3.25 An anomaly in dipole resonance couplers

B. V. STANIĆ and B. A. ANIČIN, *Institute of Nuclear Sciences "Boris Kidrič", Beograd, Yugoslavia*

Dipole resonance oscillations in a bounded plasma and possibilities to use them as a diagnostic tool have been known from the early Tonks paper1). Later on it was discovered that a series of somewhat weaker resonances appear with the main resonance and these have been studied in great detail by Dattner2).

We have studied the main dipole resonance in the positive column of a low-pressure mercury vapour discharge, using split cylinder couplers as described by Crawford3). Two couplers of different diameters were used, the first was mounted tight on the tube; the second had three times larger radius. The dipole resonance frequencies f_R have been measured over a range of discharge current I_a. This was carried out by holding constant source frequency and varying the discharge current. The effects of external circuit have been minimized by observing transmitted signals in a matched coaxial system. The results of all measurements are summarized in Fig. 1., where f_R^2 is plotted as a function of discharge current I_a. In the cold plasma approximation these curves should be straight lines passing through the origin. Our experimental results in Fig. 1. lay on straight lines not passing through the origin and the cold plasma model is not strictly applicable.

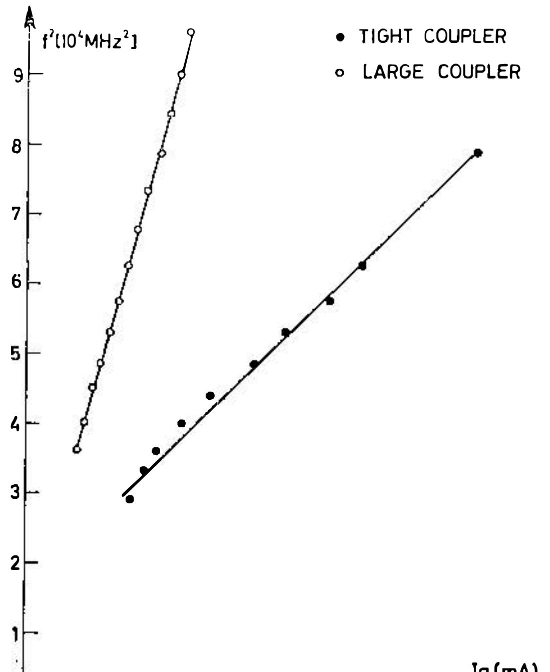

Fig. 1 Square of dipole resonance frequency as a function of discharge current.

Using hydrodynamic equations Parker, Nickel and Gould$^{4)}$ have treated the plasma wave resonances in the quasistatic approximation. By numerical solutions of corresponding equations they have found that a nonuniform plasma column gives large separations between the different resonances, as observed experimentally. They have plotted $(f_R/f_P)^2$ as a function of $(a/\lambda_D)^2$, where f_p is the mean plasma frequency, a the plasma column radius and λ_D the Debye length. For the cold plasma model this is a straight line parallel with the $(a/\lambda_D)^2$ axis. Taking into account thermal electron motion they have got corresponding curves for the main and higher resonances. We have compared our results for the main resonance with these theoretical curves. To effect the comparison, the mean plasma frequency f_p has been measured by surface wave and probe techniques$^{5)}$; the electron temperature by Langmuir probe techniques. The normalized results are presented in Figures 2 and 3. The agreement is obviously poor. The best fit would require to assume T twice smaller in the case of the tight coupler and 10 times smaller in the case of the large coupler, which is quite unreasonable. It is important to note that a large error in the measurement of electron density could not have caused the discrepancy. A 30% decrease in electron density would move the experimental points 30% up and 30% to the left, leaving the experimental curve practically unchanged; a 30% increase would move the points 30% to the right and 30% down, with much the same effect.

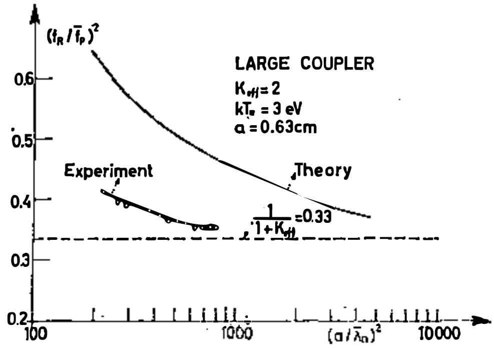

Fig. 2 Normalized curves for tight coupler.

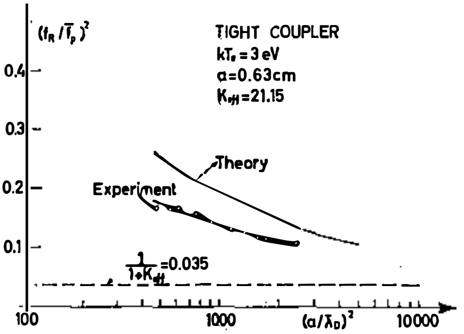

Fig. 3 Normalized curves for large coupler.

It is interesting to note that Butterworth and Moore$^{6)}$ have noted a very similar effect in an entirely different, free space experiment. They find that the electron temperature necessary to fit their experimental data to the theory of reference$^{4)}$ is 14 500 K which is much lower than expected.

References

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