§35. Properties of Pair Nanomolecule-Ion Plasma

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A special interest is focussed on a plasma consisting of charged particles with an equal mass, for example, such as two-species electron-positron plasma [1] and fine particle plasma produced by a photo-ionization [2]. Here our attention is concentrated on the generation of a stationary plasma consisting of positive and negative ions with the equal mass, and the investigation of basic plasma phenomena which are different from the ordinary plasma.

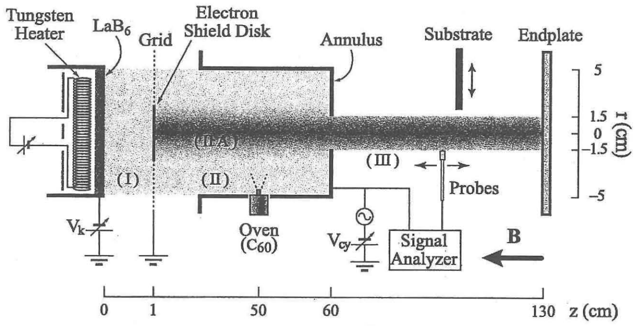

Fig. 1. Schematic diagram of experimental setup.

A conventional discharge-plasma source is modified in order to produce a fullerene-ion plasma in a experiment, as schematically shown in Fig. 1. A pair plasma including positive and negative fullerene ions (C_{60}^+, C_{60}^-) is successfully produced in the process of a hollow electron-beam impact ionization, an electron attachment, and an inward diffusion of ions in an axial magnetic field ($B = 3$ kG). The plasma density $n \simeq 2 \times 10^7$ cm^{-3} and temperature $T \simeq 1.2$ eV.

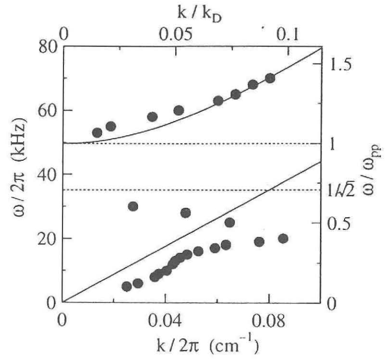

Fig. 2. Dispersion relation in the experimant.

Electrostatic plasma waves are excited using an external circuit in the region (III). The dispersion relation of the electrostatic waves are experimentally obtained in Fig. 2. Solid curves denote theoretically calculated dispersion relations ($\omega = c_s k$, $\omega = \sqrt{\omega_{pp}^2 + c_s^2 k^2}$). Here, the sound velocity $c_s^2 = \gamma T/m$ ($\gamma = 3$ for the ions) and pair-plasma frequency $\omega_{pp}^2 = 2e^2 n/\varepsilon_0 m$. Two modes are clearly found in the experimental result, which are the lower branch with frequencies less than $\omega_{pp}/\sqrt{2}$ and the upper branch with frequencies greater than ω_{pp}.

A computer simulation has been performed by means of a 3D electrostatic PIC code to investigate the properties of the excited waves in detail. The system size is 32×32×128 (grids) and the ratios of positive ion to negative ion mass and temperature are fixed to be $m_+/m_- = 1$ and $T_{+s}/T_{-s} = 1$ at the plasma source, respectively. The uniform magnetic field is $\omega_c/\omega_{ps} = 0.2$ and plasma diameter is $10\lambda_{Ds}$.

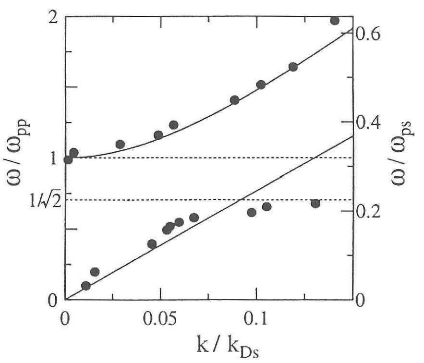

Fig. 3. Dispersion relation in the simulation ($\omega_{pp}/\omega ps = 0.32$).

The electrostatic plasma wave is externally excited by a sinusoidal variation in the number of supplied ions. The dispersion relations of the excited waves are shown in Fig. 3. Two modes are clearly found, and the lower branch appears to be an ion acoustic wave and the upper branch appears to correspond to an electron plasma wave in an ordinary electron-ion plasma. The wave does not propagte in the frequency range $1/\sqrt{2} < \omega/\omega_{pp} < 1$.

References

1) Surko, C. M. et al : Phys. Rev. Lett. **62** (1989) 901.
2) T. Yokota, T., Manabe, S. : J. Quant. Spectrosc. Radiat. Transfer **61** (1999) 219.