MODERNIZATION OF INJECTION SYSTEM OF ACCELERATOR MLUD-3

S.A. Vdovin, N.P. Gladkiy, E.V. Gussev, P.L. Makhnenko, O.V. Manuilenko, E.I. Ponomarchuk, V.S. Sokol, A.A. Turchin
National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine
E-mail: gussev@kipt.kharkov.ua

Modernization of the injector accelerator MLUD-3 [1] was undertaken in order to create preconditions for the increase of the accelerated average current and improve of control parameters of the injector. Measures to increase the accelerated averaged current was directed to the extension of the pulse duration of the injection to the value of the pulse duration of the accelerating field, the conversion of the ion beam from the injector into the converging beam with parameters required for proper matching with the accelerating structure and to ensure the possibility of increasing the frequency of the pulse of injection.

PACS: 29.20.–c, 29.27.–a, 29.27.Ac

THE VACUUM CHAMBER OF THE INJECTOR

Increasing the frequency of the pulse injection at a constant pumping speed of the vacuum chamber of the injector leads to an increase in the gas load on the accelerating structure. Therefore, first of all, was designed and constructed a new vacuum chamber of the injector. The new vacuum chamber was allowed to halve the distance between the ion source and the resonator of the accelerating structure and to double the power of pumping. The vacuum chamber of the injector (Fig. 1) made of steel 10 mm thick.

Fig. 1. Vacuum chamber of the injector

On the end faces of the chamber are located on one side a flange for mounting and setting a high-voltage source insulator, on the other – a connection flange for attachment to the vacuum chamber of the focusing lens, or of accelerating structure. The bottom of the body of the focusing lens are simultaneously diaphragms bounding a gas flow from the source. On the side surfaces placed the flanges that provide connections to vacuum units, the installation of hermetic voltage inputs and the output of measured signals. The chamber, via the plate and adjusting bolts, is mounted on a support base on which the elements of the vacuum system, cooling and gas supply devices are fixed. The base is equipped with retractable rollers, facilitating connection of the injector with the chamber of accelerating structure. In the vacuum chamber of the injector the ion source by means of an insulator for a voltage of not less than 180 kV and via a vacuum-tight branch pipe is installed. Elements of the source fixing are used simultaneously for its adjustment, and setting the necessary sizes of ionic optics gaps. The method of fixing the source in the branch pipe ensures the saving of the position of its geometrical axis. The supply of voltage to the electrodes and of current to electromagnet is realized through isolated vacuum compacted bushings. At the opposite end of the vacuum chamber of the injector a focusing electrode of ion optics is placed on three high-voltage insulators on the same axis as the source. The supply of the voltage to the extracting electrode is provided by means of a high-voltage vacuum-tight input.

A MATCHING DEVICE

The matching device is designed to focus the flow of particles from the injector diverging in the radial directions into the flow converging, with the crossover in the first gap of the accelerating structure. Matching device (Fig. 2) is electrostatic lens with four gaps, and with sing-changing distribution of potential ±U (|U|≤75 kV). It is placed between the optics of the injector and the resonator of the accelerating system. The electrostatic lens was calculated numerically. Preliminary modeling was carried out with the help of programs developed at the NSC KIPT, in which a numerical code was used to calculate the fields strength distributions based on the integral equations method, but a detailed study was carried out with used the capabilities of the 3D modeling package for optics of charged particle IBSIMU [2, 3].

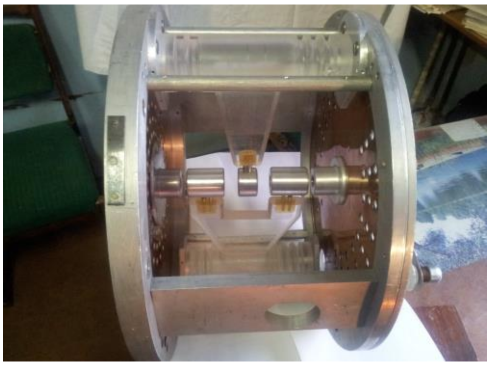

Fig. 2. General view of the matching device

In the manufacture of the device, the existing parts and assembly units of the accelerator cluster MRLD-3 were used [4]. In shortened to the necessary length of the body of the buncher on insulators, which were made from organic glass, potential tubular electrodes are fixed. The longitudinal dimensions of the focusing channel of the device are given in Table. The outer diameter of the electrodes is 42 mm, the inner diameter is 16 mm. The electrodes, which are under zero potential, are fixed on the end caps of the lens. All tube-electrodes are made of aluminum alloy. The matching device is installed on the input bottom of the first resonator of the accelerating structure by means of alignment fixtures. In the input tube there is an induction sensor for measuring the current of the injected particles.

