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A Hybrid Microwave Generator Based on a Vircator–TWT (Virtode) System

V. D. Selemir, A. E. Dubinov, E. E. Dubinov, I. V. Konovalov, and A. V. Tikhonov

Institute of Experimental Physics, Russian Federal Nuclear Center, Sarov, Russia

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Abstract—Various schemes of microwave generators (TWT, vircator, and a vircator–TWT hybrid virtode) were studied in operation under the same power supply conditions. It is demonstrated that the virtode offers the most efficient solution. © *2001 MAIK "Nauka/Interperiodica".*

As is well known, an oscillating virtual cathode modulates the electron beam transit current [1]. This circumstance allows the electron beams with virtual cathodes to be used both in microwave generators [2, 3] and in collective ion accelerators [4]. The microwave generators employing virtual cathodes (called vircators) are among the most promising devices of relativistic electronics.

An interesting approach to the development of vircators consists in creating a hybrid generator [5] in which the electron transit current modulated by a virtual cathode is fed into a retarding system operating in the backward-wave tube (BWT) mode. An SHF wave excited in BWT returns back to the virtual cathode region (thus allowing a feedback) where the microwave radiation can be extracted from the device. This generator, representing a vircator–BWT hybrid system, is called virtode.

In this study, we have designed and constructed a hybrid microwave generator of the virtode type based on the combination of a vircator and a traveling-wave tube (TWT). The virtode system consists in the idea that a modulated electron beam is fed into a TWT retarding system. As a result, the retarding system (in comparison to that in a usual TWT) is pumped with this electron beam and a microwave radiation of the vircator representing a high-Q resonator.

The virtode was supplied from a two-stage linear induction accelerator (linac) of the I-3000 type described elsewhere [6]. The pulsed electron beam parameters used in our experiments were as follows: electron energy, 2.4 MeV; beam current, 12 kA; pulse duration 20 ns.

The electrodynamic TWT system structure comprised an open cavity representing a section of ridged round waveguide with an external diameter of 67 mm, a corrugation period and profile depth of 16 and 7 mm, respectively, and the number of periods equaled 18. The corrugation profile shape represented matched semicircles. The electrodynamic system was placed inside a solenoid generating a magnetic field of up to 3 kOe.

A relativistic TWT configuration depicted in Fig. 1a is analogous to that studied previously [6]. Optimized with respect to the system geometry parameters, diode impedance, and magnetic field configuration, the TWT-based microwave generator operated at 10 GHz with a 10% efficiency [6]. The results of measurements of the spatial and temporal far-zone structure of the extracted radiation showed evidence of a narrowband and coherent character of the microwave emission. In this study, the optimum TWT configuration was used as a reference system.

Figure 1b shows a vircator configuration based on a smooth drift tube with an internal diameter coinciding with that of the corrugated TWT waveguide structure. The diode part of the vircator was separated from the drift tube by a metal grid with a geometric transparency of 90% (made of 0.1-mm-diameter tantalum wire); the cathode–grid spacing was 60 mm. This vircator system was also used for the comparison.

Figure 1c presents the geometry of a virtode based on a vircator–TWT hybrid system. It should be emphasized that both the TWT and vircator, as well as the virtode, were designed so as to operate in the microwave generation regime: in contrast to the microwave amplification mode, no external microwave signals were applied to the input of these devices. This circumstance justifies the comparison of the output radiation power of the microwave generators studied.

Figure 1d shows a magnetic field strength profile in the configurations studied. In addition, we also studied a smooth waveguide configuration without a grid (in contrast to the vircator). All the aforementioned systems were tested using identical high-voltage linac supply regimes and the same magnetic field configuration. The output microwave emission power level in the far zone (~10 m) was measured with the aid of hot-carrier germanium detectors mounted in 23 × 10 mm waveguides.

Typical normalized oscillograms of the microwave pulse envelopes are presented in Fig. 1 on the right of each configuration diagram. For comparison, all values

