Landau Waves: An Experimental Fact

H.Derfler and T.C. Simonen

Phys.Rev.Lett 17 (1966) 172

First experimental verification of Landau damping and Bohm-Gross dispersion in $\sim$ uniform 1-D plasma.

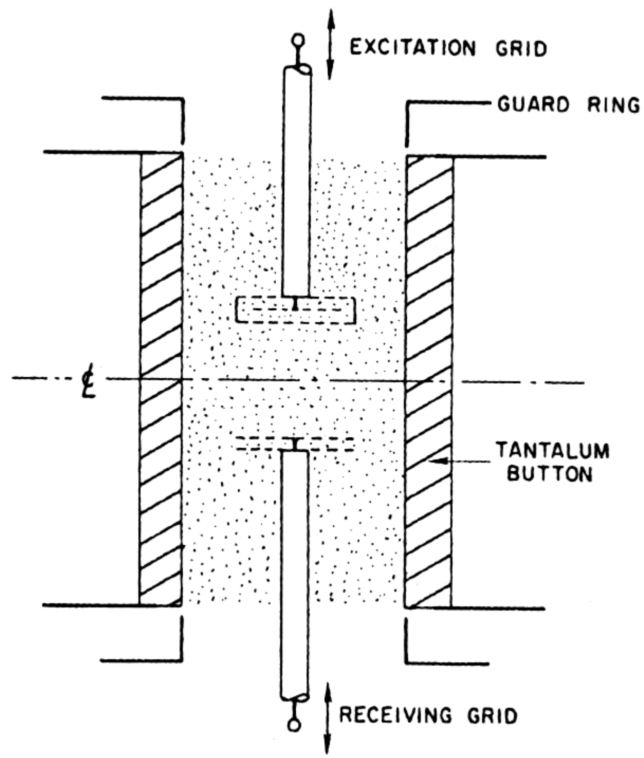

FIG. 1. Diagram of the sodium plasma tube showing the probe arrangement.

Wave launched at a steady (real) frequency ω, controlled by an RF generator.
Detected at a variable distance.

Grids used so that the problem is approximately 1-dimensional.

Observed signal

Shows an oscillation strongly damped in space.

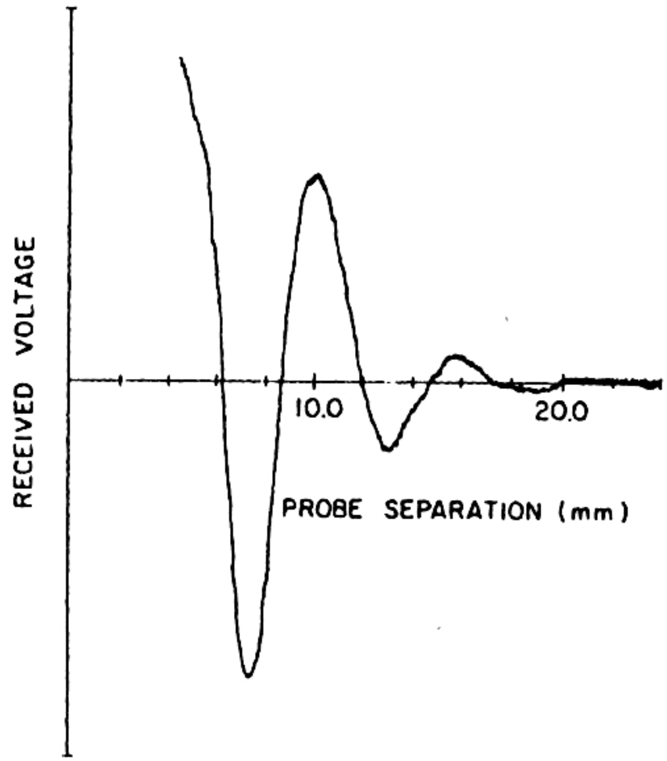

FIG. 2. Interferometer output at 95 Mc/sec as a function of grid separation.

This is interpreted as giving the real and imaginary parts $k = k_r + ik_i$.

Dispersion Relation

Shows agreement with full kinetic theory calculation for $\omega_p < \omega \lesssim 4\omega_p$

