DEVELOPMENT OF MODIFIED DOUBLE PLASMA DEVICE APPLICABLE TO BASIC PLASMA WAVE EXPERIMENTS

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A modified double plasma (MDP) device is newly developed and shown to be useful for basic plasma wave experiments. Further, the mechanism of wave excitation in the MDP device is experimentally clarified.

In the 1970's Taylor *et al.* [1] developed a double plasma (DP) device for making basic plasma experiments. Thereafter, many workers in the world have employed this type of device to perform various basic experiments on linear and nonlinear waves in plasmas. From these works the DP device is now known to be very useful to study particularly nonlinear phenomena in plasmas. The mechanism of wave excitation in the DP device was experimentally clarified by Honzawa [2] and Tsikis *et al.* [3].

By the way, we intend here to introduce a modified double plasma (MDP) device and want to emphasize its usefulness for basic plasma wave experiments. The MDP device is similar to the DP device, but it includes a discharge plasma only in the target plasma chamber and no discharge in the other (driver) chamber. But, since the separation grid is here electrically floated or negatively biased around -30 V, many plasma ions in the target plasma can pass easily through the grid and form a sheet of high density ion cloud close to the grid in the "driver" chamber, while most of plasma electrons are repelled by the negatively biased grid. In order to get an information on the density profile of ion cloud and plasma ions in the driver chamber, we performed measurements of ion energy distributions at various axial distances x_D from the grid by use of a small electrostatic energy analyzer [4], which was movable along the axis of the device (x- axis). Here, x_D means the axial distance from the grid on the *driver* side. From these measured ion energy distributions we could estimate the total ion currents as a function of x_D in the same manner as used in Ref. [4]. Profiles of the total ion current in the driver chamber thus obtained are shown in Fig. 2(a). These include several profiles observed at several values of V_B, where V_B is the driver chamber wall potential. From these observed profiles we can know that there always exists a sheet of high density ion cloud around $x_D \simeq 0.7$ cm and a small amount of ions beyond the ion cloud ($x_D \gtrsim 1$ cm). Furthermore, the profiles of the total ion cloud in both the regions of $x_D < 0.7$ cm and $x_D \gtrsim 1.0$ cm are found to be greatly changeable sensitively depending on the value of V_B under the above condition, where the grid is electrically floated ($V_g \simeq -28$ V). For example, when V_B changes from $V_B = -5.0$ V to -4.0 V in Fig. 2(a), the total ion current becomes higher by a factor 1.2 at $x_D \simeq 0.3$ cm, while it becomes lower by a factor 2 at $x_D \gtrsim 1$ cm. On the other hand, under a different condition, where V_g was much lower, for example, $V_g \lesssim -90$ V, observations indicated that the profile of the total ion current was hardly changed at all the distances x_D, as shown in Fig. 2(b), even though V_B was largely changed. Therefore, under such a condition the profile was found not to be externally controllable.

As seen from the total ion current profiles in Fig. 2(a), the ion density in a region close to the grid as $0 < x_D < 0.7$ cm in the driver chamber is found to considerably increase when V_B changes from $V_B = -5$ V to -4 V. This fact lets us expect that if the wall potential V_B is pulsedly raised, the ion density near the grid in the target chamber will be also pulsedly enhanced and then cause wave excitation there. This is because the coming and going of plasma ions between the driver and target sides are hardly interrupted by the grid. In fact, in the MDP device just as in the DP device a solitary wave could be excited in the target plasma by superposing an external positive potential pulse on the driver chamber wall potential V_B. Typical examples of evolving wave signals observed at various distances x_T are shown in Fig. 3. Here, x_T means the axial distance from the grid on the *target* side. These indicate that when a positive pulse is externally applied to the chamber wall, a positive density pulse appears at small distances ($x_T \lesssim 0.3$ cm) in the target plasma. Furthermore, it is known from Fig. 3 that a new sharp peak appears in the front part of the initial positive density pulse around $x_T \simeq 0.5$ cm and its amplitude rapidly grows with increasing x_T. Then, the amplitude of the new sharp pulse is saturated at $x_T \simeq 2.0$-2.5 cm and at the same time the steepening at the leading edge of the pulse stops. Thus, a solitary wave is formed. Around $x_T \simeq$ 2.3 cm a precursor pulse begins to separate from the solitary pulse. On the other hand, the amplitudes of the other parts behind the solitary pulse gradually damp with increasing x_T . The feature of the wave excitation is very similar to the one in the case of the conventional DP excitation [2] except the appearance of the initial positive density pulse at an early stage ($x_T \lesssim$ 0.3 cm). However, only a small amount ($n_b / n_e \lesssim 1$ %) of stationary beam ions could be generated in the MDP device, even when an appreciable potential difference was applied between the two chamber walls. Thus, excitable waves in the MDP device are expected to belong to *ion-acoustic modes*. In fact, the velocity of a solitary wave is estimated to be about 1.6 $\times 10^5$ cm/sec in the case of Fig. 3, which is almost equal to the ion-acoustic velocity as observed in a conventional DP device [2,3].

