ON CREATION OF A CATHODE UNITS FOR THE X -BAND KLYSTRON USING A HIGH-CURRENT MAGNETRON GUN AS A BASE

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The article presents the results from studies, performed at the R&D "Accelerator" NSC KIPT, on development of units for the X-band klystron with an output power 1...2 MW and at a voltage 50...100 kV. A magnetron gun with a cold secondary-emission metallic cathode is supposed to be used as an electron source.

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1. INTRODUCTION

Creation of small-scale resonance linear electron accelerators is very important for solving a number of applied problems - interoscopy (custom control), medicine (radiation therapy), technological treatment of food products etc. In this connection, the development of linear electron accelerators with an X-band operating frequency is a high-priority task. A main problem for carrying out the works in this direction is a choice of a powerful microwave source that would be capable to provide a compactness of an accelerator. The most acceptable microwave source for the small-size accelerator is an amplifier klystron with an output power 1…2 MW, a voltage up to 50 kV and an operating frequency of 11.4 GHz (fourth harmonics of the SLAC klystron frequency of the S-band). Considering that the typical value of the klystron efficiency lies within 30…50%, the pulse power of the electron beam should be 3…4 MW, i.e. at a voltage of 50 kV the beam current should be 60…80 A. The use of such a beam with a high perveance is connected with a particle bunching deterioration caused by the decrease of the wavelength of plasma oscillations in the beam with particle density increasing. One of the methods applied to decrease the beam density and to decrease the spatial charge force influence on the klystron bunch is the use of a hollow beam having a large diameter. As is shown in [1] when a hollow beam with a large diameter is used, one can apply the structure based on annular (coaxial) resonators as a resonance system. Just this type of a resonance system was chosen for the X-band low-voltage klystron that is under development at the NSC KIPT. Development of the klystron includes two stages: development of an electron source and development of a resonance system.

A main problem of the resonance system development is a possibility of a "parasitic" relation between the coaxial resonators due to the TEM wave excitation. However, by a special selection of the external and internal radii of resonators it is possible to provide the TEM mode suppression in the structure. Our preliminary calculations and experimental studies have showed that the connection/junction between resonators separated by the drift region can be made rather small in the system without beam. At the same time, the estimations showed that to increase the efficiency of the bunched beam interaction with the resonance structure, the latter should include the sections comprising several connected resonators excited at the π-mode of oscillations. The layout of the bunching resonance system of the klystron under development is presented in Fig.1.

