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PHYSICS AND TECHNIQUE OF ACCELERATORS

VEPP-5 Injection Complex

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Abstract—The VEPP-5 injection complex is a source of intense electron and positron beams that supplies the VEPP-4M and VEPP-2000 accelerator complexes through the K-500 transport channel. At present, the injection complex is in regular operation. Work is being carried out to improve the performance and stability of the facility, and possible ways of working with perspective beam users are being considered. This article presents a description of the injection complex and the experience of its operation, as well as the latest improvements being considered.

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INTRODUCTION

The VEPP-5 injection complex [1, 2] serves as a source of electron and positron beams for two operating accelerator complexes (VEPP-2000 [3] and VEPP-4 [4], [5]), with which it is connected by the K-500 transport channel (Fig. 1). Work with promising consumers, for example, with a μμ-tron [6], is also considered.

The injection complex includes linear accelerators of electrons and positrons for energies of 270 and 430 MeV, a storage cooler (SC), and the transport channels connecting them.

Linear accelerators consist of 4 modules in which there are a total of 14 accelerating structures with a constant impedance of the round diaphragm waveguide type operating at a frequency of 2855.5 MHz [7]. Each accelerating module is powered by a 5045 klystron manufactured by SLAC. The SC is designed for a maximum energy of 510 MeV; it has a perimeter of 27.4 m, and the radiative decay times at the maximum

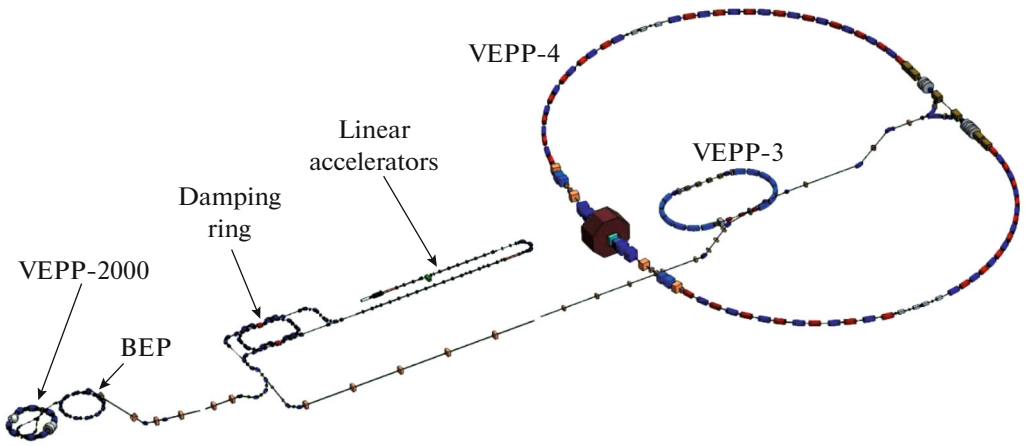

Fig. 1. Scheme of the injection complex with beam consumers.

energy are 18/11/12 ms (v, h, s). At the moment, the resonator of the first harmonic of 10.94 MHz operates at the SC [8]. Injection from linear accelerators into the SC is carried out at a frequency of up to 12.5 Hz; bypass to consumers is possible at a frequency of up to 2 Hz. It occurs once every 3 s due to restrictions on the intake systems from the booster of the VEPP-2000 complex. Currently achieved electron and positron accumulation rates are 1.1×10^{11} e^-/s and 1.2×10^{10} e^+/s.

The beam that is released is transported to consumers via the K-500 channel, the length of the branches of which is about 250 m to BEP and about 120 m to VEPP-3. The design beam energy in the transport channels is 510 MeV. The K-500 consists of five sections: the descent from the SC into the tunnel, regular FODO structures in each direction, and the risers to each of the beam consumers. To date, a bypass efficiency of about 50% has been achieved in both directions, and work is underway to improve the efficiency and stability of the bypass.

