonance. Numerous attempts have been made to explain the existence of other resonances (Gould,[4] Åström,[5] and Weissglas[6]), but no theory has been able to explain the phenomenon completely.

This Letter reports a measurement of the electron densities at which the resonances occur. The apparatus is shown schematically in Fig. 1. A plasma-filled glass tube is situated in a waveguide with its axis perpendicular to the electric field and to the direction of propagation. A cylindrical microwave cavity is used to determine the density in terms of the mean square plasma frequency in the column, $\langle\omega_p^2\rangle$, according to the method described by Agdur and Enander.[7] The cavity is mounted directly above the waveguide, its axis coinciding with the axis of the plasma column. The discharge current and thus the electron density are varied. The cavity resonance is adjusted to coincide with that plasma resonance peak for which we want to determine $\langle\omega_p^2\rangle$.

In experiments described here the waveguide frequency was varied between 1.1 and 1.9 GHz. Five glass tubes were used, with inner diameters of 8, 12, 16, 20, and 32 millimeters in which a mercury-vapor discharge was maintained. The neutral gas density was 8.7×10^{19} m^{-3}. The electron temperature T_e was measured using Langmuir probes. T_e was found to be of the order 2.3-3.2 eV, and it increased with decreasing tube diameter.

In Fig. 2 the resonance values of $\langle\omega_p^2\rangle/\omega^2$ are plotted versus $kT_e/md^2\omega^2$, where ω is the waveguide frequency, d is the tube diameter, m is the electron mass, and k is Boltzmann's constant.

The quantity $(kT_e/md^2)^{1/2}$ gives the frequency associated with the electrons' transit across the plasma column. The ratio $kT_e/md^2\omega^2$ enters into the dispersion relations suggested by Gould, Åström, and Weissglas. The pertinence of this

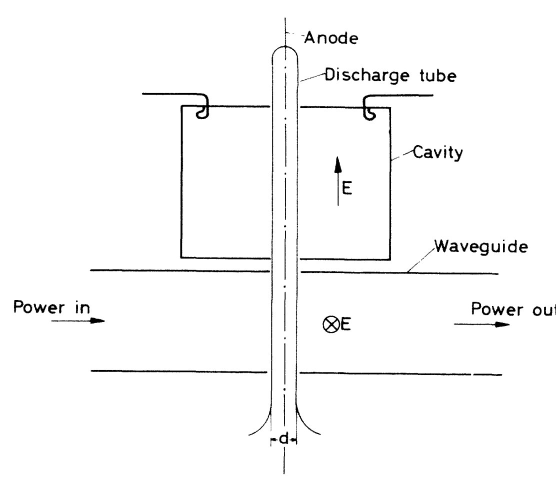

FIG. 1. Schematic diagram of the apparatus.

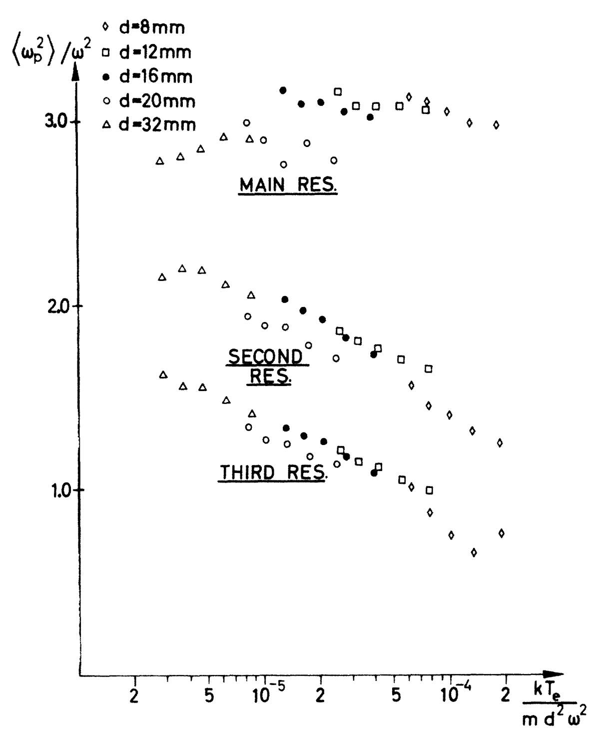

FIG. 2. The diagram of $\langle\omega_p{}^2\rangle/\omega^2$ versus $kT_e/md^2\omega^2$.

variable for the second and the third resonance is made plausible by the fact that a smooth curve can be fitted to the experimental points in Fig. 2.

The main resonance is seen to be of different character. This resonance, however, has been explained in the theory by Herlofson, and, as a particular solution, in the theory by Gould.

Following Herlofson and taking into account the finite plasma radius and the surrounding glass walls, we can compute $\langle\omega_p{}^2\rangle/\omega^2$ for the main resonance in a homogeneous plasma column. The results of this computation are compared with the measured values of $\langle\omega_p{}^2\rangle/\omega^2$ in Table I, and the agreement is found to be good.

[1]D. Romell, Nature 167, 243 (1951).
[2]A. Dattner, Ericsson Tech. 13, 309,350 (1957).
[3]N. Herlofson, Arkiv Fysik 3, 247 (1951).
[4]R. W. Gould, Proceedings of the Linde Conference on Plasma Oscillations, 1959 (unpublished).
[5]E. Åström, Arkiv Fysik 19, 163 (1961).
[6]P. Weissglas, J. Nucl. Energy 4, 329,336 (1962), part C.
[7]B. Agdur and B. Enander, J. Appl. Phys. 33, 575, 581 (1962).

Table I. Measured and calculated values of $\langle\omega_p{}^2\rangle/\omega^2$ for the main resonance.

f (GHz) / d (mm)	1.1		1.9	
	Measured	Computed	Measured	Computed
32	2.90	2.62	2.79	2.75
20	2.79	2.80	2.99	2.98
16	3.02	2.91	3.17	3.04
12	3.06	2.95	3.16	3.07
8	2.98	3.28	3.13	3.37

RESONANCE OSCILLATIONS IN A HOT NONUNIFORM PLASMA

Peter Weissglas
Swedish State Power Board, Vällingby, Sweden
(Received 12 February 1963)

In a previous paper,[1] the Boltzmann-Vlasov equation was taken as a starting point for a study of longitudinal plasma oscillations. The electron density in the steady state was assumed to be uniform and the plasma enclosed between two perfectly reflecting, infinite plane walls. A series of resonances was found for frequencies higher than the plasma frequency ω_p. Of these resonances, only odd-order ones could be excited by external fields. It was shown that the hydrodynamic equations give correct results when the applied frequency is close to ω_p. For higher frequencies, details in the velocity distribution become important which cannot be described by a pressure term. Gould,[2] using the hydrodynamic equations, has found that in the cylindrical case one obtains a resonance of a somewhat different kind at a frequency $\omega_p/\sqrt{2}$ in addition to what ap-