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Observation of instability in an electron beam plasma system between boundaries

Nobuya Hayashi[1]

[1] Fac. of Sci. and Eng., Saga Univ.

http://www.ee.saga-u.ac.jp/

When an electron beam plasma system is formed in the plasma between boundaries, the Pierce instability is generated. The chaotic dynamics of the Pierce beam plasma system including warm plasma effects has been studied numerically (H. Matsumoto et al., 1996). Also, the chaotic phenomena in the extended Pierce beam plasma system have been calculated varying the potential structure between boundaries (H. J. Lee et al., 1998). In this study, the bifurcation and chaotic phenomena due to nonlinearity of unstable waves in the electron beam plasma system between boundaries were investigated.

Unmagnetized Ar plasma was produced by the electron emission from heated tungsten wires. Two mesh electrodes made of stainless steal with the diameter of 80mm were set at parallel on the axis of the chamber with the distance of 50mm. One of the mesh electrodes was biased negatively Vm and the other was grounded. Electrons around the biased mesh were accelerated by the potential difference between the two mesh electrodes, and the electron beam was generated. The energy of the electron beam was controlled by the mesh bias voltage Vm.

The fundamental wave and its higher harmonics appeared at the mesh bias voltage Vm = 40V. The dispersion relations of observed fundamental wave agree with that of the Langmuir mode of an electron beam plasma system in the infinite space. The narrow and sharp profile of the peaks on the spectra indicates that the system is regular state. From the resonance condition of the Pierce instability: fpe = (nL)/(2v0), n number is 2.0 using the present condition of the distance between electrodes L = 5cm and fpe = 75MHz. The integer n number implies the system is on the resonance state of the Pierce instability satisfying the boundary condition. When Vm was increased to 50V, the n number of the above resonance condition is estimated to be 1.8 and the system is slightly out of resonance state. The broaden peak of the frequency spectrum imply that the system become turbulent or chaotic. At Vm = 60V, the system is completely out of resonance state and the boundary condition is no longer effective. The n number of the above resonance condition is 1.6. Then only the fundamental peak is observed in the frequency spectrum. Therefore, Vm is the control parameter of the system's behavior between boundaries. The time series of fluctuation component of the probe floating potential at Vm = 40V indicates the periodic or quasi-periodic state. The phase space attractor reconstructed from the time series is the torus type attractor in the three-dimensional phase space. The correlation dimension D is integer, 2.0. Then the system is confirmed to be the periodic or quasi-periodic state. When Vm increased from 40 V to 50V, the system would be out of the resonance slightly and becomes irregular state. The reconstructed attractor has the folding structures, and the correlation dimension of the attractor is calculated to be 2.3, fractal. Therefore, the system would reach the chaotic state at slightly out of the resonance.