

Low Frequency Oscillations in Tonks-Dattner Resonances

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A positive column has a parabola-profile of the zeroth order electron density, Tonks-Dattner resonances efficiently absorb H.F. (high frequency) power at $\omega \simeq \omega_p$ and L.F. (low frequency) oscillations are parametrically excited.

In this programs, advanced experiments are scheduled based on the results up to now.

An inquiry of the source of the parametric excitation is described in Program 1.. A research for the ion plasma oscillation is in Program 2.. A description of the measuring-mode of Q value is in Program 3.. The last Program 4. is a study on the frequency shift of the L.F. oscillation.

Program 1. 2. are carried out in a lager discharge tube (inner diameter=94mm) of mercury vapor.

1. Introduction

We have studied a consistent observation of low frequency oscillations parametrically excited in Tonks-Dattner resonances.¹⁾

In our experiment, important merits in the observation are brought about by the following features:1). The frequency of H.F. wave is selected in VHF region (413 MHz), and a large tube with a moving probe to the radial direction (inner diameter=46 mm or 94mm, mercury vapor discharge tube) can be employed. 2). Exciter of Tonks-Dattner resonances is a split cylinder dipole studied by Parker and Nickel.²⁾

Owing to the above points, radial patterns of L.F. wave (ion sound wave) and H.F. wave (Tonks-Dattner resonances) are experimentally obtained.¹⁾ The former's pattern is qualitatively agreeable with the theoretical curve given by R.Rosa et al.³⁾ The latter's fairly agrees with the result of the direct measurement obtained by Parbhakar et al.⁴⁾. Other merit is that due to the split cylinder dipole the H.F. system becomes more simple than other wave guide or cavity system, but a disadvantage may be acknowledged that there is much leakage of H.F. power and Q value is not measured accurately compared with the cavity system.

The results of experiment until now are following:¹⁾

1). When the power of H.F. wave is increased and then decreased at the constant discharge current 20~30mA, hysteresis loops appear. They are Resonantly sustained modes (Auto-resonance modes) of Tonks-Dattner resonances.

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- 2). In a certain region of the hysteresis loop, there excited low frequency oscillations parametrically. One is an ion sound wave and its harmonics, the other may be an ion plasma oscillation.
- 3). In the superposed region of the two excitations, there appears the latter's spectrum amplitude-modulated by the former's.
- 4). According to the lock-in operation fixing the H.F. power at the last Resonantly sustained mode, it is shown that the ion sound wave is not a standing wave having the maximum amplitude at $2/3 \cdot b$ position (b : plasma column radius).⁵⁾
- 5). In Non-resonantly sustained mode obtained in the case when the discharge current is increased, the ion sound wave is excited at lower H.F. power and the frequencies f_n shift to the high frequency side with increasing the H.F. power. The relation is assumed to be $f_n \propto n\sqrt{T_e}$ (n : integer of harmonic order, T_e : electron temperature).
- 6). The ion sound wave disappears as the pressure is increased.
- 7). The low frequency oscillations are not excited in the surface mode region.⁶⁾

The main purpose of this paper is proposals of interesting experiments for the next research based on the above results, and the expected results will be soon published anywhere. The authors wish this paper to cause a good deal of comment.

2. Programs

Program 1.

Where does the ion sound wave come from? The question is not answered because the radius of tube is so small that the moving probe to the radial direction cannot be inserted. This is related that the the frequency of the H.F. wave was set in μ -wave region. The merit described in above introduction enables the investigation of the source parametrically excited in Tonks-Dattner resonances.

As shown in Fig. 1, a large tube (inner diameter=94mm, mercury vapor discharge tube) is employed so that steady state discharge current is swept all over the Tonks-Dattner resonances. Phase operation is executed as well as lock-in operation at any Tonks-Dattner modes. Watching the branch-point of the phase (e.g., the phase lag and the phase lead), this is the source-point, which may be expected to move toward the outside as the discharge current is increased up to the main mode. At a distance from the source-point the phase is lag and inside the source-point, maybe $\omega_p > \omega$ and outside, the inequality may be reversed as, $\omega_p < \omega$. The relation suggested above is shown in Fig. 2.

