MICROWAVE GENERATION BY SUPERCRITICAL REB AT PLASMA ASSISTANCE

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The experimental researches on generation of microwave radiation in a system with a supercritical current of a relativistic electron beam produced in the magnetically isolated diode and external plasma source are carried out. The researches have shown that in the presence of external plasma the power of microwave radiation is increased in comparison to vacuum system.

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1. INTRODUCTION

The structure with a virtual cathode (VC) is in the first section of a collective ion accelerator based on simultaneous temporal and spatial modulation of a relativistic electron beam (REB) [1, 2]. In this section, the low frequency modulation of supercritical high current REB is caused by periodic compensation of VC by ions of an external plasma source and the ion flow is formed in an electrical field of VC. Confirmation of existence of VC in electrodynamic structure is the generation of microwave radiation. The low frequency modulation of microwave radiation corresponds to the time modulation of REB.

2. MICROWAVE GENERATOR

Fig.1 shows the structure of a microwave generator that was realized in the first section of a collective ion accelerator, in which the electron accelerator "Agat" forms the REB with energy 210 keV with apulse current duration of 0.8 μs. The total energy of the Marx generator (MG) is equal to 0.9 kJ when each stage is charged by voltage of 30 kV.

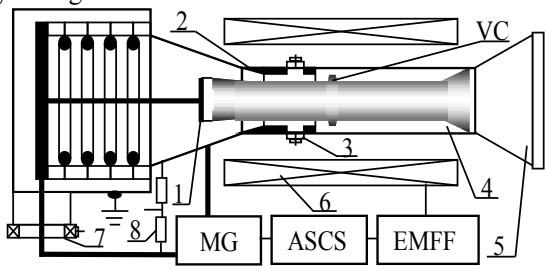


Fig. 1 Schematic diagram of experimental installation
1 – cathode; 2 – anode; 3 – plasma source;
4 – drift chamber; 5 – horn; 6 – solenoid;
7 – Rogovsky coil; 8 – voltage divider
VC – virtual cathode; MG – Marx generator;
ASCS – accelerator starting and control system;
EMFF – external magnetic field formation

The MG high-voltage pulse is applied to the magnetically-insulated diode. The cylindrical cathode is made from stainless steel and has diameter of 30 mm and depth of an emission edge of 0.1 mm.

The tubular electron beam has been formed by the magnetron type diode. The emission current value of the electron beam equal to 4.4 kA was determined by the diameter of input cylindrical anode equal to 40 mm. The inner diameter of the drift electron cylindrical chamber was equal to 50 mm. The jumping of electrodynamic structure was necessary for formation of the virtual cathode. In such a system the limiting vacuum current of an electron beam had the value of 3.4 kA.

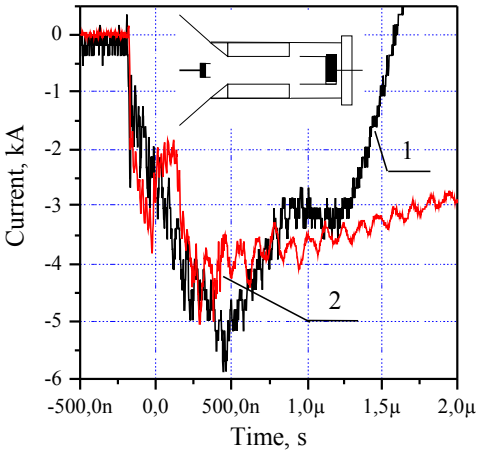
The electron beam was conveyed by a longitudinal external magnetic field of the solenoid with inductance of 810 μH and maximally possible induction up to 1.33 T that was supplied by the system of external magnetic field formation. The period of the external magnetic field was of 11.4 ms. In the cathode region the induction value of magnetic field has quantity ~60% from induction value inside the solenoid. Such configuration of the magnetic field formed the electron cylindrical beam with diameter of 30 mm and wall thickness of 3 mm in the liner.