№	Length of the electrode tube, mm	Length of focusing gap, mm
1	50.0	8.6
2	52.2	18.5
3	27.8	18.5
4	52.4	8.6
5	40.0	-

Potential tube-electrodes are supplied with a pulsed voltage: the extreme electrodes have a voltage of negative polarity equal to 72 kV, the average electrode have positive voltage equal to 42 kV.

POWER SUPPLY OF INJECTOR

The power supply system of the injector provides the generation of voltages necessary for the operation of the ion source and ion optics. It consists of modulators, pulse boosting transformers, to obtain accelerating and focusing voltages, power sources for a gas valve, discharge gaps and electromagnet. Measurement of impulse high voltage voltages is made by compensated active-reactive divisors. The transfer of power to the device of power supply of ion source is carried out through the separation transformer 220/220, designed for operating voltage of 180 kV.

Earlier high-voltage keys of modulators based on four thyristors were triggered by pulses of ~ 100 mks duration, which was much higher than the duration required for reliable key operation. To eliminate this drawback pulsed thyristor triggering transformers with trigger fronts a duration of ~ 0.3 mks were developed, which ensured the simultaneous operation of the keys.

The high voltage of the ion source of 150 kV was formed by means of a cascade transformer consisting of five pulse transformers connected in series according to the autotransformer circuit. Under such a scheme, the high-voltage pulse practically did not have a flat top. This disadvantage was eliminated by remodeling of circuit of high-voltage modulator of the source. As a result, a pulse with a front-side duration of 150 mks and a flat vertex of 300 mks duration was generated. All the elements of the power system and the injector designs, which are at high potential, are located behind the standard fence, which provides protection against high voltage. Pulses of synchronization are delivered to the elements under high potential through a remote control system.

SYSTEMS OF OPERATION AND CONTROL INJECTOR'S PARAMETERS

The effectiveness and reliability of accelerator operation substantially depends on the quality and functionality of the control system. Especially for accelerator MLUD-3 was designed, constructed and tested a device to driving and control parameters of the injector accelerator, which is under a high potential. The device consists of 2 modules – management and execution. The control module is designed to receive pulsed electrical control signals from a synchronizing or control device, to convertion them into pulsed light signals of infra band and signals transmission into fiber line.

The module have placed in the operator room of the experimental setup. The module has 4 channels of transmission of synchronization signals to the actuating module and 5 analog optical channels for receiving signals from the executive module, which is under high potential (+180 kV). Electrical and optical connectors of input and output channels have been installed on the front panel of the module and are numbered 1...5. Synchronization channel 1 transmits the control pulses with duration of 1.5…3.5 ms on the valve for adjustment gas yield. Channels 2-4 transmit the control impulses for a thyristor modulators with the duration of 10 mks. Analog optical channels intended for transmission of analog signals of currents and voltages of the injector's modulators which is under a high potential. The bandwidth of each channel 300 kHz, accuracy not worse than 3%. The executive module consists of two blocks: of block for reception of synchronization signals under a high potential and of block for transmission of analog signals of currents and voltages to the control module (Fig. 3).

Fig. 3. Fiber-optic receiver-transmitter

Block for signals reception intend for intake pulsed light signals of synchronization, which came from the control module via fiber optic lines, converting them into electrical signals and amplification of these signals to the values necessary to control actuators of the injector.

The signal receiving unit designed to receive pulsed light signals sync supplied via fiber optic lines from the control module, converting them into electrical signals, amplification of these signals to the values necessary to control actuators of the injector. Block of the transmission of analog signals is designed to receive electrical signals from the injector's modulators, convert these signals into light signals and transmit them in a fiber-optic line for conveying to the control module. The module allows you to transmit voltage -2 kV for discharge initiation modulator and +400 V for a modulator of discharge current. Characteristics of the signals of execution module correspond to the characteristics of the signals of the control module.

In addition to device of operation and control of injector's parameters, were designed, constructed and tested on a new elements base a module for network synchronization and block for delay starting the timer (Fig. 4).

The device is designed for simultaneous change of delay the start pulses coming from the module of synchronization to the modulators of sources of high voltage of the accelerator.

Fig. 4. Timer-Synchronizer

The module allows you to simultaneously hold all of the timing pulses, coming to the accelerator, relative to the valve firing for adjustment gas yield of the source. The module provides operative search of optimum modes of operation of the ion source without disturbing the parameters settings of the accelerator systems.