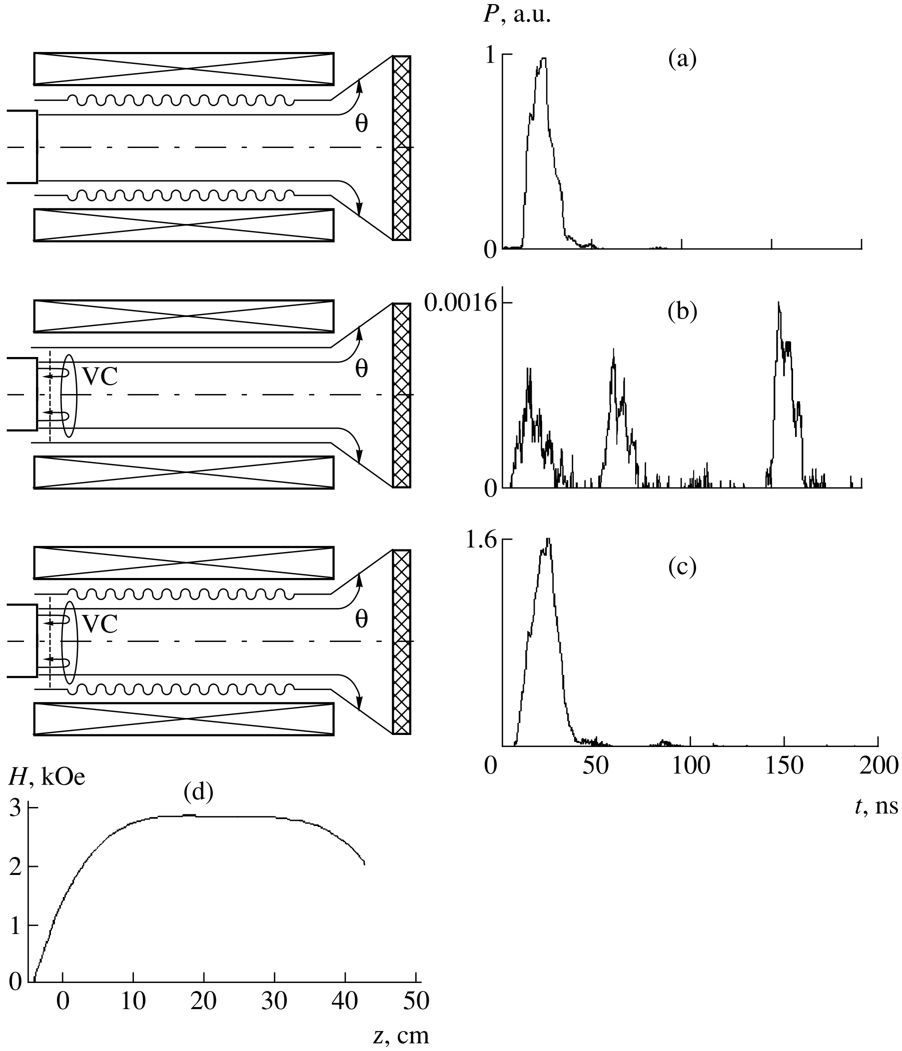

Fig. 1. Schematic diagrams of the microwave generators studied (left) and normalized oscillograms of the output microwave pulse envelopes (right): (a) TWT; (b) vircator; (c) virtode; (d) axial magnetic field strength profile matched to the waveguide configurations; VC—virtual cathode.

were normalized to the TWT peak power density (taken to be unity). As can be seen, the vircator emission power is markedly lower as compared to that of TWT; at the same time, the virtode power markedly exceeds the total power of both the TWT and vircator. The smooth waveguide gridless configuration exhibited no microwave emission at all. Thus, the virtode is the most effective microwave generator among the systems studied.

It should be noted that the vircator produces three sequential microwave pulses, the third carrying a maximum power. The formation of several pulses is explained by the fact that, in a regime of unmatched load, linacs employing the lines with distributed parameters generate a sequence of decaying high-voltage echo pulses. Such a multipulse operation regime was previously also observed in a relativistic TWT system with an I-3000 linac [6]. The maximum power observed for the third vircator pulse is consistent with the fact that a vircator-based generator operates most effectively at a supply voltage of 100–500 kV, the efficiency dropping sharply in the range of ultrarelativistic electron energies. Note that this circumstance is not manifested in the virtode generator where a virtual cathode operates only as a beam modulator.

Thus, a TWT with an anode grid analogous to that described in [6] exhibits an increase in the microwave generation efficiency up to 16%, which is explained by the system operating in a virtode mode. It should be noted that the grid arbitrarily positioned in the TWT does not always allow an increase in the operation efficiency. The grid position has to be adjusted so as to ensure that (i) the virtual cathode will form in the drift tube and (ii) the virtual cathode oscillation frequency will be equal to the intrinsic TWT frequency.

REFERENCES

1. V. I. Kurilko and Ya. B. Faĭnberg, Pis'ma Zh. Tekh. Fiz. **2** (9), 397 (1976) [Sov. Tech. Phys. Lett. **2**, 154 (1976)].
2. V. D. Selemir, B. V. Alekhin, V. E. Vatrunin, *et al.*, Fiz. Plazmy **20** (7-8), 689 (1994) [Plasma Phys. Rep. **20**, 621 (1994)].
3. A. E. Dubinov and V. D. Selemir, Zarubezhn. Radioélektron., No. 4, 54 (1995).
4. V. A. Balakirev, A. M. Gorban', I. I. Magda, *et al.*, Fiz. Plazmy **23** (4), 350 (1997) [Plasma Phys. Rep. **23**, 323 (1997)].
5. N. P. Gadetskiĭ, I. I. Magda, S. I. Naĭsteter, *et al.*, Fiz. Plazmy **19** (4), 530 (1993) [Plasma Phys. Rep. **19**, 273 (1993)].
6. A. I. Pavlovskiĭ, V. S. Bosamykin, V. D. Selemir, V. S. Gordeev, A. E. Dubinov, V. V. Ivanov, A. P. Klement'ev, V. G. Kornilov, V. E. Vatrunin, V. S. Zhdanov, I. V. Konovalov, I. G. Prikhod'ko, V. G. Suvorov, and K. V. Shibalko, in *Relativistic High-Frequency Electronics: Collection of Scientific Works* (Inst. Prikl. Fiz. Akad. Nauk, Nizhni Novgorod, 1992), Vol. 7, p. 81.

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