HIGH-VOLTAGE ACCELERATORS INTENDED TO PRODUCE CONTINUOUS AND PULSE NEUTRON FLUXES

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Abstract

Recently, in NIIEFA a series of high-voltage accelerators intended to produce continuous and pulse neutron fluxes with a yield of 10^{10}-10^{12} n/s has been designed. The facilities designed can be used for operation in the continuous, microsecond and nanosecond modes, in any combination. In the pulse microsecond mode, ion currents of up to 100 mA with pulse lengths ranging from 2 up to 100 µs can be obtained on target. In the nanosecond mode, the accelerator produces an ion beam current of up to 5 mA with a pulse length in the range of 2-30 ns.

Over the last years the interest towards pulse neutron generators is growing due to continuation of research in the field of nuclear physics using time-of-flight methods. One more reason of such interest is that the development of high-effective systems for the detection of fissionable substances, explosives, drugs and poisons is a currently central issue. R & D works have been carried out in NIIEFA to design and build neutron generators, which produce neutron fluxes of high-intensity in the continuous operating mode and, in addition, will be capable of producing neutron fluxes in a wide range of the pulse repetition rate and pulse length.

The NG-12-2 neutron generator [1] is a high-voltage accelerator of deuterium ions with an acceleration voltage of 300 kV and a beam current of deuterium atomic ions of up to 15 mA.

The general view of the NG-12-2 neutron generator is shown in figure 1.

Figure 1: The NG-12-2 Neutron Generator Installed in the Institute of Nuclear Physics and Chemistry, CAEP, China.

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The ion injector is installed in a high-voltage terminal of the accelerator and consists of an ion source with initial beam forming system, analyzing 90^0 electromagnet, autonomous vacuum system, electric power supply and control systems. The ion source is of an ECR type with a four-electrode ion beam forming system [2]. Spatial and angular characteristics of the beam at the accelerating tube input are controlled with a double-focusing analyzing electromagnet and electromagnetic solenoid lens.

The ion optical system of the accelerator was designed so that to obtain at the accelerator output in the switching magnet plane a deuterium ion beam with a current of up to 20 mA, an emittance and regular divergence values required for its further transport towards the target. A 45^0 electromagnet serves for the beam switching to two beamlines. The first of them is intended for the operation in the continuous and pulsed microsecond modes. An ion beam with a pulse length of 10-100 µs and pulse repetition rate up to several kHz is produced by the microwave discharge modulation in the ion source. The second is designed for the production of ion pulses with the 1-2 ns length on a stationary target. Such pulses are produced in a beamline, which consists of a beam chopper, klystron particle buncher, target device and beam focusing and measuring system. The system of nanosecond pulse forming is described in detail in [3]. The length of the beamline is about 6 m.

Thus, the neutron generator described in the paper allows a beam of atomic ions with a current of up to 15 mA and beam diameter of 20 mm to be obtained on a rotating target of 230 mm diameter. In the pulsed mode, a pulse length can be 10-100 µs and current amplitude of up to 20 mA. In the second beamline, a peak ion current of 10 mA with a pulse length of 1.7 ns was obtained. The pulse repetition rate can be set to 1, 2, 4 MHz; a mode is provided when it can be smoothly varied in the 1-100 kHz range.

The generators of the NH-12-2 model can be successfully operated at large research centers. However, there exists a demand for less expensive generators with lower neutron yield but also equipped with auxiliary systems to widen the fields of possible applications.

The NG-11I neutron generator is designed for a neutron yield of 5×10^{11}n/s in the continuous operating mode. It is equipped with a system for production of pulse neutron fluxes in the microsecond range by modulating the ion source discharge. The generator is a deuterium ion accelerator with an acceleration voltage of 180 kV and atomic ion beam current on target up to 5 mA. An ECR ion source is also used in the accelerator. An electromagnetic analyzer mounted behind the accelerating

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tube serves for the mass separation of the ion beam and its simultaneous switching between two beamlines. This makes much simpler the design of the injector and the whole accelerator. The ion-optical system of the accelerator with the main focusing element being an adjustable input lens of the accelerating tube serves to form a beam with parameters required for its transport to the target in the continuous operating mode and its modification in the beamline, in which a nanosecond pulse is produced. The latter is completely similar in design to the beamline of the NG-12-2 neutron generator. The NG-11I generator is shown in Figure 2.

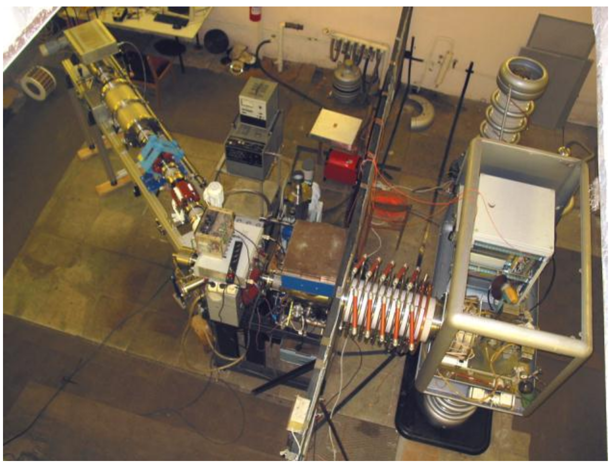

Figure 2: The NG-11I neutron generator at a test facility.

One more generator, the NG-11I-1, with a yield of 2×10^{11} n/s has been developed on the basis of duoplasmatron ion source, which allows shorter beam current pulses, compared to the ECR source, to be obtained in the microsecond mode. This is very important for certain applications. Figure 3 shows the general view of the NG-11I-1 neutron generator.

Figure 3: The NG-11I-1 Neutron Generator at a Test Facility in the MIPHI.

A deuterium ion beam produced by the duoplasmatron is accelerated up to 180 keV, separated with a 90^0 electromagnetic analyzer and directed towards the target through a beamline. The atomic ion beam current on target is up to 3 mA both in the continuous and microsecond pulse modes. To produce nanosecond pulses, a system similar to that of the NG-12-2 generator is used with minor modifications in power supply systems of the beam chopper and buncher.

Nowadays, the designing of the NG-10 neutron generator has been finished and works on its manufacturing have been started. This machine is designed to work as a reference source of a neutron flux and neutron flux density. The accelerator is designed for obtaining a stable current of an atomic deuterium ions on target up to 500 μA with the acceleration voltage smoothly controlled in the 120-150 keV range. The generator can be operated both in continuous and pulse modes. The current amplitude of the atomic deuterium ions is 1mA, pulse length can be varied from 2 up to 100 μs, pulse repetition rate can be controlled from single pulses to 20 kHz.

Works to increase the neutron flux intensity are in progress. For the neutron generator with a yield of 5×10^{12}-10^{13} n/s, an ECR ion source with a current of up to 100 mA and pulse lengths in the 10-200μs range has been designed. The source has been successfully tested at a test facility in NIIEFA.

The control systems of the designed generators are based on industrial computers, which provide control of the accelerator parameters, keep the parameters within a selected range, inform the operator on the current state of the main sub-systems and switch the accelerator off in case of an emergency. The power supply sources of the accelerators operate at a frequency of 20 Hz, which allowed their overall dimensions to be significantly decreased and the stability of operation to be increased. High-voltage systems are controlled via fiber-optical communication channels.

In conclusion, four neutron generators have been designed and built over the last years in NIIEFA. These machines can satisfy a demand of research centers for a sufficiently wide range of applications. Different configurations of these accelerators can be provided and output parameters can be varied on request.

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