Towards High-Power Microwaves

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Abstract — In this paper, we review and compare high-power microwave (HPM) sources operating without a magnetic field to guide the electron beam that are capable of producing HPM pulses with a duration of about 100 ns. The proposed analysis summarizes multi-year research carried with three types of HPM sources: an axial vircator, a split-cavity oscillator and a virtual cathode oscillator in reflex triode geometry. These options were simulated for electron beam energy ~400 keV and for pulsers with demonstrated capability to provide HPM pulses with the required pulse duration. Designed sources were experimentally tested, and their advantages and weaknesses are discussed with respect to high output power, long pulse duration, and good operation stability.

Keywords-high-power microwaves; reflex triode; vircator; split-cavity oscillator

I. INTRODUCTION

The aim of the presented analysis is to compare HPM sources of different types and substantiate the choice of a source that will provide high output power, long pulse duration and good operation stability. The technical requirements for the HPM source are operation without a magnetic field and compact design. Single frequency operation during the 100 ns is desired. Three types of HPM sources were analyzed: an axial vircator, a split-cavity oscillator, and a virtual cathode oscillator in reflex triode geometry. The paper is organized as follows. Each HPM source is described in a separate section. Some general approaches and design solutions were applied to all of them – they are discussed in a particular section for one of the sources. Each section presents the experimentally obtained results and discusses the observed advantages and weaknesses of each source.

II. AXIAL VIRCATOR

Using [1] as a starting point for the development, we designed the axial vircator. In the simulation, it looked to be efficient, and the output power looked very promising. However, the experiments demonstrated low reproducibility of results [2]. The subsequent analysis [3] explained the unstable operation by high dependence of source efficiency on the spread of of the electron velocities in the beam.

III. SCO

The split-cavity oscillator, as proposed in [4], was designed to operate at 400 kV. Simulated and experimental results showed that the stability of the observed results was high, but the experimental results showed that the radiated power and pulse duration were low when compared to the simulation. Analysis of results enabled us to assume that pulse shortening was being caused by expanding plasma cloud, which is formed in the vicinity of extractor as a result of its being bombarded by electrons causing the beam to be compressed by its own magnetic field.

IV. REFLEX TRIODE

The virtual cathode oscillator in reflex triode geometry [5] demonstrated higher operation stability at high-power operation with longer pulse duration as compared with other sources. It provided good single frequency operation during the 100 ns pulse [6] (see Fig. 1). High operation stability was ensured by use of multi-capillary cathode [7].

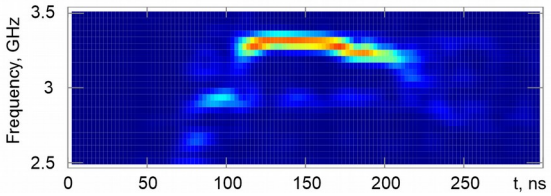

Figure 1. Shot-time fourier transform of HPM pulse

REFERENCES

[1] L. Zhi-Qiang et al., “Simulation and experimental research of a novel vircator,” Chin. Phys. Lett., vol. 25, no. 7, pp. 2566–2569, 2008.
[2] V. Baryshevsky, A. Gurinovich, E. Gurnevich, P. Molchanov, “Experimental study of an axial vircator with resonant cavity,” IEEE Trans. Plasma Sci., vol. 43, no. 10, pp. 3507–3511, 2015.
[3] E. Gurnevich, P. Molchanov, “The effect of the electron-beam parameter spread on microwave generation in a three-cavity axial vircator,” IEEE Trans. Plasma Sci., vol. 43, no. 4, pp. 1014–1017, 2015.
[4] B.M. Marder, “The split-cavity oscillator: a high-power e-beam modulator and microwave source,” IEEE Trans. Plasma Sci., vol. 20, no. 3, pp. 312–331, 1992.
[5] A.G. Zherlitsyn, G.V. Mel’nikov, P.Ya. Isakov, “Effect of feedback on the microwave radiation in a triode with a virtual cathode,” J. Commun. Technol. and Electron., vol. 52, no. 7, pp. 798–802, 2007.
[6] V. Baryshevsky, A. Gurinovich, E. Gurnevich, and P. Molchanov, “Experimantal study of a triode reflex geometry vircator,” IEEE Trans. Plasma Sci., vol. 45, pp. 631–635, 2017.
[7] J.Z. Gleizer, T. Queller, Yu. Bliokh, S. Yatom, V. Vekselman, Ya.E. Krasik, and V. Bernshtam, “High-current long-duration uniform electron beam generation in a diode with multicapillary carbon-epoxy cathode,” J. Appl. Phys., vol. 114, 123303, 2013.