1. SOFTWARE DEVELOPMENT

The software of the complex is based on the CXv4 modular framework [9]. Initially, this framework served to abstract the hardware of the accelerator, but now the practice of using CX servers for exchanging data between programs at the client level has developed. That is, CXv4 serves as a common software bus, which greatly simplifies communication between programs. The injection complex uses centralized loading/saving of plant states, which required a configuration database containing structured information about subsystems and devices. The state loader serves as the basis for automation that implements the accumulation-release cycle and switching between consumers or particle types [10]. For the operation of automatic software, it was immediately necessary to exchange data with the control systems of the beam consumers. The situation is complicated by the fact that the control systems of the injection complex and beam consumers were initially developed independently and, as a result, they use different basic software. EPICS is on the VEPP-4 side and VCAS and TANGO are on the VEPP-2000 side. Previously, the data necessary for automation was transmitted by gateway programs using the common network of the institute. The rest of the data, for example, the diagnostic information of the K-500 channel, was not transmitted, but instead the practice of remotely launching client programs was adopted.

To improve interaction with beam consumers for CXv4, client modules for VCAS, EPICS, TANGO, and a server module for EPICS were developed. The client modules make it possible to access data from third-party software using the CX client libraries, and the server module allows the CX server to respond using the protocol of another framework. A driver was implemented for mirroring device data or individual channels for CXv4 was well. This set of tools allows one to create very flexible "gateways" between all existing installations. The configuration database of the complex has now been supplemented with CXv4 configuration automation tools, which greatly simplifies the creation of software devices and the configuration of gateways. The exchange of data between control systems has now been brought to a separate network, and work is underway to gradually abandon the remote launching of applications through the institute's network.

Currently, the configuration database is also used as a data source for application programs. For example, software tools for controlling the storage cooler [11] use the architecture described above with CX servers as a common software bus and use the configuration database to select the elements of the magnetic system involved in the measurement of the response matrix. To date, the set has implemented semiautomatic iterative orbit correction in the storage ring.

2. WORK IN THE 2021–2022 SEASON

Since the beginning of the 2019–2020 season, a new cathode assembly with a maximum current of 10 A has been operating in the electron gun of the complex. Previously, a node with a maximum current of 4 A was used, the service life of which under the conditions of the injection complex was about 2 years. In the first season with the new cathode, a study was made of the possibility of working with a high current or beam duration, as a result of which significant improvements in the characteristics of the complex for consumers were not obtained. After that, the gun is tuned to a pulse duration of 5 ns and a current of about 5 A. After that, a slight drop in the gun current with time is observed and corrected by a gradual increase in the cathode incandescence.

In the 2020–2021 season, work was carried out to more accurately adjust the phases of the accelerating structures; as a result, the complex was switched to an energy of 430 MeV. In 2021–2022, work on this energy was continued. In the second half of the season, the energy stability of the linear accelerators deteriorated significantly, which also affected the injection efficiency. This was caused by the unstable operation of the thyratron trigger circuits in the third modulator, which proved impossible to eliminate during the season, so it was decided during the summer shutdown to update the power part of the modulator. In the last month of the season, the first klystron went out of service and needed serious repairs. The study of the situation at the same time showed that work at an energy of 395 MeV is available for electrons, which made it possible to carry out work with synchrotron radiation planned for the end of the season at VEPP-4

3. ABILITY TO WORK WITH SHORT BUNCHES

In the current configuration, the injection complex produces beams with a longitudinal duration of about 5 ns. This is too much for the projected collider with a 350 MHz RF station, so the possibility of forming shorter bunches is being studied. Previously, the longitudinal motion of particles in an SC, taking into account collective effects, was studied experimentally, and a model was created that describes the observed results well [12]. To form short bunches, you can install 32 harmonics of the revolution frequency on the SC resonator. Since the parameters of such a resonator are well known, it was added to the existing longitudinal motion model, on which it is possible to obtain lossless beam rearrangement with a relatively smooth switching on of the 32nd harmonic resonator.

CONCLUSIONS

The injection complex continues to provide beams for the BINP installations. The possibility of operation in the electronic mode at an energy of 395 MeV without a single accelerating module is shown. Work continues on automation, improving reliability, and increasing the productivity of the injection complex. Studies into the possibility of working with promising users of the beam continue.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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