PULSED NEUTRON GENERATORS AT D.V. EFREMOV RESEARCH INSTITUTE

D.A. Solnyshkov, G.G. Voronin, A.P. Strokach, V.I. Grigoriev, A.V. Morozov ,A.I. Solnyshkov, D.V. Efremov Research Institute, Saint-Petersburg, Russia.
E-mail: d-soln@mail.ru

Abstract

In the last years the interest towards pulse neutron generators is growing due to continuing research in nuclear physics (using flight time methods) and due to the importance of possible applications. Such generators allow to develop highly effective detectors for radioactive materials, but as well for explosives, drugs, and poisons. The Efremov Institute has carried out a series of research and development projects in order to create generators capable of producing neutron fluxes of high intensity in continuous mode, but also capable of operating in pulse mode with a wide range of pulse frequency and repetition rate.

Fig.1 Neutron generator NG-12-2

The neutron generator NG-12-2 [1] is a high-voltage accelerator for deuterium ions with an acceleration voltage 300 kV and a beam current of deuterium atomic ions up to 15 mA. The generator is shown on figure 1. The ion injector is installed in the high-voltage terminal of the accelerator. It includes an ion source with initial beam forming system, an analyzing 90-degree electromagnet, an autonomous vacuum system and electric power supply and control system. The ion source is an ECR one [2] with a four-electrode ion beam formation system. Spatial and angular characteristics of the beam at the accelerating tube input are controlled with the analyzing electromagnet with double focusing and a solenoid lens. The ion optical system of the accelerator has been designed in order to obtain the deuterium ion beam current of up to 20 mA at the accelerator output, in the plane of the distribution magnet. This beam has an emittance and regular divergence values required for further transport towards the beam. The 45-degrees electromagnet allows switching the beam between the two transport channels. The first channel is designed to operate in continuous and microsecond pulse modes. An ion beam with pulse duration of 10-100 ms and repetition rate up to several kHz is
obtained by microwave discharge modulation in the ion source. The second channel is
designed for obtaining ion pulses of 1-2 ns duration at the stationary beam. Such pulses are obtained by means of a beam chopper and a clystron buncher. The channel also includes a target device and a beam
focusing and measuring device. This nanosecond pulse formation system is described in details in [3]. The oscillogram of the beam current pulse obtained with a Faraday cylinder installed before the target is shown in figure 2. The length of the beam formation channel is about 6 m.

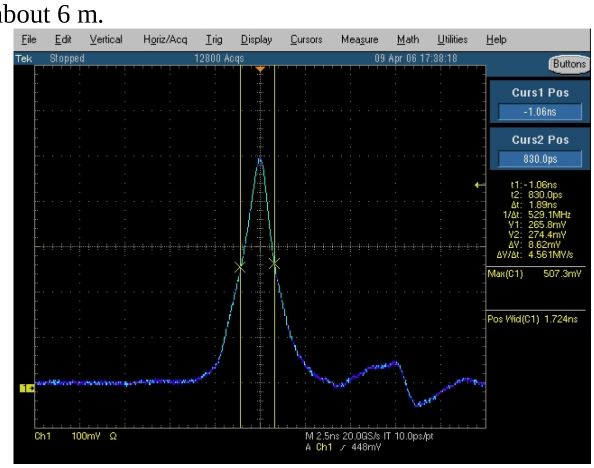

Fig.2. The oscillogram of the beam current pulse

The neutron generator allows obtaining the beam current of atomic deuterium ions of 15 mA at the rotating target of 230 mm diameter, with the beam diameter of 20 mm. For the pulsed mode with pulse duration 10-100 ms current amplitude can be up to 20 mA. The second channel allows obtaining peak current up to 10 mA with pulse duration 1.7 ns. The repetition rate can be set to 1, 2, and 4 MHz, or it can be varied smoothly between 1-100 kHz. The generators like NG-12-2 can operate in large research centers, but there is also a demand of less expensive generators with lower neutron yield, but with auxiliary systems broadening the range of possible applications.

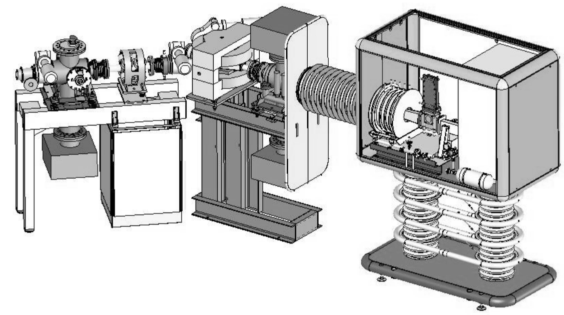

Fig.3.Neutron generator NG-11I

A neutron generator NG-11I (shown on figure 3) is designed to obtain a neutron yield of $5x10^{11}$ n/s in continuous mode. It is supplied with a microsecond pulse generation system which operates by modulation of the ion source microwave discharge. The generator consists of an accelerator of deuterium ions with acceleration voltage of 180 kV and atomic ion beam current at the target up to 5 mA. This accelerator is also using an ECR ion source. Mass separation of the ion beam and switching between two channels is performed by an electromagnetic analyzer, which is installed after the acceleration tube. This simplifies significantly the injector and accelerator design. The ion optical system of the accelerator with the main element being the adjustable lens of the accelerating tube, provides beam formation with parameters required for transporting it to the target in the continuous mode or modifying it in the nanosecond pulse channel. The latter channel is completely similar to that of NG-12-2.

