

COAXIAL PULSED 3 MW RF POWER INPUT FOR 176 MHz ACCELERATING STRUCTURE

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Design of the power input is described in the paper. The power input is a low-impedance coaxial line with the wave resistance of about 30 Ohm. One of the line ends is shorted, the other turns into the coupling loop, which inductance is compensated by the stray capacitance. The vacuum section of the power input is separated from the atmosphere by the cylindrical insulator made of 22XC ceramics. The coaxial part of the power input is divided into the 176 MHz quarter-wave-length insulator and quarter-wave-length transformer by the point of the 50 Ohm RF power feeder connection. Power input testing technique is described in the paper together with the results obtained when operating at the high power level.

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INTRODUCTION

176 MHz pulsed electron accelerator for 5 MeV electron energy and average beam power of 300 kW [1] is under construction at Budker INP. The commissioning work at the accelerator prototype is being carried out [2]. 3 MW pulsed power source is required to provide efficient power transfer to the electron beam. At operating frequency of 176 MHz, the power input design must be coaxial. In the accelerator prototype, the RF source power is by order lower, so the power input does not require blast cooling. It simplifies the power input design. The ceramic insulator which separates the accelerating structure vacuum volume from the atmosphere should meet the requirements of breakdown strength and heat load. Before installation into the accelerating structure, the power input was tested at the stand. The paper presents the power input design and results of its testing at the stand and being installed into the accelerator.

POWER INPUT DESIGN

The power input (see Fig.1) is made as low-resistance coaxial line 5 with the following dimensions: $D=160$ mm, $d=100$ mm. Wave impedance of that line is close to the optimal value $W=30$ Ohm with minimal surface electric field on the central conductor. One end of the line is short-circuited, and the other turns into the coupling loop 1. The loop inductance is compensated by the stray capacitance. The vacuum section of the power input is separated from the atmosphere by the cylindrical insulator 2 with the following dimensions: $D=80$ mm, $d=70$ mm, and $h=60$ mm. The insulator is made of 22XC ceramics ($\epsilon=9.3$, $\tan\delta=7\cdot 10^{-4}$, $\lambda=13.4$ W/m·K). Mechanical decoupling of the ceramics from the rigid coaxial is provided by the bellow 3. Also the watercooling 6 is provided. The power input is installed at the central cavity of the accelerating structure. Vacuum sealing is provided by 1 mm diameter indium wire. RF power is transferred through the 50 Ohm feeder 4 to the place which divides coaxial input section into the quarter-wavelength insulator and quarter-wave-length transformer. General view of the power input is shown in Fig.2.

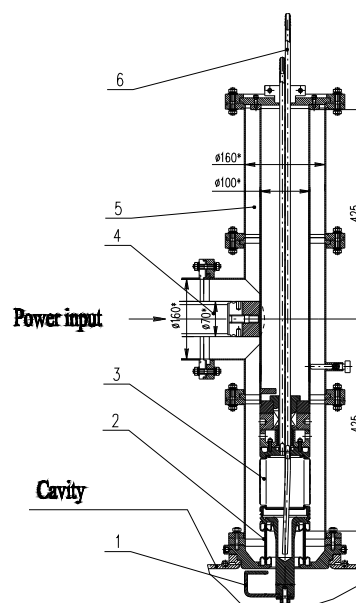


Fig.1. Power input sketch

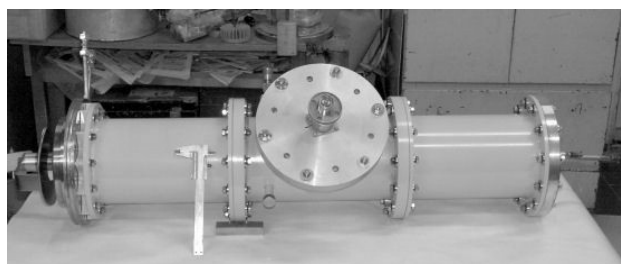


Fig.2. Power input general view

COMPUTER SIMULATION OF THE CERAMIC-METAL UNIT OF THE POWER INPUT

At the operating traveling wave mode, pulsed voltage in the feeder is 17.3 kV at power level $P=3$ MW. Voltage on the insulator after quarter-wavelength 28 Ohm transformer is 9.8 kV in the matched regime.

Simulations of electric fields in the power input and unit power were carried out with computer code SuperLANS [3]. Simulation results show that electric field strength does not exceed 10 kV/cm, power losses in the insulator (at off-duty factor 7) is 10 W, temperature gradient along the insulator is 5 K.