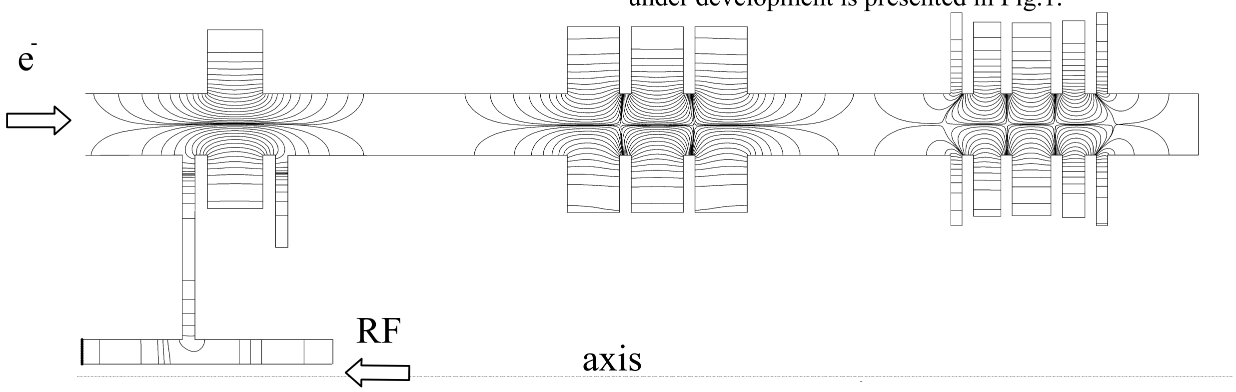

Fig. 1. The layout of the bunching resonance system

2. EXPERIMENTAL INSTALLATION AND PROCEDURE

The experiments were performed at the installation, the layout of which is shown in Fig. 2. The voltage pulse, of a special form, having the amplitude up to 100 kV, a pulse flat top duration of ~5 μ, a pulse repetition rate of (12±15) Hz from pulse modulator 1 was applied onto cathodes of the system 6, and anode 7 grounded by means of resistor R3. The voltage pulse top necessary to generate the beam was formed on the cathodes of the system by adding the short pulse from the single generator at the thyratron T2 and the flat-top voltage pulse from the modulator with the thyratron T1 [4]. The duration and slope of the pulse voltage decay were ~0.3 μs and ~150 kV/μs, respectively.

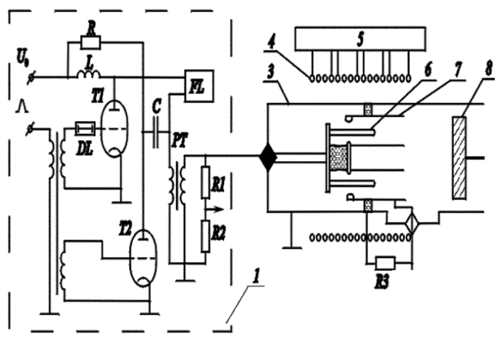

Fig. 2

The magnetron beam was located in vacuum chamber 3, where a pressure was ~10^{-6} Torr. The magnetic field for the beam generation and transport was created by solenoid 4 (comprising 4 sections), that was supplied from constant-current source 5. The strength and longitudinal distribution of the magnetic field in the vacuum chamber were controlled with changing the current value in the solenoid sections. The nonuniformity of the longitudinal magnetic field in the system and the channel of beam transport to the Faraday cup is ±8%.

We have studied the magnetron gun having a copper cathode diameter of 40 mm, an anode diameter of 50 mm, a cathode length 70 mm and anode length of 140 mm. The amplitudes of the voltage pulses and the beam current from each section of the Faraday cap and the beam imprint were measured. It has enabled us to determine the beam dimensions and its position on the Faraday cup.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The performed investigations showed that the beam generation is stable during 32 pulses measured by the help of an information measuring system. For example, for one of operating modes at a cathode voltage of 26 kV, a beam current of 52 A and a magnetic field 2500 G, the current instability of each of Faraday cup's sections at a cathode voltage instability of 1.8% was not higher than 4.5%. In another case at a cathode voltage of 27 kV, a beam current of 49A and a magnetic field of 2300 G the instability of each of beams getting the Faraday cup's sections at a cathode voltage instability of 1.7% was 1.8…2.9%. The investigation demonstrated that such a beam shapes a tubular beam with an external beam diameter of 43 mm, internal diameter of 41 mm. The duration of the beam current pulse was ~5 μs, the repetition rate was 15 Hz, the pulse beam power was ~1.5 MW with a microperveance of ~10.

The measurement of the beam density distribution on the azimuth showed that this uniformity has a significant nonuniformity. Fig. 3 presents the distribution of the beam charge from each of eight Faraday cup's sectors (channels 4 and 10 are not connected to the system). From the figure it is seen that the charge distribution on the azimuth is nonuniform and the nonuniformity amounts 400%.

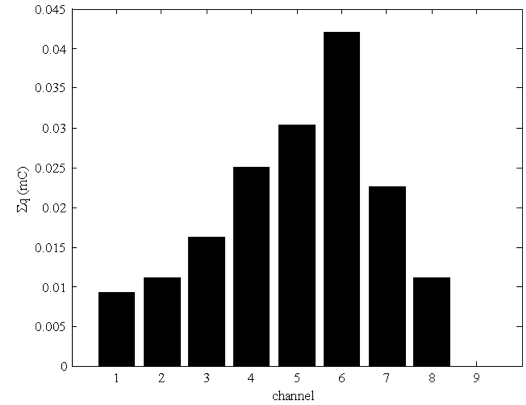

Fig. 3

The nonuniformity of the azimuthal distribution within 200…400 % was observed for different parameters of the high-voltage supply of the gun and for different values of the magnetic field. Moreover, it has been established that there exists also a significant asymmetry in the spatial particle distribution, i.e. the annular beam as a whole displaces relatively to the gun axis. In some cases this displacement on the collector was 8 mm. As is shown, the azimuthal distribution of the beam density and its position at the collector plane are depending on the magnetic field direction. Changing the magnetic field direction leads to the beam displacing in the opposite direction that is illustrated in figures 4 and 5.