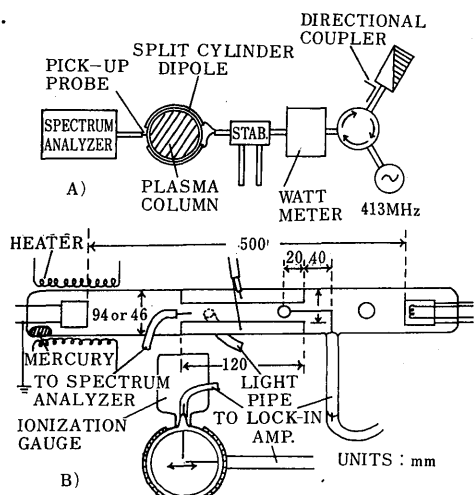


Fig. 1. Experimental set-up.

A). Sketch of the outline.

B). Discharge tube.

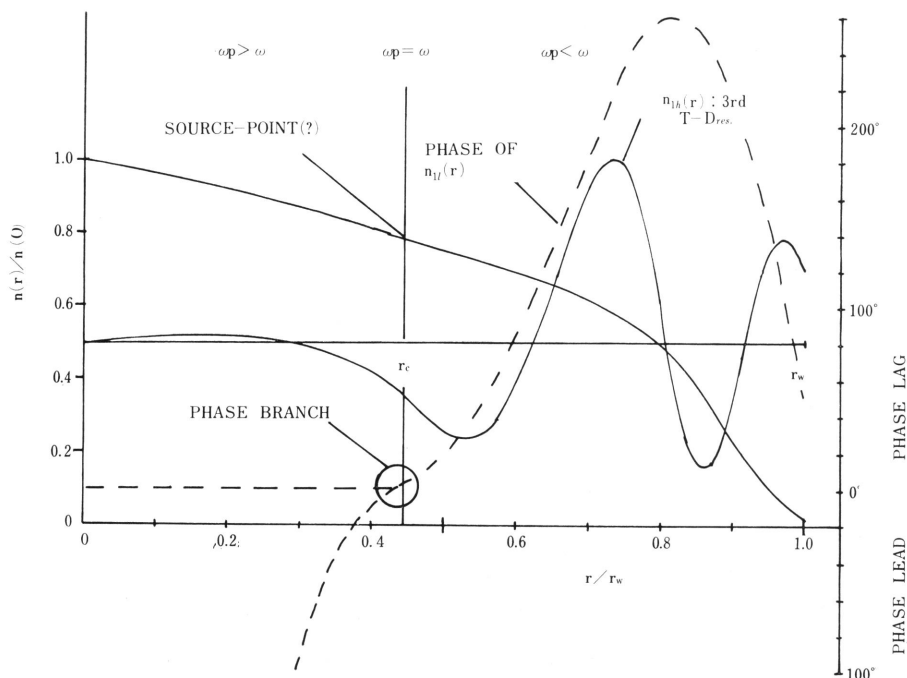


Fig. 2. Source-point of parametric excitation. $n(r)/n(0)$ and $n_{1h}(r)$ are from reference 2. Dashed line is examined for the source point.

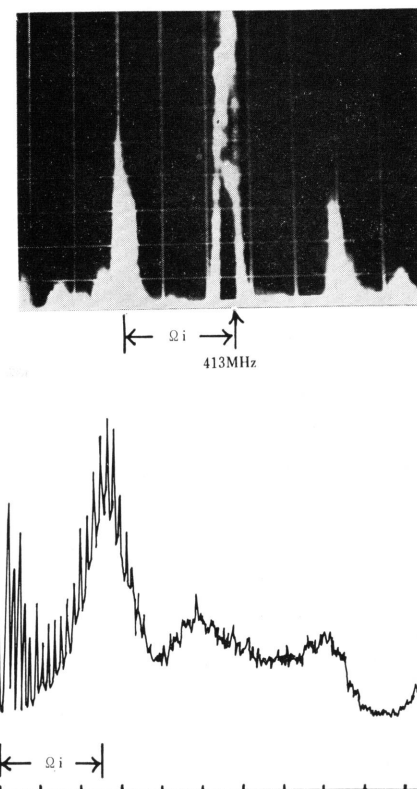
Program 2.

Recently, ion plasma oscillation excited in Tonks-Dattner resonances has been studied.⁷⁾ This program is also carried out in 94mm tube. The radial pattern of ion plasma oscillation is examined and, if possible, the excited-processes are also examined. The amplitude-modulated spectrum excited in 46mm tube at the last Tonks Dattner resonance is shown in Fig. 3.