POWER INPUT TESTS

Tests of the RF power input were carried out at the stand consisted of the vacuum chamber and 180 MHz RF generator (see Fig.3). The generator power is $P=2$ kW at pulse duration of $100 \mu\text{s}$, repetition rate of 1 kHz, off-duty factor of 10.



Fig.3. Power input workbench

Having the limited generator power at the stand, tests were carried out in two stages with the use of coaxial circuit resonant behavior. At the first stage, the insulator electric strength was tested. For that purpose, power input coupling loop was removed and quarter-wavelength circuit with conductive coupling was organized. Fig.4 presents the first stage experimental setup scheme.

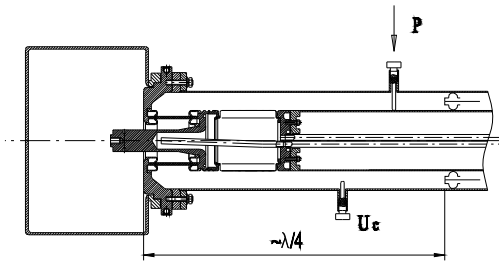


Fig.4. Quarter-wave circuit scheme

The circuit parameters are: quality factor of 1500, characteristic impedance of 30 Ohm, shunt impedance of 45 kOhm. At generator power of 2 kW, the insulator voltage is 13.4 kV, what is 30% higher the rated value in traveling wave mode.

Before the tests, vacuum in the chamber was at $8 \cdot 10^{-9}$ Torr level, and then it dropped down to 10^{-6} Torr at RF power supply turned on. After that, vacuum rapidly reached the stable level of $1.6 \cdot 10^{-8}$ Torr. So, the multi-

factor zone at 13.4 kV voltage was passed at the expense of high rate of pulse rise. Multipactor appears at pulse fronts, it may be seen from the fact that short-term switching the generator into CW regime leads to vacuum improving up to 10^{-8} Torr in spite of increase of RF voltage existing time by order. At lowered RF power level, multipactor burns at the major part of the pulse front and then passes to the pulse itself. Vacuum sharply drops. Two-day-long conditioning resulted in decreasing by order the voltage level of multipactor appearing. At total power of 2 kW, the vacuum level was stabilized at 10^{-8} Torr level.

At the second stage of tests, the power input with the coupling loop was transformed into three-quarter-wave circuit (see Fig.5). In that case, the insulator is placed into the voltage minimum of the standing wave. Capacitive coupling with the circuit takes place at the feeder connection area.

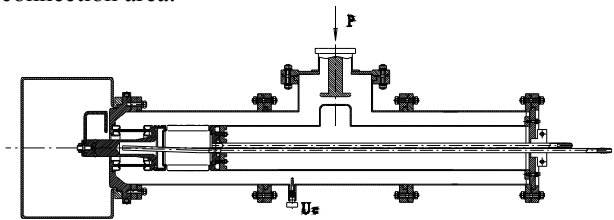


Fig.5. Three-quarter-wave circuit scheme

Three-quarter-wave circuit parameters are: quality factor of 2000, characteristic impedance of 14 Ohm, shunt impedance of 28 kOhm. At generator power of 2 kW, the maximal voltage in the power input is 10.6 kV, what is lower than the rated value in traveling wave mode (17.3 kV) by a factor of 1.5.

Before the tests, vacuum in the chamber was at $1.6 \cdot 10^{-9}$ Torr level, and then at 2 kW RF power supply turned on the multipactor was observed during the pulse and vacuum dropped down to 10^{-6} Torr. Vacuum degradation may be activated by decreasing the RF power level. In that case, multipactor zone cannot be passed because of decreasing of the rate of pulse rise of RF voltage. After two hours of conditioning, by multipactor at the worst vacuum level at lowered RF power, the full RF power was supplied, and vacuum was improved up to $2 \cdot 10^{-8}$ Torr with no multipactor during the pulse.

Two-day-long conditioning with step-by-step decreasing of the RF power level allowed us to obtain $1.6 \cdot 10^{-8}$ Torr vacuum.

Oscillograms on Fig.6 represent pulses of incident (1) and reflected (2) waves in the feeder together with the cavity voltage (3) during power input conditioning.

