BLOCK OF AN ELECTRON GUN COMBINED WITH A GETTER - ION PUMP DESIGNED FOR HIGH - POWER BEAM - PLASMA MICROWAVE DEVICES

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The paper presents the design description and the results of tests of the block combining an electron gun and a getter - ion pump, providing plasma - forming gas evacuation from the slow - wave structures. The block is designed for use in high-power beam - plasma devices. The construction under consideration minimizes the overall block dimensions. The block, in the assembly of the generator with a hybrid slow-wave structure (a sequence of inductively coupled resonators and a plasma - filled transport channel) provides the generation of stochastic oscillations in the tenth-centimeter wavelength range in the frequency band of 1 GHz, 40 kW microwave power in the continuous mode of operation and 100 kW in the pulse of 4 ms duration.

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In microwave devices of the non-relativistic plasma electronics – beam - plasma generator, beam - plasma amplifiers - the plasma filling of slow - wave structures, placed in the magnetic field, is an essential element forming a hybrid slow - wave structure. The devices with a hybrid slow - wave structure possess unique features: volume type of excited waves, broad spectrum of oscillations, and high value of the power of oscillations generated and amplified in the continuous and pulse modes of operation [1,2].

The problem of plasma - forming gas evacuation into such devices calls for the necessity to develop new evacuation units used in them in order to minimize the weight and overall dimensions. The development of such devices is related with plasma - creation techniques.

A simple method of plasma creation is the use of a beam - plasma discharge in the magnetic field. The electron beam, used as an energy source for excitation of microwave oscillations, initiates the plasma and interacts with it [3].

The electron operation, at accelerating potentials of tens kilovolts, is possible in vacuum not worse than 10^{7}–10^{-5} Torr, while in the hybrid slow - wave system the pressure should be of about 10^{-5}–10^{-4} Torr. Consequently, there are contradicting requirements to the pressure for plasma creation and to the gun operating conditions which can be satisfied only by creating the pressure difference between the gun and the area of interaction with the plasma. This condition can be reached by evacuating the plasma - forming gas through the transport channel between these areas which provides the pressure difference. However, the length and the cross - section of the transport channel can not be chosen arbitrary considering the physical processes taking place in these devices. An acceptable length of the transport channel is determined by the mechanism of excitation of microwave oscillations by an electron beam in the plasma. To increase the channel length is not optimum decision because it can lead to the transition of the microwave oscillation excitation by a beam from the hydrodynamic stage into the kinetic one in the slow - wave structure and, consequently, the efficiency of a device might be decreased.

The relaxation length of the ~ 40 kV no relativistic electron beam, used in this generator, in the hydrodynamic mode with a maximum efficiency was from 0.26 to 0.6 m according to estimations of [4]. (Here the relaxation length is the distance where the beam transfers its energy into excited microwave oscillations).

The given estimate determines a required acceptable length of the device where the hydrodynamic stage of beam interaction will be kept. Taking into account that the slow-wave structure length can be 0.2 m, the transport channel length should not exceed ~ 0.06 – 0.1 m [3].

The channel cross - section is determined by the electron beam diameter. For devices under consideration in the tenth-centimeter wavelength range with a power of tens kilowatts this diameter can reach a centimeter. The use of such a large transport channel for these devices is possible due to excitation in them of volume waves. The channel cross - section of this value permits to obtain high - power microwave oscillations. Therefore, in the hybrid slow - wave structure the transport channel can be increased, as compared to the vacuum devices of the indicated wavelength range [1,2,4].

As is obvious from the foregoing, a necessary evacuation rate is 0.07 − 0.11 $m^3 s^{-1}$ at a pressure from 10^{-7} to 10^{-5} Torr.

An important problem is the choice of plasma - forming gas. To minimize the neutral gas in leakage into the gun region it is desirable to have a maximally heavy gas, the leakage rate decreases with gas mass increasing. For "sealed - off" devices the most suitable evacuation method is the getter technique. A simple getter, titanium, absorbs well, in main, hydrogen and nitrogen. Therefore, nitrogen was chosen as a plasma-forming gas. This choice was due to the property of nitrogen to form with titanium a high - temperature compound which does not release the absorbed gas during the repeated vacuum training of the device. However, the getter alone can not provide a sufficient evacuation rate in the high vacuum. Therefore, as an evacuation device we selected a getter-ion pump permitting to reach an acceptable evacuation rate in the high vacuum. A getter-ion pump means a device having the electrons ionizing the evacuated gas and the getter atoms being accelerated by the electrical field onto its gettering surfaces.