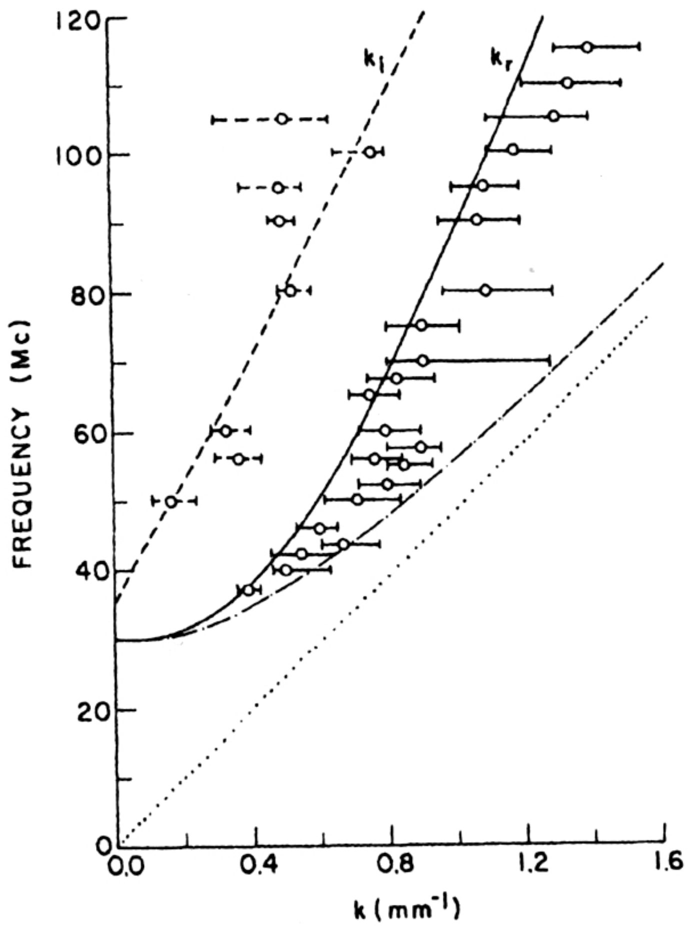

FIG. 3. Dispersion diagram: Circles with bars through them, experimental measurements; k_γ and k_i Landau Eq. (1); dotted curves, thermal speed $\omega/k = \sqrt{3}\,\kappa T/m$; and dash-dotted curves, Bohm and Gross, Eq. (2).

[Bohm-Gross relation a poor approx for higher ω.]

Dispersion of Electron Plasma Waves

J.H.Malmberg and C.B.Wharton

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Performed in a longer plasma column.

The transverse gradients are large.

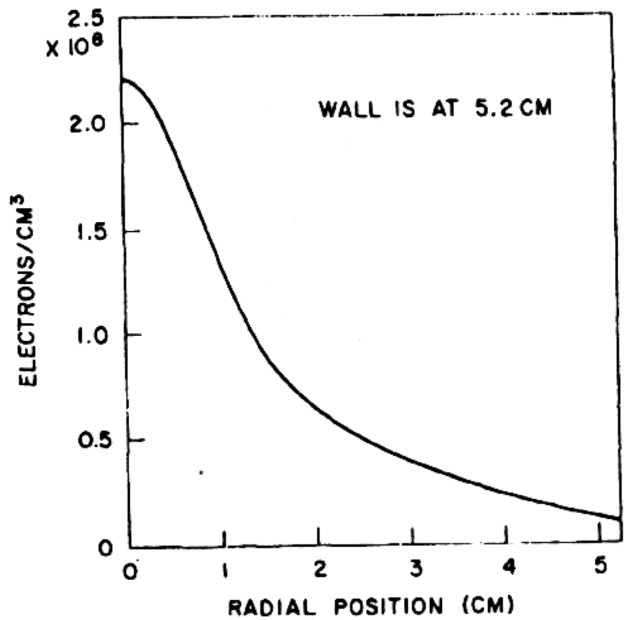

FIG. 1. Electron density as a function of radial position.

Not quite as ideal a situation, but rather quieter signals. Basically similar technique.

Data Obtained

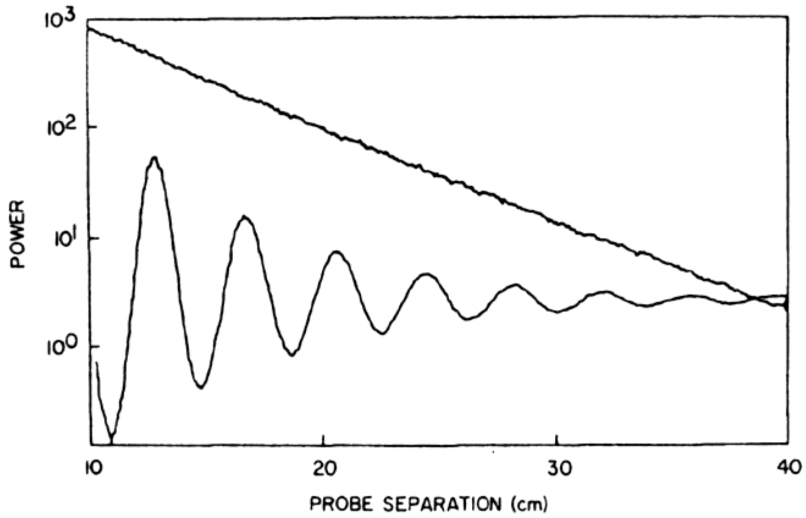

FIG. 2. Raw data. Upper curve is the logarithm of received power. Lower curve is interferometer output. Abcissa is probe separation.

