§20. Basic Experiment of a Plasma-Filled Backward Wave Oscillator Utilizing TPD-S Machine

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It is well known that, in high power backward wave oscillators (BWO), the presence of plasma in the passage of beam improves the performance of operation significantly. We are planning to design and construct an advanced version of plasma-filled BWO utilizing TPD-S machine. In our device, conventional corrugated-wall slow wave structure is replaced by coupled cavity chain (CCC) surrounding the plasma beam tunnel that is the source of RF energy.

Coaxial cavities with TM(010) mode are coupled each other by small holes (aperture) that transfer RF energy that results in amplification of RF power. At the center of the CCC, there exists an electron beam neutralized by plasma. In such configuration, the passage of RF energy is separated completely from beam plasma column, and operation can be improved from conventional BWO's.

Design study of the device has been made as follows. Dispersion relation of the present BWO/TWT was derived by Prof. T. M. Antonsen, Jr., Univ. of Maryland, USA. Under the approximation that the operation is limited to the condition near the resonant frequency of a cavity without aperture, the dispersion curve through CCC is derived. From the boundary condition that the Poynting flux through the gap between the CCC and beam plasma tunnel is continuous, the final dispersion relation is obtained. Assuming various size and beam plasma parameters for infinitely long CCC, temporal growth rate versus real wave number k is calculated numerically. We consider that the resonant frequency of TM(010) the single cavity to be 2.6 GHz, and the BWO is operated near that frequency.

First, we analyzed the simple case without plasma. Figure 1 shows the results of dispersion curves. Upper and lower figures are, respectively, the operating frequency and growth rate. Here, single cavity length is 1.573 cm, outer and inner radii of the single cavity are, respectively, 0.5 cm and 6.0 cm. Beam current I_b is 1.0 A and beam radius is 0.8 cm. Beam energy V_b is changed from 7 kV to 80 kV. It is shown that BWO is attained for V_b less than 20 keV. TWT results above 20 keV.

Figure 2 shows the effect of the presence of plasma in the beam. Upper and lower figures are, respectively, changes in the frequency and growth rate from vacuum case in Fig. 1 as a function of plasma density. Here, msize in upper figure means the truncated number of Floquet harmonics. For density 1.5×10^{11} cm^{-3}, the growth rate increases by a factor 2. This enhancement is believed to be the three mode linear resonant interaction caused by Trivelpiece-Gould mode in addition to conventional beam space charge mode and structure mode. Amplification of 30 dB is possible in 30 cm long CCC. Further precise analysis is under way.

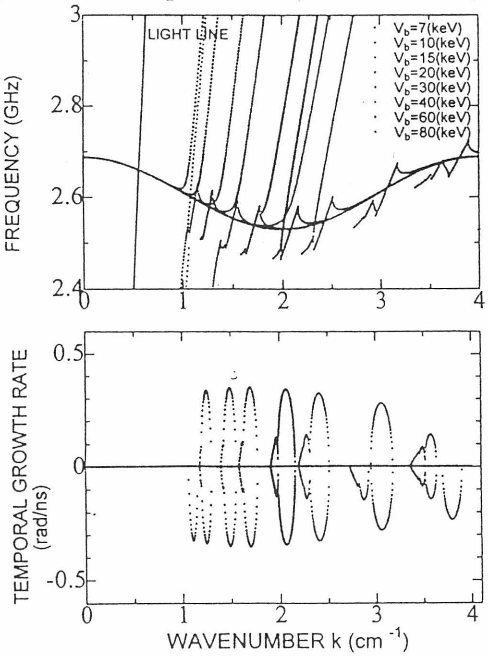

Fig. 1 Dispersion curves without plasma

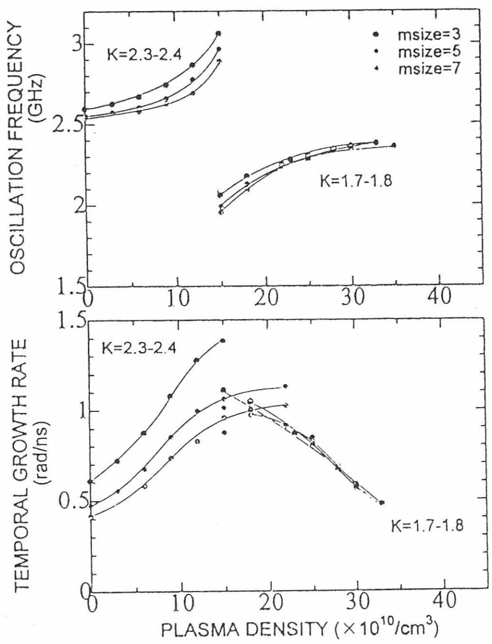

Fig. 2 Effects of presence of plasma