The first example of the generator NG-11I is mounted on a stand and currently being tested. A photograph is shown on figure 4.

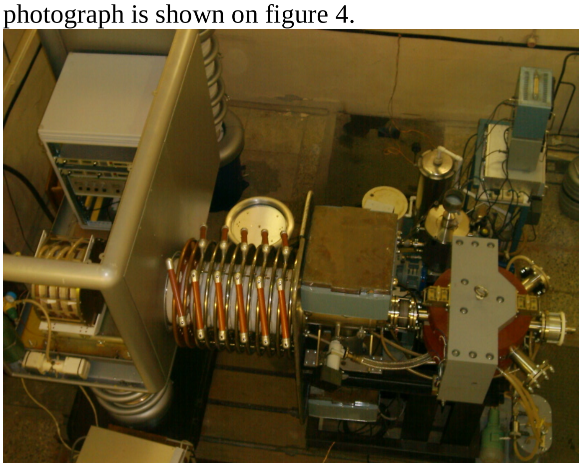

Fig.4. Fotograph NG-11I

Another generator with a yield of $2x10^{11}$ n/s has been developed on the basis of a duoplasmatron ion source, which allows obtaining even shorter pulses, than by using an ECR ion source in microsecond mode. This is very important for certain applications. The electric power supply system of the duoplasmatron is shown on figure 5.

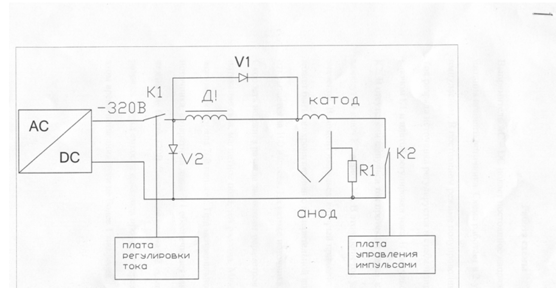

Fig.5. The electric power supply system of the duoplasmatron.

The AC-DC rectifier supplies constant voltage to the ion source power supply circuit, which can operate in continuous and pulse modes. In the continuous mode the K2 switch is open, and the discharge current is controlled and stabilized by the semiconductor switch K1 and the current control circuit. In the pulse mode the K2 switch is operating (closed). During the gap, the current flows through the switch K1, the choke B1, the closed switch K2 and the diode D2. This circuit keeps the current constant at a preset value. At the pulse edge coming from the control rack, the switch K2 opens in about 100 ns. The pulse edge can be synchronized with measurement apparatus. The cathode voltage of the source is then increased up to the discharge value. Discharge start-up time depends on the pressure and the magnetic field and can be about 700 ns. Closing the switch K2 sets the second edge of the pulse. Discharge is turned off in less than 1 microsecond. The diode V1 provides protection against overvoltages. The deuterium ion beam obtained from the duoplasmatron is accelerated up to 180 keV, separated by a 90-degrees electromagnetic analyzer and directed towards the target via the beam transport channel. The atomic ion beam current can be up to 3 mA both in continuous and microsecond pulse modes. A nanosecond pulse formation system similar to that of the NG-12-2 generator can be used, with small changes in the beam chopping and bunching systems.

The control systems of the proposed generators are based on industrial computers which provide control of the accelerator parameters, keeping them in the selected range, inform the operator on the state of the system components and switch off the accelerator in case of emergency. The power supply sources of the accelerators operate at a frequency of 20 kHz which has allowed to decrease significantly their size and increase their stability. High-voltage systems are controlled via fiber-optical channels.

To conclude, in the last years the Efremov Institute has developed 3 neutron generators for research centers and industrial applications. Different configurations of accelerators can be provided with various output parameters.

REFERENCES

[1]. Г.Г.Воронин и др. Генератор нейтронов НГ-12-2. Сборник докладов одиннадцатого международного совещания по применению ускорителей заряженных частиц в промышленности и медицине, Санкт-Петербург, 10-14 октября 2005 г., стр.278-281.

[2]. Voronin G., Solnyshkov D., Solnyshkov A., Svinin M., Nucl.Instr. and Meth. In Phys. Res.B. 161-163 2000 ,1118-1122

[3]. Г.Г.Воронин и др. Ускоритель для получения пучков ионов в непрерывном и импульсном режимах. 20th Russian Conference on Charge Particles Accelerators, September 10-11,2006, BINP, Novosibirsk, Russia.

.

.