Longer wave train allows more accurate k-determination.

Dispersion Relation

Has to account for transverse variation.

Consequently is not simply

$$\omega^2 \approx \omega_p^2[1 + 3(k\lambda_D)^2]$$

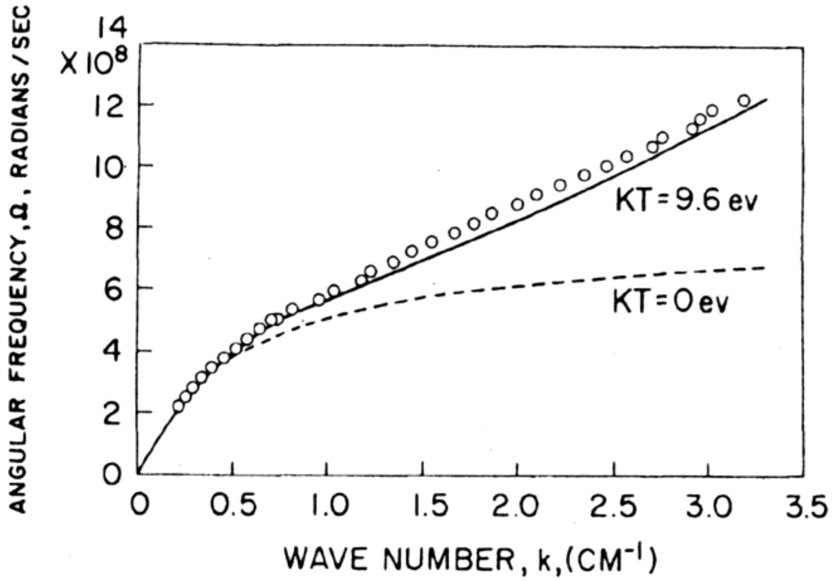

FIG. 3. Dispersion curve. The dashed line is computed assuming the plasma temperature is zero. The solid line is computed using the measured plasma temperature. The circles are experimental.

Theory and experiment agree well using exptl T_e

(n_e adjusted within exptl uncertainty to fit).

Agreement becomes exact if T_e is increased 10%.

Damping Agrees with Landau Theory

Plotting (log)k_i/k_r versus $(\omega/k_r v_{te})^2 = (v_p/v_{te})^2$

gives a straight line.

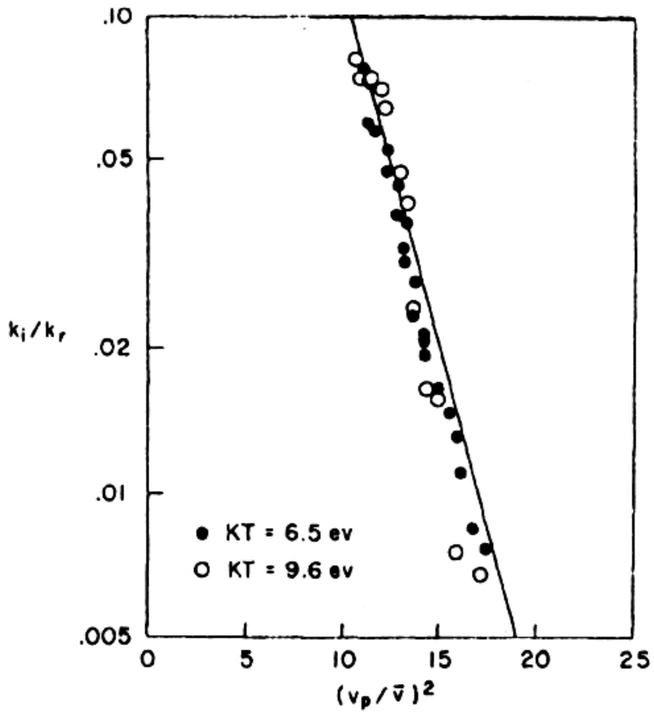

FIG. 4. k_i/k_γ vs $(v_p/\bar{v})^2$. Solid curve is the theory by Landau.

Theory is verified over a factor of about 10 in damping decrement.

