NON-CONVENTIONAL OPERATION MODES FOR MILLIMETER WAVE RELATIVISTIC MAGNETRONS

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The operation of 8-mm band relativistic magnetrons is considered for traditional and inverted-voltage regimes. The results obtained in a series of experiments are discussed.

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INTRODUCTION

The paper is a continuation of our previous studies of millimeter wave relativistic magnetrons (RM) [1, 2]. According to the existing terminological convention, magnetrons are categorized within two principal type groups, 1) conventional devices where electrons are provided either by a thermionic or a secondary-emission cathode, while the anode is united with a slow wave structure (SWS), and 2) inverted magnetrons where the anode block lies inside an annular cathode.

We will discuss here millimeter wave RMs which operate in the explosive emission regime, with electric field strengths near the SWS reaching $(1\ldots5)\cdot10^7$ V/m. Such electric parameters are unique, in the sense that they enable RM operation both with the 'properly' connected driving source (the cathode is at a lower potential than the anode block) and with a reverse polarity. In the latter case, it is the SWS that becomes the source of electrons.

EXPERIMENT

The experiments involved RMs of the two above mentioned configurations, the conventional and the inverted design. The conventional type was represented by a device with a 48-cavity SWS: the anode and cathode of respective diameters d_A=22 mm and d_c=14 mm; cavity height 1.65 mm, and axial extent Z=6 mm. The operating regimes under study were specified by the range of applied voltages, U_0=150 to 320 kV, and magnetic field strengths H_0= 3 to 11 kOe.

The inverted RM possessed a 24 cavity SWS, with d_A = 18 mm and d_c = 28 mm; cavity height of 0.5 mm, and axial extent of the structure Z=7 mm. The operating modes of RM-24 corresponded to U_0 = 150 to 320 kV and H_0 = 3 to 11 kOe. In fact, the RM of inverted design could operate at higher magnetic fields.

Fig. 1 shows typical waveform records from the conventional RM-48, obtained for a 'proper' (panel *a*) and reverse (panel *b*) connection of the driving voltage. As seen from the Figure, the length of the microwave pulse (3) was about 20 ns in the case of a 'properly' connected driving voltage. With a reversely applied voltage the microwave pulse length increased to 30 ns or more. In Fig. 2 the magnitude of the microwave signal from the conventional magnetron is shown in dependence on the magnetic field strength for the cases of 'proper' (curve 1) and reverse (curve 2) polarity of the applied voltage. With the reverse polarity the range of microwave generation has diminished by nearly a factor of two. Indeed, the generated frequency lay between 37 and 37.8 GHz in the 'properly' connected device and dropped down to 36.7…37 GHz when the applied voltage was reversed. The radiated power remained practically the same in the both operation modes.

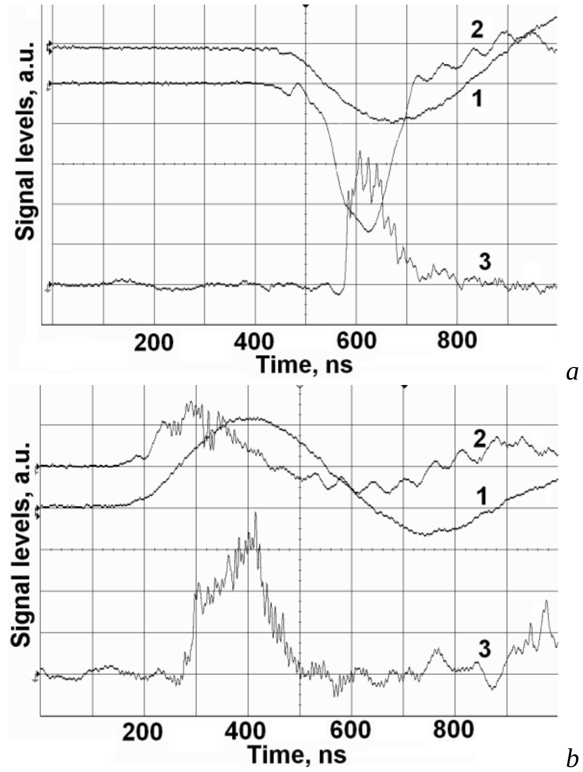

Fig. 1. Characteristic waveforms of the conventional RM-48 operating with: a – 'proper' polarity of the driving voltage and b – with a reverse connection. Curve 1 – is the anode voltage; curve 2 – represents total current, and 3 – is the response of a microwave sensor