The detailed investigation of the magnetic field topology showed that the magnetron source axis at the experimental installation was deviated from the solenoid axis (the deviation from the axis in the collector point was ~5 mm, in the cathode connection point was ~2 mm, the tilt was ~1°). Probably, this circumstance can be a cause of the asymmetry in the azimuthal particle density distribution and beam displacement. This may be explained by misalignment of magnetic and geometrical axises of the system or by development of diocotron instability of the beam. [3]. Thus, the experiments showed that the electron source with a secondary-emission cathode has a rather high stability. However, to define the conditions of obtaining the high azimuthal uniformity of the beam it is necessary to carry out supplementary investigations.

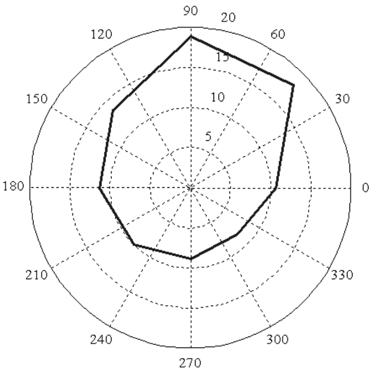

Fig. 4

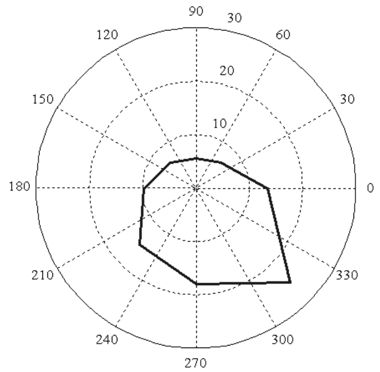

Fig. 5

4. CONCLUSION

Our investigations have demonstrated the possibility of a stable generation of electron beams in the magnetron gun with a cold secondary-emission cathode. It is shown that the stability of the beam current amplitude is ~2...3% and under optimum conditions can reach ~1%.

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О СОЗДАНИИ КАТОДНОГО УЗЛА КЛИСТРОНА Х-ДИАПАЗОНА НА ОСНОВЕ СИЛЬНОТОЧНОЙ МАГНЕТРОННОЙ ПУШКИ

А.Н. Довбня, Н.И. Айзацкий, В.Н. Борискин, В.В. Закутин, В.А. Кушнир, В.В. Митроченко, С.А. Пережогин, Н.Г. Решетняк, Д.Л. Стёпин

Приведены результаты исследований направленных на разработку в НИК «Ускоритель» ННЦ ХФТИ узлов клистрона Х-диапазона с выходной мощностью 1…2 МВт и напряжением 50…100 кВ для медицинских терапевтических ускорителей. В качестве источника электронов предполагается использовать магнетронную пушку с вторично-эмиссионным холодным металлическим катодом.

ПРО СТВОРЕННЯ КАТОДНОГО ВУЗЛА КЛІСТРОНУ Х ДІАПАЗОНУ НА ОСНОВІ МАГНЕТРОННОЇ ГАРМАТИ З ВЕЛИКИМСТРУМОМ

А.М. Довбня, М.И. Айзацький, В.М. Борiскiн, В.В. Закутiн, В.А. Кушнiр, В.В. Митроченко, С.А. Пережогiн, М.Г. Решетняк, Д.Л. Стьопiн

Приведено результати досліджень, направлених на творення в НДК "Прискорювач" ННЦ ХФТІ вузлів клістрона Х-діапазону з вихідною потужністю 1...2 МВт и напряженим 50...100 кВ для медичних терапевтичних прискорювачів. В якості джерела електронів передбачається використання магнетронної гармати з вторинно-емісійним холодним металевим катодом.