CONCLUSIONS

Undertaken measures on the upgrade of the injector allow to increase the current of ions entering the accelerating structure in the pulse up to 150 mA. This will make it possible to increase the accelerated average current to ~ 100 mkA at a frequency of injection pulses of 10 Hz, with a capture coefficient of particles in the acceleration process of 0.3. The new operation and monitoring devices of the injector's parameters have provided transmission of noise-immunity control and measuring signals with a galvanic decoupling up to 180 kV in the presence of powerful impulse noise, generated by power supply devices of the accelerator. The application of these developments not only increased the reliability of activity and control of the accelerator's injector, but also ensured the on-line monitoring of the parameters of the ion source that is under high potential, which was not available before.

REFERENCES

1. L.N. Baranov, Ye.V. Gussev, S.S. Kaplin, N.E. Kovpak, V.T. Onoprienko, V.G. Papkovich, N.A. Khyzhnyak, N.G. Shulika. Experimental study of a compact linear deuteron accelerator with alternating phase focusing // *Problems of Atomic Science and Technology. Series "Linear Accelerators"*. 1977, № 2(5), p. 12-14.
2. A.G. Belikov, L.A. Bondarenko, S.A. Vdovin, Ye.V. Gussev, O.V. Manuilenko. Investigation of beam extraction and formation in ions injector // *Problems of Atomic Science and Technology. Series "Nuclear Physics Investigations"*. 2018, № 3, p. 63-67.
3. A.G. Belikov, L.A. Bondarenko, S.A. Vdovin, Ye.V. Gussev, O.V. Manuilenko, N.G. Shulika. Transport and matching of the injecting beam // *Problems of Atomic Science and Technology. Series "Nuclear Physics Investigations"*. 2018, № 3, p. 68-72.
4. Ye.V. Gussev, P.A. Demchenko, N.G. Shulika, O.N. Shulika. The buncher beam linear accelerator of deuterons // *Problems of Atomic Science and Technology. Series "Plasma Electronics and New Acceleration Methods"*. 2008, № 4(6), p. 322-326.

Article received 12.02.2018

МОДЕРНИЗАЦИЯ СИСТЕМЫ ИНЖЕКЦИИ УСКОРИТЕЛЯ МЛУД-3

С.А. Вдовин, Н.П. Гладкий, Е.В. Гусев, П.Л. Махненко, О.В. Мануйленко, Е.И. Пономарчук, В.С. Сокол, А.А. Турчин

Представлены результаты модернизации системы инжекции ускорителя МЛУД-3. Система инжекции дополнена устройством согласования на основе многоэлектродной электростатической линзы, которая обеспечила транспортировку и согласование характеристик инжектируемого пучка с ускоряющим каналом. Усовершенствована система электропитания инжектора. Улучшены характеристики и надежность работы высоковольтных модуляторов источника ионов и линзы. Управление работой устройства питания ионного источника, находящегося под высоким потенциалом, и съем информации с устройства переведены на оптронные линии связи. Создано современное таймерное устройство для управления и синхронизации импульсных устройств ускорителя. Устройство сопрягается с персональным компьютером, обеспечивающим управление и сохранение режимов работы. Увеличены объем вакуумных камер системы инжекции и мощность средств откачки, что улучшило вакуумные характеристики и повысило надежность работы системы инжекции.

МОДЕРНІЗАЦІЯ СИСТЕМИ ІНЖЕКЦІЇ ПРИСКОРЮВАЧА МЛУД-3

С.О. Вдовін, М.П. Гладкий, Є.В. Гусєв, П.Л. Махненко, О.В. Мануйленко, Є.І. Пономарчук, В.С. Сокол, О.А. Турчін

Представлено результати модернізації системи інжекції прискорювача МЛУД-3. Система інжекції доповнена пристроєм узгодження на основі багатоелектродної електростатичної лінзи, яка забезпечує транспортування і погодження характеристик інжектованого пучка з каналом, який прискорює. Удосконалена система електричного живлення інжектора. Поліпшені характеристики й надійність роботи високовольтних модуляторів джерела іонів і лінзи. Управління роботою пристрою живлення іонного джерела, що знаходиться під високим потенціалом, і знімання інформації з пристрою забезпечують оптроні лінії зв'язку. Створено сучасний таймерний пристрій для управління і синхронізації імпульсних пристроїв прискорювача. Таймер сполучається з персональним комп'ютером, що забезпечує управління і збереження режимів роботи. Збільшено об'єм вакуумних камер системи інжекції і потужність засобів відкачування, що поліпшило вакуумні характеристики і підвищило надійність роботи системи інжекції.