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Generation of high power microwave from multistage axial virtual cathode oscillator for efficiency enhancement

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1. Introduciton

The high power microwaves sources play a significant role in a variety of applications such as particle accelerators, magnetic confinement fusion, astronomy, communications, and various industrial fields. A number of high-power microwave sources have been developed. A virtual cathode oscillator (vircator) is attractive due to its high-power capability, device simplicity, and frequency tunability, whereas relatively low efficiency (typically about 3%) of beam-to-microwave power conversion and wide frequency bandwidth are its common disadvantage. One could gain the enhanced efficiency and single frequency operation gain the enhanced efficiency and single frequency operation by introducing a resonant feedback into the system. However, the best efficiency is up to 10% and an order of magnitude less than that of other high-power sources.

To improve the conversion efficiency and narrow the output frequency, we have performed the experiments on an axially extracted vircator with the resonant cavity, which was installed by inserting a movable disc plate in the drift space. However, the electrons pass through the virtual cathode and the beam energy is wasted, resulting in limiting the conversion efficiency. In order to exploit leaking electrons to the benefit of microwave generation, a novel concept of multistage vircator with grounded reflectors, which works as anode, has been proposed and numerically shown to overcome the efficiency of the conventional axial vircator [1].

We have developed a prototype of multistage vircator with reflectors. The characteristics of high power microwaves depend sensitively on the electrode material and the reflector spacing length. We report the preliminary results on the efficiency of high power microwaves emitted from the multistage vircator for various reflector spacing length and number of reflector.

2. Experimental setup

The vircator is driven by a pulse power system (400 kV, 50 ns, 3 Ω), which consists of a Marx generator, a single pulse forming line (PFL), a gas SF_6 spark gap and a pulse transmission line. Figure 1 shows the schematic structure of the multistage axial vircator and the microwave measurement setup. The high-voltage pulse generated from the pulsed power system is applied to the cathode of the electron beam diode. A vacuum explosive electron emission diode was used to generate an intense electron beam. A stainless-steel meshed anode with a transparency of ~65% was used. To improve the microwave efficiency and control the output frequency, the multistage vircator was constructed by introducing stainless-steel meshes as reflectors behind the anode. Electrons leaking from the upstream region are expected to build up the oscillating virtual cathode beyond each reflector. In addition, a series of the quasi-cavity is formed by two successive reflectors and waveguide wall, resulting in an enhanced beam-microwave interaction.

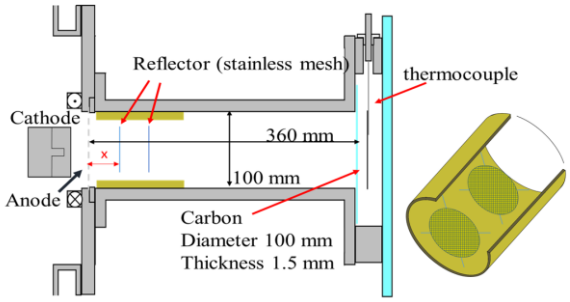

Figure 1 Schematic structure of the multistage axial vircator and experimental setup.

3. Experimental Results

First, we evaluated diode current and output energy of microwave emitted from the axially extracted vircator without the reflector for various cathode. The current of 20 kA and conversion efficiency of 3.1 % was obtained at the velvet cathode. Figure 2 shows the dependence of the microwave conversion efficiency on the spacing length and diameter of reflector. When one reflector was installed in the vircator, the conversion efficiency increased to 7.8 % at the velvet cathode and the microwave with the resonant frequency is enhanced. When two reflectors were installed, the conversion efficiency of 5.7 % was smaller than that in the case of one reflector. The frequency spectrum of microwave shrank to the resonant frequency.

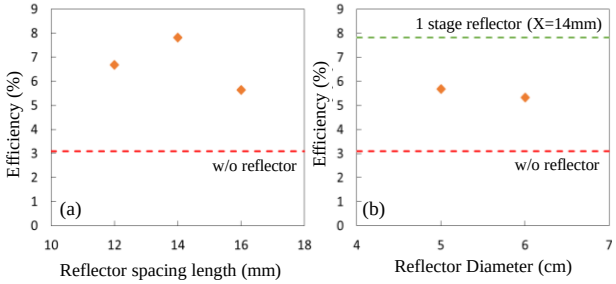

Figure 2 Dependence of efficiency on (a) reflector spacing length and (b) diameter of second reflector

Reference

[1] S. Champeaux, *et al.*, "Improved design of a multistage axial vircator with reflectors for enhanced performances", IEEE Trans. Plasma Sci., vol.44, pp.31-37 (2016).