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Emission of High Frequency Oscillations and its External Control by Low Frequency Fields

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Emission of high frequency oscillations, whose frequencies (30–150 MHz) are close to the plasma frequency $\omega_p/2\pi$, are observed in low density plasmas only at pressures of 10^{-5} Torr. The emission is observed to occur continuously or intermittently depending on the plasma condition. Further, the emission is found to be possibly controlled by an externally applied low frequency (kHz) field under some appropriate condition.

INTRODUCTION

Amplification or emission of high frequency plasma waves or oscillations, caused by an externally appplied dc or low frequency field, is one of the most attractive phenomena in plasma physics, because this has something in common with the laser or maser oscillators. Some of the past studies on such a problem lead nawadays to the availability of powerful generators of microwaves such as gyrotrons. On the other hand, a phenomenon of high frequency wave emission by the plasma maser has been theoretically studied by Nambu [1]. However, nobody has experimentally succeeded in verification of such emission as predicted by him. In this paper, we report observational results on the emission or self–excitation of high frequency (30–150 MHz) plasma oscillation and try the external control of the emission by a low frequency (kHz) field.

EXPERIMENTAL METHODS

In this experiment we used a conventional double plasma (DP) device [2]. Then, in low density plasmas ($n_e \lesssim 2\times10^8$ cm^{-3}) only at pressures of 10^{-5} Torr we could observe the emission of high frequency (HF) oscillations in the range of 30–150 MHz. Here, measurements of the emitted oscillations were always made in the 'target' plasma region despite with or without discharge in this region. Signals received by a probe were led to an oscilloscope or a specral analyzer.

To control the emission by a low frequency (LF) field, an rf voltage with an appreciable amplitude V_{ex} ($\lesssim$ 50 V) and a frequency f_{LF} ($\lesssim$ 400 kHz) was externally applied to the driver plasma chamber, so that the plasma potential in the chamber was largely shaken around a dc level. Therefore, the plasma condition for the emission was periodically changed.

EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Emission of high frequency oscillations

To know what plasma parameter determines the frequency of an emitted HF oscillation, we studied first the properties of the oscillations through their spectra at various gas pressures, keeping filament temperature constant. From the spectra observed, the frequency f_{HF} of the HF oscillation was found to change with changing plasma density n_e, as shown in Fig.1. This relation indicates that the frequencies of HF oscillations are very close to the plasma frequency ω_p. A similar relation was obtained in experiment where the plasma density n_e was varied by changing the filament temperature at a fixed gas pressure. From these results it is concluded that the emitted HF oscillations correspond to the plasma oscillations.

Furthermore, the emission of HF oscillations was observed to occur continuously or intermittently depending on the plasma condition, as seen from Fig.2. Moreover, simultaneous observations of the spectra of HF oscillations let us know that the continuous emission brings only a sharp spectral line in the specrum, but the intermittent emission does a group of several lines. This means that the intermittent emission is obtained as a result of a kind of amplitude modulation of the emission by some lower frequency oscillations. Here, the modulation frequencies in this case depend on the plasma condition and position.

B. External control of the emission by a low frequency field

Under some appropriate plasma condition the emission of HF oscillation was found to be possibly controlled by a LF field, externally applied to the driver plasma chamber. In this case the applied LF field lets the driver plasma potential greatly oscillate around a dc level. Here, the dc level is also externally controllable. In this experiment we studied first the dependence of the HF oscillation power on the LF amplitude V_{ex}. Examples of oscilloscope traces, showing both the applied LF signals and the emitted HF ones, are shown in Fig.3(a) and the corresponding spectra are also given in Fig.3(b). On the basis of such spectra thus observed we can obtain a relation of the HF oscillation power with V_{ex}, as shown in Fig.4. Using a similar method, the dependence of the HF oscillation power on the LF frequency f_{LF} at a fixed value of V_{ex} (= 50 V) was studied. From the spectra observed at various f_{LF} the relation of the HF oscillation power with frequencies f_{LF}, as shown in Fig.5, is obtained.

Moreover, we studied the effect of the applied LF field on the spectral line shape of HF oscillation. Observations demonstrate that the increase of f_{LF} reduces the width of the main spectral line. Sideband peaks appearing in the observed spectra are generated by the coupling of the emitted HF oscillation (corresponding to the main spectral line) with the applied LF one. Furthermore, the center frequency of the main spectral line

was also observed to be slightly changeable depending on f_{LF}.

CONCLUSION

Based on the relation of the emitted HF oscillation frequency f_{HF} with plasma density n_e, the HF oscillations are concluded to correspond to the plasma oscillations. Further, the HF emission were found to depend on various plasma parameters. These dependences can not be well interpreted at present, because the mechanism of the emission is not yet clarified. So, to clarify the mechanism of HF emission, it is necessary to study the emission under various realizable conditions in near future. In addition, the control of the emission by externally applied LF fields were observed to be possible under some appropriate plasma condition, but reasons for this are not yet clear, too.