Ion Acoustic Waves

A.Y.Wong, N.D'Angelo, and R.W.Motley

Phys.Rev.Lett. 9 (1962) 415

In the plasma column of a Q-machine

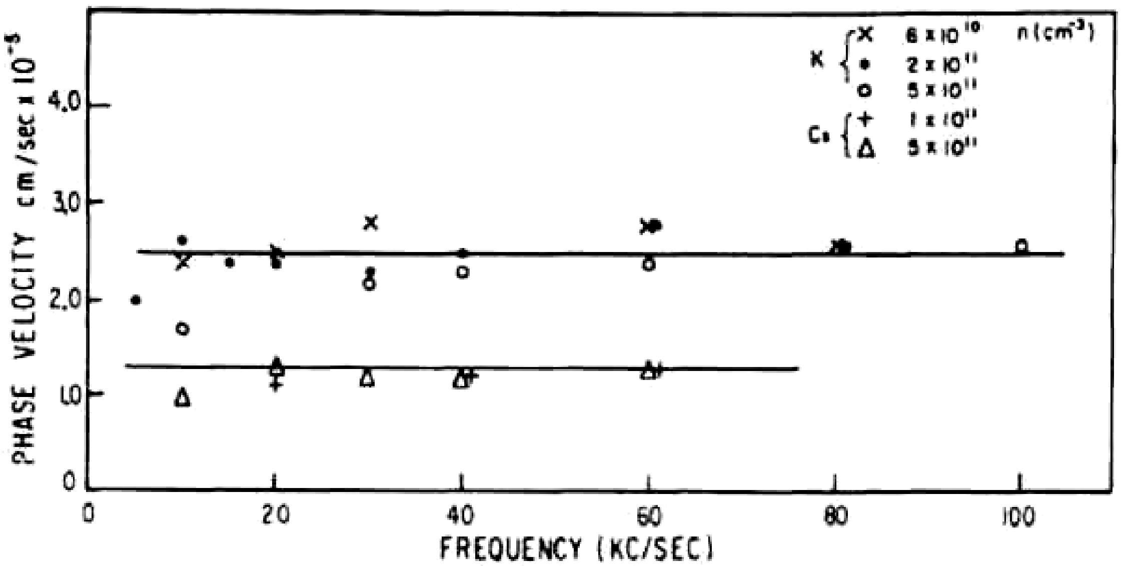

FIG. 1. Phase velocity of ion waves vs frequency, for cesium and potassium.

Have constant phase-velocity, independent of frequency.

Plasma temperature not well measured.

Density varied nearly a factor of 10.

Damping Decrement

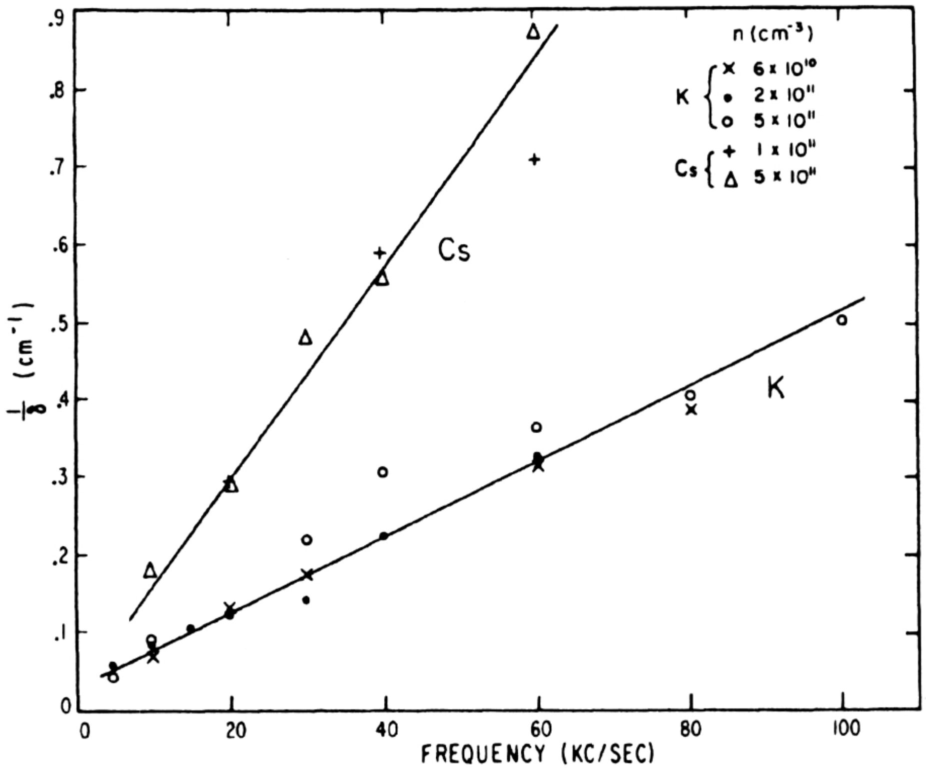

FIG. 2. $1/\delta$ vs frequency, for cesium and potassium; δ = damping distance.

Damping goes like $\exp(-x/\delta)$

- $1/\delta \propto \omega$. $\delta \approx 0.6\lambda$
- δ independent of n (not collisions).
- $\delta \propto m_i^{-1/2}$

Consistent with Landau damping.