The control and measurement of parameters of the high-current electron accelerator were made by a high-voltage divider and induction sensor of a current used on the input current-conductor of magnetically-insulated diode (Fig.1). The induction of the external magnetic field of solenoid was measured by the induction-magnetic probe. The division factor equal to 6.8×10^3 due to the MG activity in aperiodic regime was selected from a condition of signal registration on broadband TDS224 oscillograph with the use of a low-voltage divider, which had the input and output resistance of 50 Ohm.

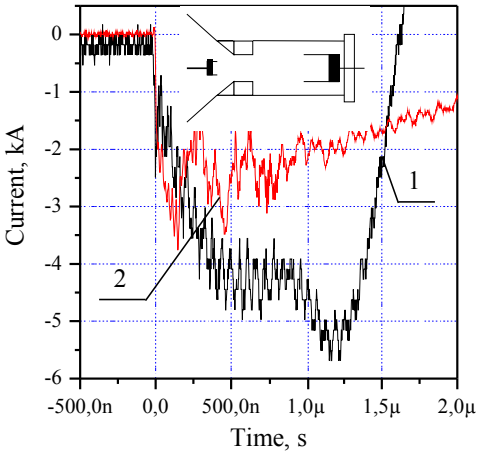
3. FORMATION OF VIRTUAL CATHODE

The conditions of virtual cathode formation in the diode with magnetic insulation were studied using the cylindrical electrodynamic structures. Structures of two types: the circular tube of diameter 41 mm and the waveguide with jumping namely "diode anodic unit of diameter 41 mm that jumped in cylindrical drift liner of a greater diameter 50 mm" were investigated experimentally. In Fig.2 the oscillograms of the diode input current and the REB current on the collector (Faraday cup) are shown. As it is seen from Fig.2,a that in the first case the REB current injected from the cylindrical cathode was transported practically without losses to the collector placed at the end of the drift liner and in the homogeneous constant magnetic field with induction 0.88 T. In the electrodynamic structure with jumping, the REB current on the collector was much less, than the diode input current and corresponded to value of a

space charge limiting vacuum current in the drift liner (Fig.2,b). It proved the possibility of the virtual cathode formation in the structure with jumping.



a)



b)

Fig.2. Current oscillograms
1 – the diode input current;
2 – the collector current of REB

4. PLASMA ANODE

The plasma anode was formed by a plasma source consisting of four plasma guns with breakdown on a dielectric surface. The guns were placed uniformly on peripherals of the drift chamber (Fig.3) in the region up to the virtual cathode (Fig.1). The start unit (1) performed their synchronous start. In each gun, the voltage breakdowns on an organic glass surface in vacuum of pressure 2×10^{-4} Torr were provided by voltage pulses with maximum values of 12 kV and durations of 6 μs. These pulses were formed by aperiodic discharge of condensers of capacity 0.25 μF that were charged by the charge unit (2). The Ampere force caused by the own magnetic field of the surface electric discharge loop circuit has provided initial radial motion of plasma to the liner axis of the ion accelerator under elaboration.

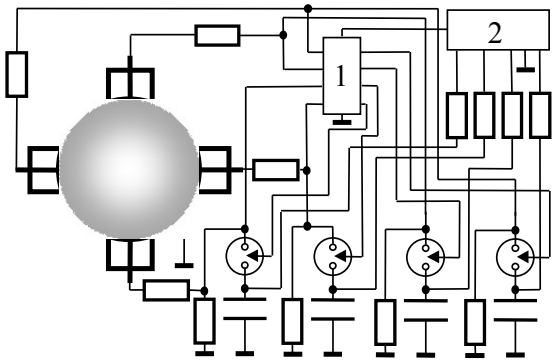
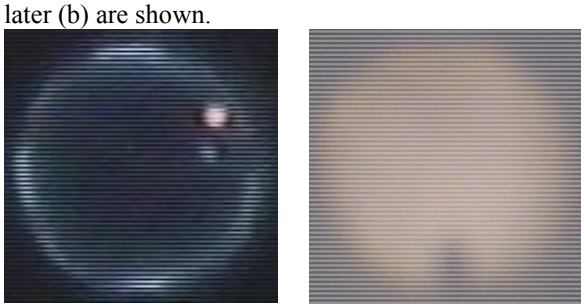


Fig. 3. The structure scheme of plasma source and its supply
1 – start unit; 2 – charge unit

As a result the plasma layer was formed in the cross section of the liner (Fig. 4). It served as a plasma anode and a source of ions. In Fig. 4 the photos of the visible spectrum of the voltage breakdown on the organic glass surface at discharge start (a) and plasma layer formed later (b) are shown.