When an rf voltage was applied to the driver chamber, groups of ions could be periodically injected from the driver chamber to the target one through the grid. As a result, a continuous wave was possibly excited in the target plasma. Evolution of such a continuous wave was similar to the one of a solitary wave described above. In this case, however, the efficiency of the periodic ion injection into the target plasma is expected to be dependent on the applied rf frequency. This is because a finite time may be required for the ion density profile in the driver chamber to recover from the deformation after it is changed by the ion ejection. In order to study the frequency-dependence of the wave excitation efficiency, we observed the amplitude of excited wave as a function of the rf frequency f_{rf} at a fixed position ($x_T \simeq 5$ cm). Result thus obtained shows that the wave excitation efficiency gradually falls with increasing f_{rf} above $f_{rf} \simeq 200$ kHz. Furthermore, we studied the dispersion relation of continuous waves excited in the MDP device. For this purpose the wave patterns of small amplitude waves were measured at various f_{rf} . Dispersion relation of the excited waves thus obtained is shown in Fig. 4. This relation demonstrates that the waves excited in this device belong to the *ion-acoustic modes.* We could not observe any other mode in the MDP device..

References

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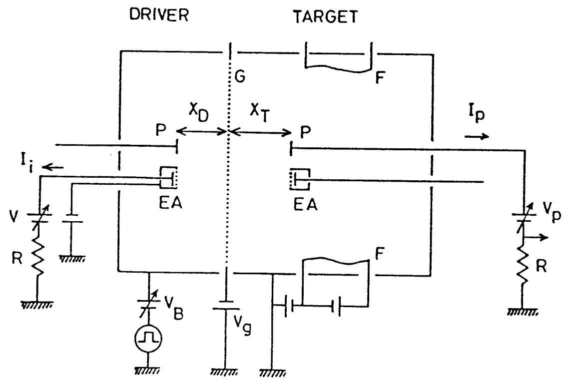

Fig.1. Schematic picture of apparatus.

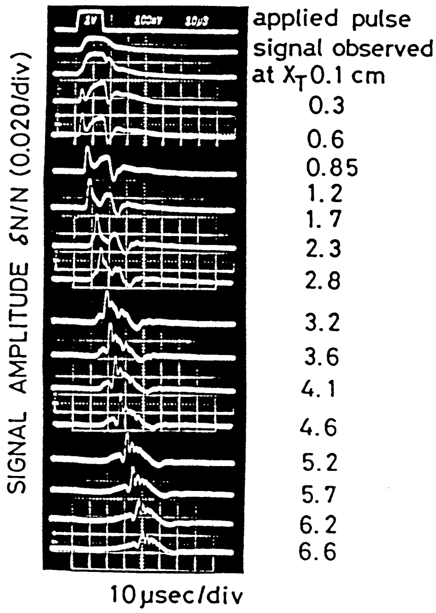

Fig.3. Oscilloscope traces of evolving waves.

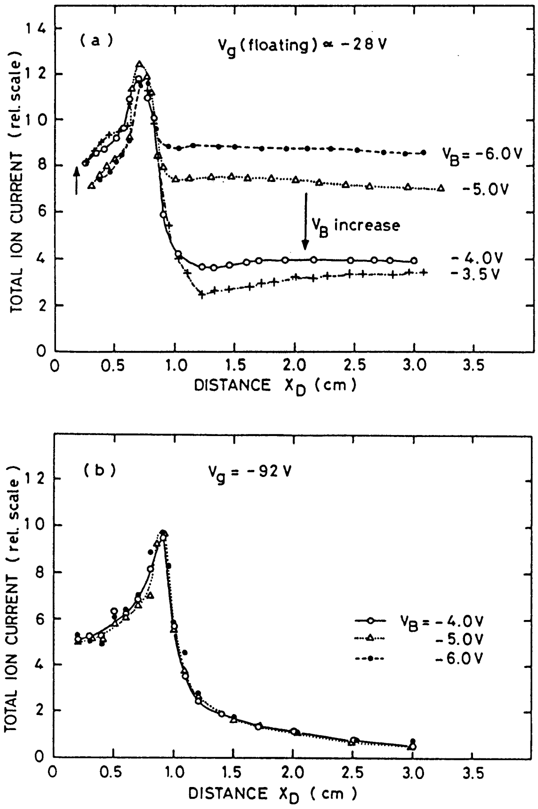

Fig.2. Profiles of the total ion currents at (a) Vg(floating) = −28 V and (b) Vg = −92 V.

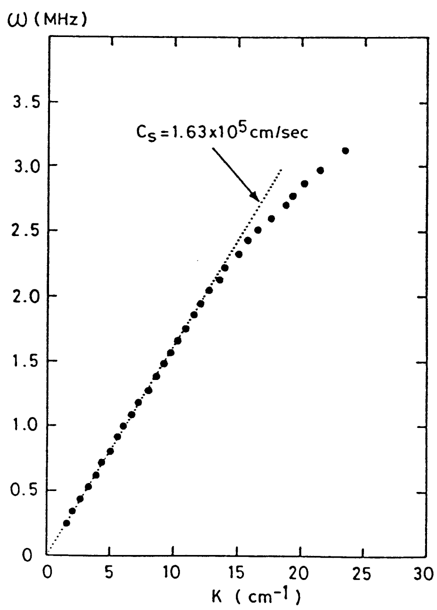

Fig.4. Dispersion relation of waves excited in the MDP device.