For minimization of the weight and overall dimensions of beam - plasma devices it is necessary to combine an electron gun with an evacuation device. Thus, the large-scale vacuum line from the pump to the gun can be excluded. Therefore, constructively the block is designed so, that the electron gun is placed in its center and the getter - ion pump is arranged coaxially to the gun. In this combination the operation of the high - voltage electron gun should not be influenced by the pump and vice versa. Necessary conditions were provided in the block under consideration. The schematic of an electron gun combined with a getter-ion pump is shown in Fig 1.

The vacuum housing of the block (1) is made of non - magnetic steel X18H9T (Russian Standard) in the form of a cylinder having 0.38 m diameter, 0.26 m height with cone face ends. The housing has double walls with welded partition plates between them being the bearing elements and, simultaneously, its cooling system. The cylindrical internal surface has radial crimps with a radius of curvature to 0.015 m. The getter surface to be cooled is 0.57 m^2.

One of the block face ends is made in the form of a removable flange (2) with a metallic wedge - type seal. On the flange, also made in the form of a truncated being cooled cone, mounted are the elements of the electron gun (3) and of the pump (5), a vacuum-sensing device and a valve with a metallic sealing for detachment of the device from the vacuum post after the training cycle (5). Such a dismountable block construction allows one to perform design improvement and to repair its elements.

The electron gun is a triode with an intermediate anode installed under the positive potential of about 1-3 kV for slowing down the ion component drifting along the channel from the slow-wave structure to the gun. The gun cathodes (3), made of LaB_6, are provided with electron heating. The intermediate anode is made in the form of a cylinder composed of jalousie designed to increase the rate of gas evacuation from the gun region. The intermediate face end of the anode is made of tantalum in the form of a hemisphere. In the inside of the cylinder – intermediate anode, two cathodes and a tungsten directly heating heater fixed at tubes are coaxially installed. To screen the electron gun from the sputtered getter it is placed into the double perforated titanium screen.

The gun has a system of electron beam positioning relatively to the transport channel in the evacuated state.

Deposition of titanium onto the pump guttering surface is performed by three V-shaped wire elements of 4 mm in diameter made of iodide-titanium. They are installed uniformly on a circle of the removable flange so that the internal pump surface is covered. The voltage at the sputters Up=10 V, the current is 137 A.

Gas ionization in the pump volume is performed by electrons emitted from the direct - heating wire tantalum cathode (3) at the positive potential of the grid (4). The cylindrical pump grid arranged coaxially to the electron gun occupies entirely the free block volume. The grid transparence is ~ 95%.

The electron source of the getter - ion pump is made in the form of a single block placed in the grid volume.

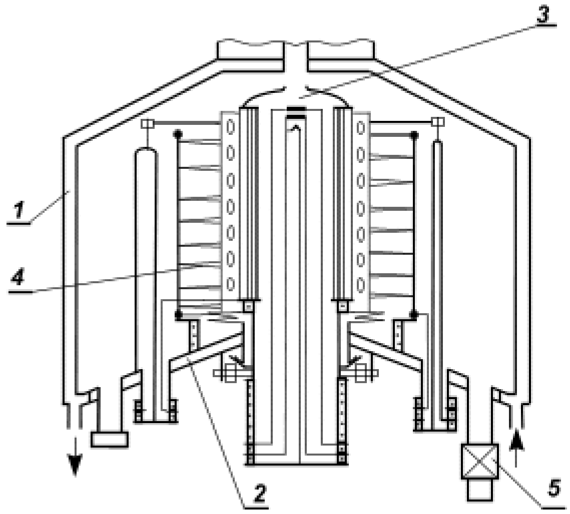

Fig.1 Schematic of the block

Acceleration of gas ions ionized by electrons in the pump grid volume is provided by its positive potential. The grid current is 1 ampere at a voltage of 2 kV. The positive potential of the intermediate electron gun anode is also applied to the getter-ion pump grid. Thus, the number of sources necessary for block power supply can be reduced. The evacuation rate of the pump of 0.008 – 0.11 $m^3 s^{-1}$ at a pressure of $10^{-7} – 10^{-5}$ Torr is increasing to 1 m^3s^{-1} at $5 \cdot 10^{-4}$ Torr. The plot of the evacuation rate of the ion - getter pump as a function of the pressure for nitrogen being evacuated is given in Fig.2.

