§7. Study on Electron Distribution Function and Spatial Structure of Weakly Relativistic Electrons in Microwave and Mirror Devices

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This project is aimed at studying weakly relativistic electrons distributing in a form of beam, plateau, or other shape in the energy or momentum space. For the GAMMA10 tandem mirror at University of Tsukuba, it is necessary to clarify distribution and structure of electrons in both momentum and real spaces to study the confinement mechanism of high temperature plasma. At Niigata University, the pulsed microwave devices based on slow-wave interaction with a weak relativistic electron beam are studied.[1-4)]

With well-controlled beams in both real and velocity spaces being available, important physics related to the moving electrons can be examined by a rather simple model and system of microwave devices.[1,3)] In other words, microwave radiations from slow-wave devices can be used as one of the diagnostic methods. In this work, a new type of cold cathode is proposed for generations of well-controlled annular electron beam in a weakly relativistic energy region.

Most high-power microwave sources in the relativistic region have used simple tubular explosive cold cathodes as shown in Fig.1. However, it is very difficult to generate a uniformly distributed electron beam with a good reproducibility. With the help of dielectrics such as a velvet, a fairly uniformity beam is obtained, see Fig.1. Figure 2 shows the proposed cold cathode, consisting of metal only with a solid conical disk shape.[1)] It is able to operate in the weakly relativistic energy region with a high current density of some 100 A/cm^2. A beam burn pattern is shown in Fig. 2, without any coating on the emitting edge. Beam voltage and current are respectively about 90 kV and 400 A.

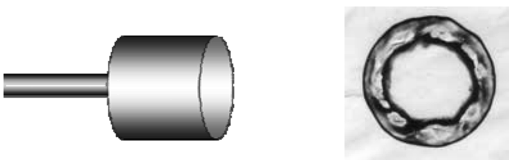

Fig. 1 Tubular cold cathode (left) and beam burn pattern (right).

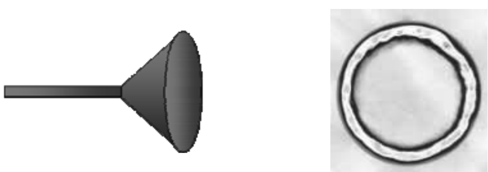

Fig. 2 Solid conical disk cathode (left) and beam burn pattern (right).

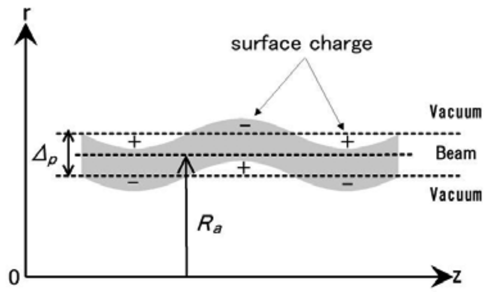

Fig. 3 Beam surface with three-dimensional beam perturbations. R_a and Δ_p are an average beam radius and a beam thickness, respectively.

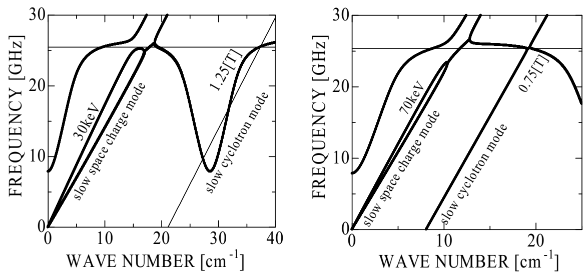

Fig. 4 Dispersion curves of fundamental TM_{01} and beam modes in an oversized periodic slow-wave structure. The beam energy and current are 30 keV and 200 A (left) and 70 keV and 800 A (right), respectively.

Boundary conditions on beam surfaces like Fig.3 need to be considered self-consistently, taking into account of three-dimensional beam perturbations.[2,4)] Figure 4 shows slow cyclotron maser operations in the weakly relativistic region using a rectangularly corrugated K-band SWS.[3)] Due to the vertical perturbations, cyclotron interactions as well as the Cherenkov ones appear. For a slow cyclotron maser operation at 30kV (left), the Cherenkov instability due to the space charge mode becomes absolute one and an amplification of signal occurs at a convective instability due to the second harmonic slow cyclotron interaction. In another type of slow cyclotron maser can realize with the higher energy region near 70kV (right). This maser operation is based on a combined resonance in which the absolute instability is driven by the fundamental slow cyclotron interaction and the Cherenkov interaction drives a convective instability and amplifies signals. Performances of these slow cyclotron masers are examined experimentally and compared with numerical results. By analyzing the effects of spatial spread and energy of annular beam on the slow cyclotron maser, the physics of beam-wave interaction are studied.

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2) Y. Takashima, K. Ogura *et. al.*, J. Plasma Fusion Res. SERIES 8 (2009) pp.1512-1517.
3) K. Bansho, K. Ogura *et. al.*, Plasma Fusion Res. 5 (2010) S1049.
4) K. Otubo, K. Ogura *et. al.*, Plasma Fusion Res. 5 (2010) S1047.