Program 3.

Accurate measurement of Q value due to the power loss of low frequency oscillation is difficult,⁸⁾ chiefly because the H.F. wave exciting the L.F. oscillations has considerably high power so that the pattern of the Q value is no longer defined. In order to answer the problem, the

→**Fig. 3.** Spectra of parametric excitation carried out in 46mm tube. Ω_i is the frequency of ion plasma oscillation. Spectrum of the L.F. oscillation is amplitude-modulated by ion sound wave. The photo is the H.F. spectrum.



measuring-mode at lower H.F. power is experimentally examined.

The Q value belongs to both eigen cavity mode and its loss process by nature. When an eigen mode is chosen, the main field components and their patterns must be accepted. If the vector k_h of the main field component is parallel to the vector k_i of the L.F. wave, i.e., $k_h \parallel k_i$ and if the distribution of the H.F. wave pattern is localized at that of the L.F. wave pattern, the coupling between the H.F. wave and L.F. wave is strong. Mis-coupling mode is not available for the measuring mode because its signal is not assured to involve the L.F. information. In conclusion, the stronger coupled mode as well as the lower-power mode is the more suitable for the measuring-mode.

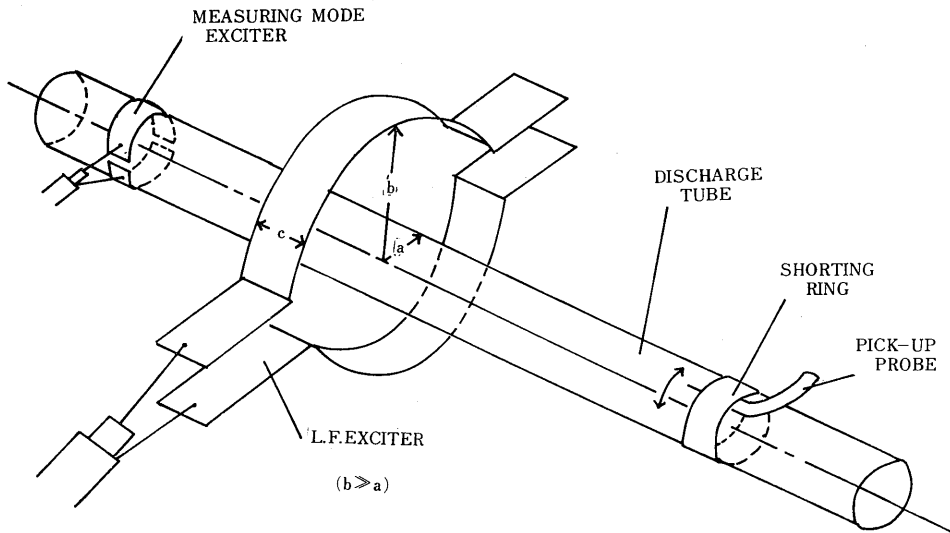


Fig. 4. Experimental set-up for the measuring-mode of Q value. The measuring-mode of Tonks-Dattner resonance traveling toward the axial direction is beamed by the split exciter and the wave travels through the L.F. exciter ($b \gg a$, the L.F. oscillation is excited parametrically) and is reflected by the shorting ring, and the Q device is formed. It may be better for the width c of the exciter to be widened and to cover the measuring-mode rings completely.

According to the last result in the introduction, surface mode cannot be adopted for the measuring-mode because of mis-coupling. Fortunately the Tonks-Dattner mode⁹⁾ traveling toward the axial direction is more suitable. The experimental set-up in order to examine that the Tonks-Dattner mode is more suitable for the measuring-mode of Q value than the surface mode is shown in Fig. 4.

Program 4.

The frequency shift of the L.F. oscillations (especially ion sound wave) is interesting.¹⁰⁾ The resulting figures described in the above introduction are shown in Fig. 5 and Fig. 6. The relation is assumed to be $f_n \propto n \sqrt{T_e}$ due to the rising of electron temperature. Another frequency shift to the low frequency side is shown in Fig. 7. This appears often at lower H.F. power. The phenomenon seems to be Landau-damping of ion sound wave.