а) б)

Fig. 4 Formation of plasma anode

The dot image (actually of red color) in Fig.4,a represents the light emitted by the light diode. It was installed for adjusting of the video camera sharpness. The dark area in the glow of a plasma layer at the bottom of Fig.4,b is the shadow image of the electrical probe. The light emitting diode and Langmuir probe were placed instead of one of the plasma guns. Density of formed plasma on an axis of the drift chamber was equal 2×10^{13} cm^{-3}.

5. MICROWAVE GENERATION OF VIRCATOR AT PLASMA INJECTION

Additional confirmation of existence of the virtual cathode in foregoing electrodynamic structure was the microwave generation and radiation, power of which did not practically depend on the value of external magnetic field induction. In Fig. 5 the oscillograms of pulses of the detected microwave radiations of vircator are shown. The pulse (1) corresponds to the generation at the absence of external plasma. The maximum power of radiation in this case was 0.2 MW. The power of microwave radiation was determined according to the technique of paper [3]. The pulse (2) corresponds to generation of microwave radiation at presence of plasma formed by an external plasma source. The maximum

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power of radiation of the plasma generator had value 5 MW. The duration of pulses of microwave radiation was equal to duration of the REB current.

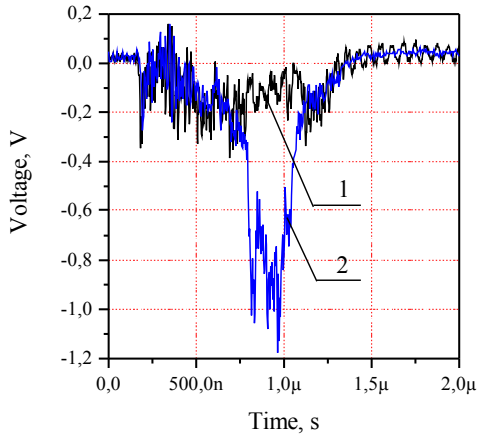

Fig.5. Vircator microwave radiation without (1) and with (2) plasma gun

The observable low-frequency modulation of vircator microwave radiation was probably caused by the charge compensation of space charge of the virtual cathode by plasma. It requires further research. The low modulation frequency of microwave radiation had value ~40 MHz.

6. CONCLUSIONS

Thus, the microwave generator with supercritical REB and external plasma anode was realized in the first section of the collective ion accelerator. Comparison of power radiation by the generator was made at the absence and presence of the external plasma injection. The presence of plasma in the electrodynamic structure of the generator has resulted to increase of radiation power more than one order of magnitude in comparison with the vacuum case. The low frequency modulation of microwave oscillations of the space charge was probably formed by charge compensation of the virtual cathode by plasma from the external source. Adding confirmation of existence of these oscillations is the presence of low-frequency modulation of the REB collector current shown in paper [2].

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СВЧ ГЕНЕРАЦИЯ СВЕРХКРИТИЧЕСКИМ РЭП ПРИ НАЛИЧИИ ПЛАЗМЫ

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Проведены экспериментальные исследования генерации СВЧ излучения в системе со сверхкритическим током релятивистского электронного пучка и внешним плазменным источником. Исследования показали, что при наличии внешней плазмы мощность СВЧ излучения увеличивается по сравнению с вакуумной системой.

НВЧ ГЕНЕРАЦІЯ НАДКРИТИЧНИМ РЕП ПРИ НАЯВНОСТІ ПЛАЗМИ

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Проведені експериментальні дослідження генерації НВЧ випромінювання в системі з надкритичним струмом релятивістського електронного пучка і зовнішнім плазмовим джерелом. Дослідження показали, що при наявності зовнішньої плазми потужність НВЧ випромінювання збільшується в порівняні з вакуумною системою.