References

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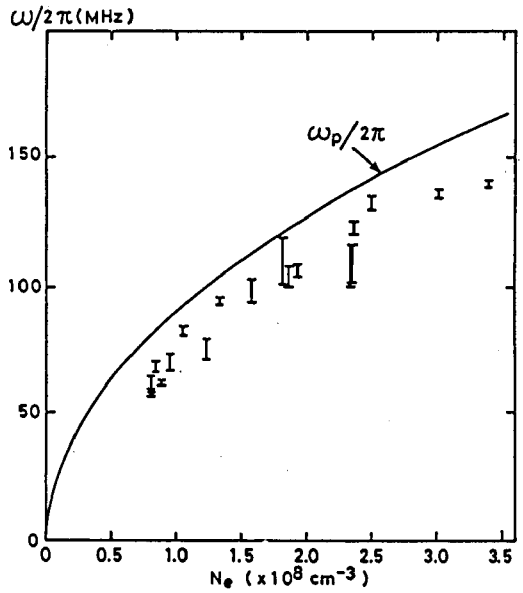
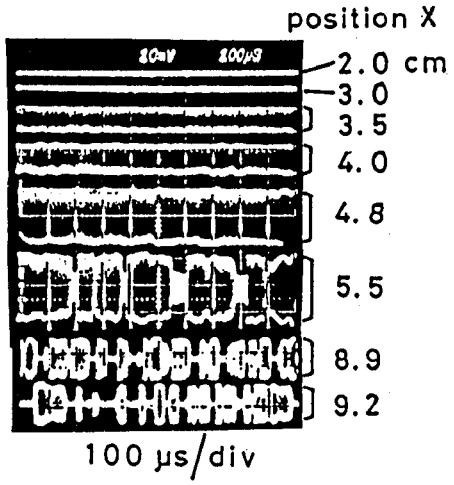
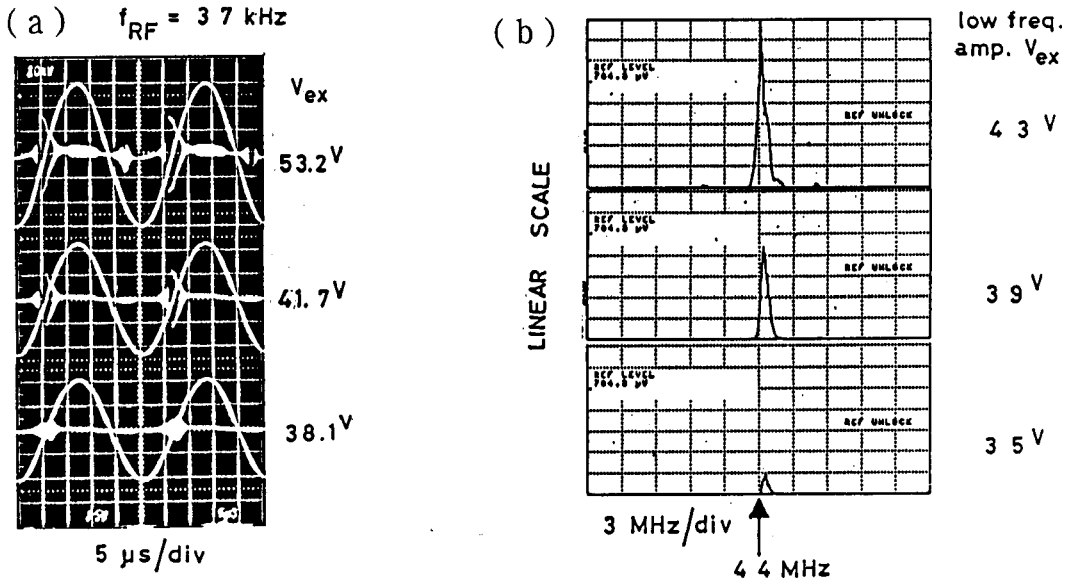


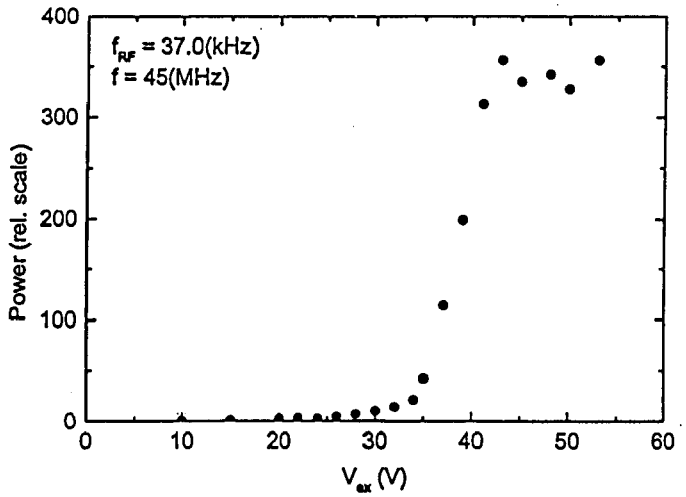
[Fig.1] Relation of HF oscillation frequency with plasma density.



[Fig.2] Oscilloscope traces of HF oscillation signals observed at various x. (f_{HF} = 40−45 MHz)



[Fig.3] (a) HF signals controlled by applied LF fields with amplitudes V_{ex}. (b) Spectra of HF oscillations changing with V_{ex}.



[Fig.4] Relation of HF power with LF amplitude V_{ex}.

[Fig.5] Relation of HF power with LF frequency f_{RF}.