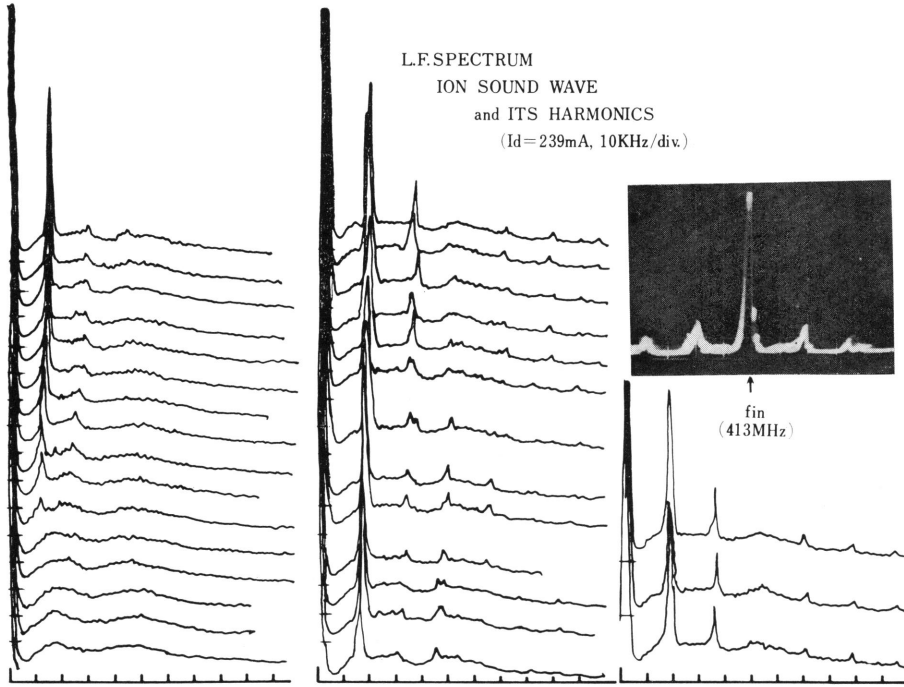


Fig. 5. Spectra with the frequency shift to the high frequency side. From the downward to the upper and from the left side to the right, the parameters V_B (Battery-voltages of the H.F. generator) are increased up to about 1 watts of the H.F. power. The photo is the H.F. spectrum.

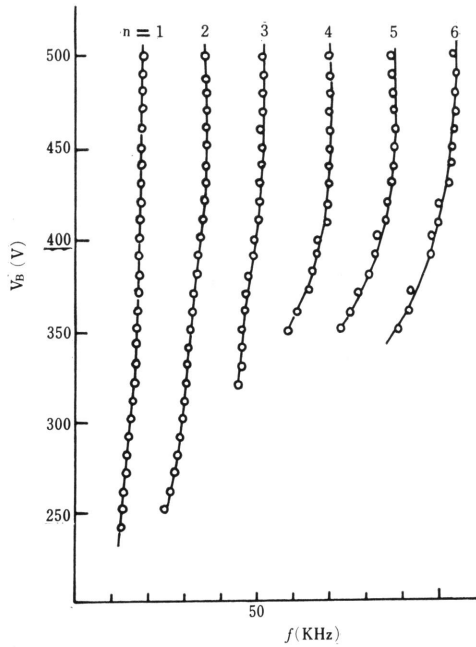


Fig. 6. Assumed curve $f_n \propto n\sqrt{T_e}$. n : integer of harmonic order, T_e : electron temperature, V_B : Battery-voltages of the H.F. generator.

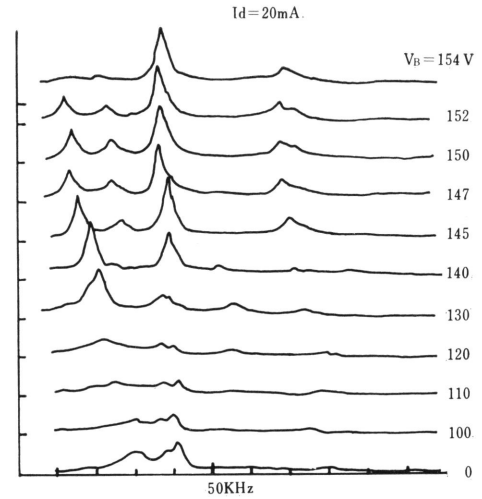


Fig. 7. Spectra with the frequency shift to the low frequency side observed in 25mm tube. The parameters are V_B .

The experiments of the programs 1.3.4. are executed about Non-resonantly sustained mode of Tonks-Dattner resonances.

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