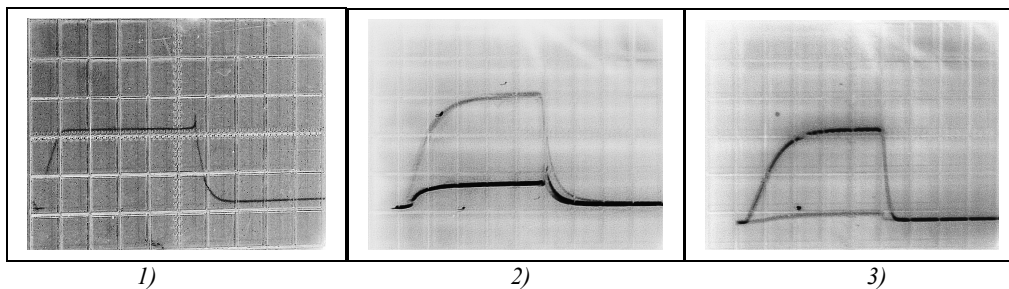


Fig.6. Power input conditioning oscillograms.

1) incident wave; 2) reflected wave (lower beam corresponds to a normal duty, upper beam – to the multipactor); 3) cavity voltage (upper beam – normal duty, lower beam – multipactor)

At present, the power input is installed into the accelerating structure (see Fig.7) after successful conditioning. VSWR of 3.3 has been adjusted by turning the coupling loop. 2.5 MW of power is transmitted through the power input into the accelerating structure at acceleration of 350 mA beam current up to 5 MeV. VSWR is measured with the directional coupler installed in the feeder section between the generator and accelerating structure.

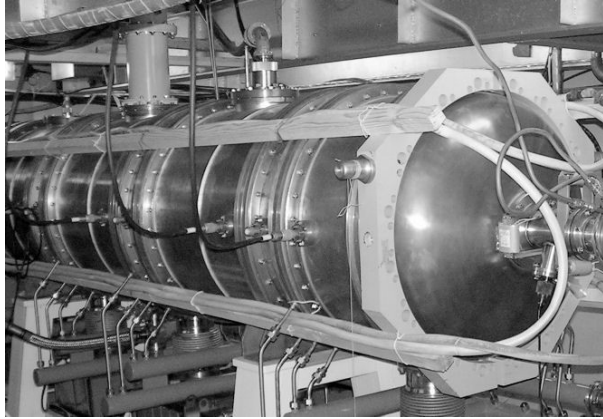


Fig.7. Power input installed into the accelerating structure

CONCLUSIONS

The tests carried out at the stand proved serviceability of the power input for the accelerating structure. Conditioning carried out allowed us to pass the multipactor zone at operating power level. Vacuum in the power input was improved as a result of multipactor appearance level drop. Discharges along the insulator were not observed at voltage by 30% higher than design level in traveling wave regime in the feeder. At short-term switching on of the stand generator in CW mode, the insulator was not damaged by thermal load. Power input operation was tested at the accelerator in 2.5 MW of power transfer operating regime.

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КОАКСИАЛЬНЫЙ ВЫСОКОЧАСТОТНЫЙ ВВОД ИМПУЛЬСНОЙ МОЩНОСТИ 3 МВт В УСКОРЯЮЩУЮ СТРУКТУРУ 176 МГц

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Приведена конструкция ввода мощности. Он представляет собой низкоомную коаксиальную линию с волновым сопротивлением порядка 30 Ом. Один конец линии закорочен, а другой – переходит в петлю связи, индуктивность которой компенсирована конструктивной емкостью. Вакуумная часть ввода мощности отделена от атмосферы цилиндрическим изолятором из керамики 22ХС. Высокочастотная мощность подводится фидером в месте, разделяющем коаксиальную часть ввода на четвертьволновый изолятор и четвертьволновый трансформатор на частоте 176 МГц. Волновое сопротивление подводящего мощность фидера 50 Ом. Описана методика испытания ввода мощности на стенде, приведены результаты его работы на большом уровне мощности.

КОАКСІАЛЬНИЙ ВИСОКОЧАСТОТНИЙ ВВІД ІМПУЛЬСНОЇ ПОТУЖНОСТІ 3 МВт У ПРИСКОРЮЮЧУ СТРУКТУРУ 176 МГц

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Наведено конструкцію вводу потужності, що являє собою низкоомну коаксіальну лінію з хвильовим опором порядку 30 Ом. Один кінець лінії закорочено, а інший – переходить у петлю зв'язку, індуктивність якої компенсована конструктивною ємністю. Вакуумна частина вводу потужності відділена від атмосфери циліндричним ізолятором з кераміки 22ХС. Високочастотна потужність підводиться фідером до місця, що розділяє коаксіальну частину вводу на чвертьхвильовий ізолятор і чвертьхвильовий трансформатор на частоті 176 МГц. Хвильовий опір фідера, що підводить потужність, 50 Ом. Описано методику випробування вводу потужності на стенді, наведені результати його роботи на великому рівні потужності.