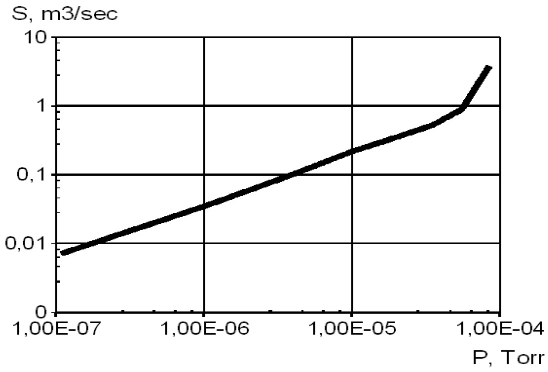

Fig.2. Evacuation rate of the getter - ion pump as a function of the pressure for nitrogen being evacuated

The construction of the block, the electron gun and the pump is made on the whole in the metal-ceramic version.

The pump was started after heating the block and the generator together at a temperature of ~ 450° 120 hours (not less). The initial titanium sputtering onto the block gettering surfaces was carried out at a wall temperature of 350 - 450 °and a pressure of 10^{-7} Torr. The block was heated by means of the pump electron current and external heaters, all the vacuum generator system being heated. Then the generator was cooled. After reaching a nominal rating, the intercepting vacuum valve was closed from the training bench, and the generator was operating in the independent mode.

The residual pressure in the oscillator was $10^{-8} – 10^{-9}$ Torr.

The running hours of the block in the oscillator structure is 950 hours.

The use of such a block in the generator structure in the continuous mode of operation permitted to obtain the 40 kW stochastic oscillations in the tenth-centimeter wavelength range in the frequency in the frequency band of 1 GHz, 40 kW microwave power in the continuous mode of operation and 100 kW in the pulse of 4 ms duration.

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БЛОК ЭЛЕКТРОННОЙ ПУШКИ, СОВМЕЩЕННОЙ С ГЕТТЕРНО - ИОННЫМ НАСОСОМ ДЛЯ МОЩНЫХ ПУЧКОВО - ПЛАЗМЕННЫХ СВЕРХВЫСОКОЧАСТОТНЫХ ПРИБОРОВ

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Описана конструкция блока, объединяющего электрону пушку, и геттерно - ионный насос, для мощных пучково – плазменных приборов, обеспечивающий откачку плазмообразующего газа из замедляющих структур. Такая конструкция минимизирует весогабаритные параметры блока. Блок, входящий в состав генератора с гибридной замедляющей структурой - цепочкой индуктивно связанных резонаторов, заполненной плазмой, обеспечивает генерацию стохастических колебаний в десятисантиметровом диапазоне длин волн в полосе частот 1 ГГц, при непрерывном режиме работы 40 и 100 кВт в импульсе длительностью 4 м.

БЛОК ЕЛЕКТРОННОЇ ГАРМАТИ, ПОЄДНАНОЇ З ГЕТТЕРНО - ІОННИМ НАСОСОМ ДЛЯ ПОТУЖНИХ ПУЧКОВО – ПЛАЗМОВИХ НАДВИСОКОЧАСТОТНИХ ПРИЛАДІВ

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Описана конструкція блоку поєднучого електронну гармату і гетеро - іонний насос для потужних пучково – плазмових приладів, забезпечуюющого відкачку плазмостворуючого газу із уповільнюючих структур. Така конструкція мінімізує малогабаритні параметри блоку. Блок, що входить до складу генератора з гібридною уповільнюючою структурою - ланцюгом індуктивно зв’язаних резонаторів, заповнених плазмою, забезпечує генерацію стохастичних коливань в десятисантіметровому діапазоні довжини хвиль в смузі коливань 1 ГГц в постійному режимі роботи 40 і 100 кВт в імпульсі тривалістю 4 мс.