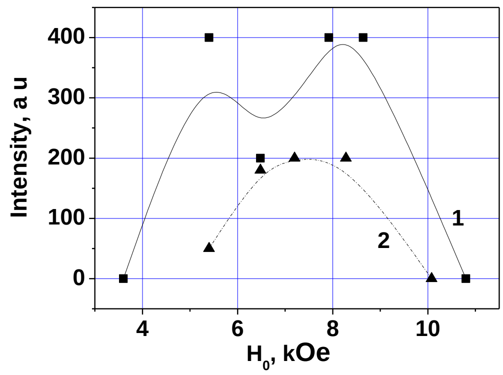

Fig. 2. Microwave generation levels of RM-48 with 'properly' (1), and reversely (2) connected driving voltage

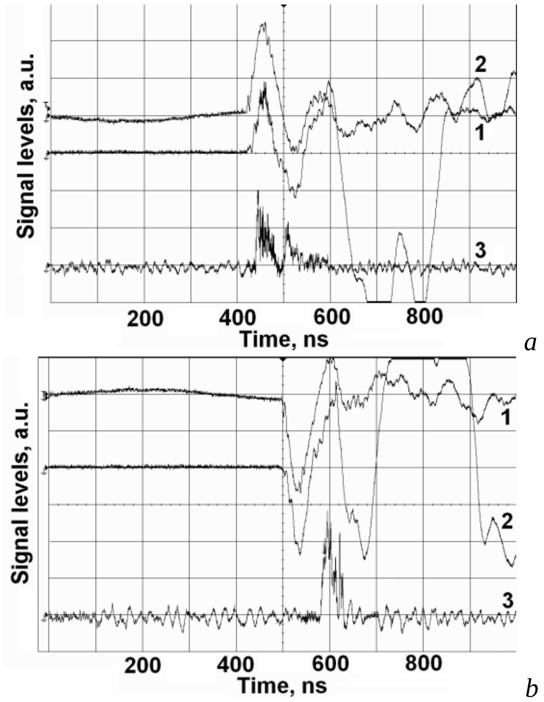

Fig. 3. Characteristic waveforms of the inverted RM-24 operating with: a – 'proper' polarity of the driving voltage and b – with a reverse connection. Curve 1 – is the anode voltage; curve 2 – represents total current, and 3 – is the response of a microwave sensor

Similar investigation was carried out with the inverted RM. Shown in Fig. 3 are typical oscillograms of the inverted RM-24 for the cases of proper (panel *a*), and reversely (panel *b*) applied driving voltage. As can be seen from the oscillograms, the inverted RM-24 showed practically invariant radiated pulse lengths in all the operation modes under study. Also, it seems worth noting that the inverted magnetron, when connected in the reverse manner, demonstrated microwave generation for a 'proper' polarity of the driving voltage (*i.e.* during the second half-wave of the applied pulse). The generated frequency was greater than 42.3 GHz when the device was 'properly' connected, and dropped down to 37…37.3 GHz for the reversely applied driving pulse.

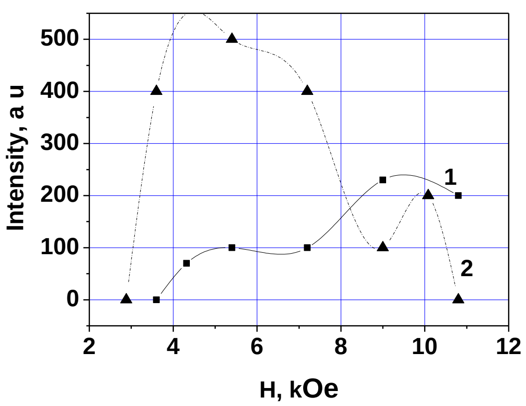

Fig. 4. Microwave generation levels of RM-24 with 'properly' (1), and reversely (2) connected driving voltage

Fig. 4 shows microwave intensities from the RM-24 versus applied magnetic field, for the cases of 'proper' (curve 1) and reverse (curve 2) polarity of the driving voltage. Similar as with the conventional RM, the range of magnetic field strengths where microwave generation occurs is wider for the 'proper' driving polarity. Meanwhile, the radiated intensity observable during the second ('correct') half-wave of a reversely connected driving voltage happened to be much higher, despite the lower amplitude of that half-wave. Most probably, the effect is due to the greater .emission current during the second half-wave which owes to plasma effects near the cathode.

In a number of tests microwave generation of noticeable intensity was observed during subsequent half-waves of the driving voltage (that followed the principal one), in 'correctly' connected magnetrons of both conventional and inverted design. The amplitudes were of comparable size. A typical record for the inverted magnetron is shown in Fig. 5. Apparently, these anomalies require further investigation.

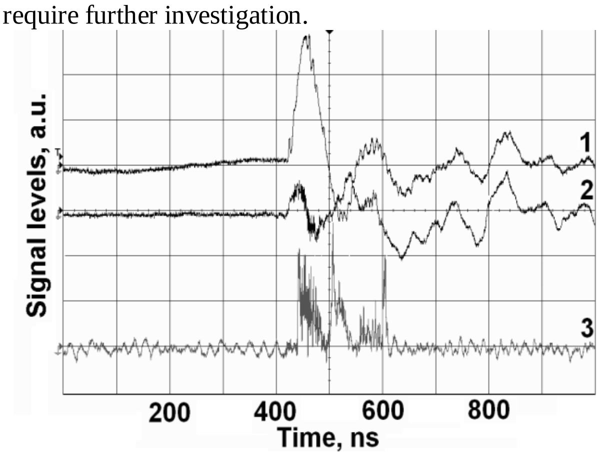

Fig. 5. Characteristic waveforms to describe microwave generation in the inverted RM-24 with different signs of subsequent half-waves of the driving voltage. Curve 1 – is the anode voltage; curve 2 – represents total current, and 3 – is the response of a microwave sensor

CONCLUSIONS

Peculiar operation modes of relativistic magnetrons have been studied for the first time, such that are fundamentally impossible in non-relativistic cross-field devices. Among the results obtained for the conventional-type relativistic magnetron, note the following. By reversing the polarity of the driving voltage the microwave pulse length was increased by almost a factor of two, however the active range of magnetic field strengths diminished. The frequency generated by the magnetron of traditional design varied but slightly both with the classic and reversed polarity of the driving voltage.

In the inverted magnetron, the rf pulse length remained essentially unchanged with either polarity of the driving voltage. Similar as with the conventional design, the active range of the magnetic field diminished as the applied voltage was reversed in the inverted device. The generation frequency of the inverted magnetron suffered a noticeable change with reversal of the driving voltage, which is in a contrast to the traditional design. Thus, the feasibility of 'cathode priming' of the operation mode [3] can be recognized as an unusual function of the SWS when used in the capacity of a cathode.

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ОСОБЕННОСТИ РАБОТЫ РЕЛЯТИВИСТСКИХ МАГНЕТРОНОВ МИЛЛИМЕТРОВОГО ДИАПАЗОНА В НЕТРАДИЦИОННЫХ РЕЖИМАХ

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Работа посвящена исследованию релятивистских магнетронов 8-мм диапазона в традиционных и инвертированных режимах. Обсуждаются результаты, полученные в серии экспериментов.

ОСОБЛИВОСТІ РОБОТИ РЕЛЯТИВІСТСЬКИХ МАГНЕТРОНІВ МІЛІМЕТРОВОГО ДІАПАЗОНУ В НЕТРАДИЦІЙНИХ РЕЖИМАХ

М.П. Гадецький, О.М. Лебеденко, І.І. Магда, А.О. Штанько, М.В. Воловенко

Робота присвячена дослідженню релятивістських магнетронів 8-мм діапазону в традиційному та інвертованому режимах. Обговорюються результати, отримані в серії експериментів.