NEUTRON GENERATORS OF THE NG-10 SERIES FOR METROLOGY

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Abstract

Neutron generators NG-10 and NG-10M with a neutron yield of $1 \cdot 10^{10}$ n/s and $2 \cdot 10^{11}$ n/s respectively have been designed in the JSC “NIIEFA”. The generators are high-voltage accelerators with target devices, in which Ti-T/Ti-D targets of different diameters are used. A duoplasmotron allowing a beam current up to 5 mA to be obtained is used in the NG-10 generator, and the NG-10M employs a microwave ion source providing the beam current up to 10 mA. The power supplies, which are under a high voltage, are controlled via fiber-optic communication lines. A beam of ions produced in the ion source is accelerated up to 150 keV in a sectionalized accelerating tube, separated in mass with an electromagnetic mass-separator and focused onto a target with a doublet of electromagnetic quadrupole lenses.

The generators are equipped with several lines to transport the beam to target devices, which can be placed in separate rooms. In addition to a high and stable yield of neutrons when operating continuously, the generators can provide the pulsed mode with a time from 2 µs up to 100 µs and pulse repetition rate from 1 Hz up to 20 kHz.

INTRODUCTION

Neutron generators NG-10 [1] and NG-10M designed in NIIEFA are intended for application in metrological laboratories as apparatus generating reference neutron fluxes and can be also used for neutron-activation analysis in different fields of science and engineering. The machines are designed for neutron yields up to 10^{11} n/s in the continuous operating mode. The generators consist of a deuterium ion accelerator with an accelerating voltage continuously adjustable in the range of 120-150 keV, beam current of atomic deuterium ions on a target up to 2 mA and a series of target devices, in which Ti-T and Ti-TD targets of different diameters are used. In addition to a high and stable in time neutron yield in the continuous mode, such generators provide pulse neutron fluxes with pulse durations and pulse repetition rates varying over a broad range [2, 3].

The ion beam produced by the ion source is accelerated up to 150 keV in a sectionalized accelerating tube, separated in mass with an electromagnetic mass-separator and then focused to a target by a doublet of quadrupole electromagnetic lenses. The generators can be equipped with lines to transport beams to target devices placed in separate rooms.

VERSIONS OF ION SOURSE

A duoplasmatron-type source is used in the NG-10 generator. Duoplasmatron is the most widely used ion source applied in neutron generators. However, poisoning of the used heated cathode as a consequence of a micro leakage appeared in the discharge chamber or gas-supply system of the source makes necessary its cleaning or replacement, which requires opening of the vacuum volume and results in long-term shutdowns of the generator. The general view of the NG-10M generator is shown in Fig. 1.

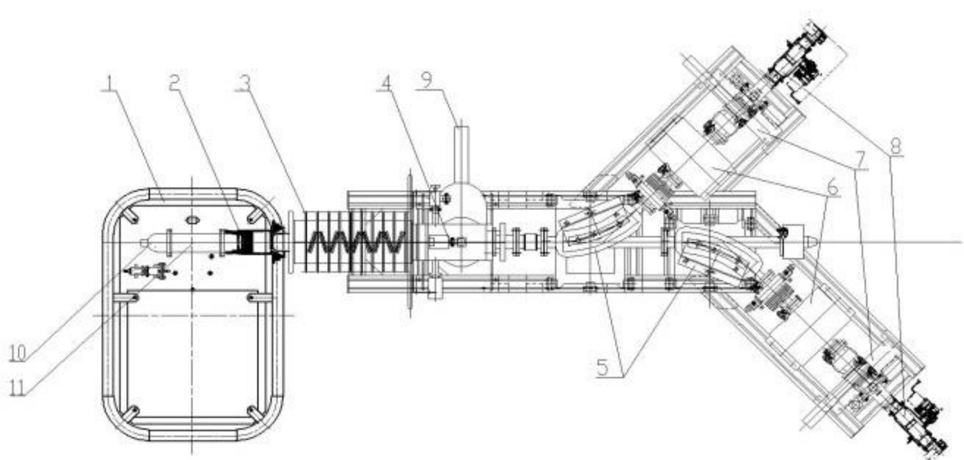

Figure 1: The NG-10M ion accelerator. General View. 1 - high-voltage terminal, 2 - ion source, 3 - accelerating tube, 4 - vacuum chamber, 5 - electromagnetic mass-separator, 6 - quadrupole lens, 7 - gate valve, 8 - target device, 9 - gate valve, 10 - magnetron, 11 - circulator.

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This machine employs an ECR ion source, which in addition to highly reliable operation makes possible producing of ion beams with high optical characteristics and offers high gas and energy efficiency. The atomic component content in the beam produced by a source of similar type attains 80%.

The ECR source consists of a cylindrical discharge chamber with a dielectric window to input the microwave energy, magnetic coils intended to form a magnetic field along the chamber axis, 3-electrode “accel-decel” system for ions extraction and a system of microwave power supply. The discharge chamber is made of non-stainless steel; a movable diaphragm installed in front of the plasma electrode serves to tune the microwave system to a minimum standing wave coefficient. The microwave energy inputs the ion source chamber from a magnetron with an operating frequency of 2.45 GHz through a dielectric window. This window is made of 3 layers: a quartz disc to provide vacuum sealing, disc of silicon nitride preventing the window against back scattered electrons accelerated in the extraction gap and disk of aluminium dioxide to match the dielectric constant with the system.

To supply power to devices under high voltage, a compact isolation transformer was designed. The secondary winding of the transformer consists of 4 turns of a hv cable with an insulation designed for 160 kV placed inside ferrite cores located uniformly around the winding perimeter. The transformer operates at a frequency of 50 kHz, and its design allowed its overall dimensions and weight to be significantly reduced. Photo of the NG-10M neutron generator at a test-facility in NIIEFA is shown in Fig. 2.

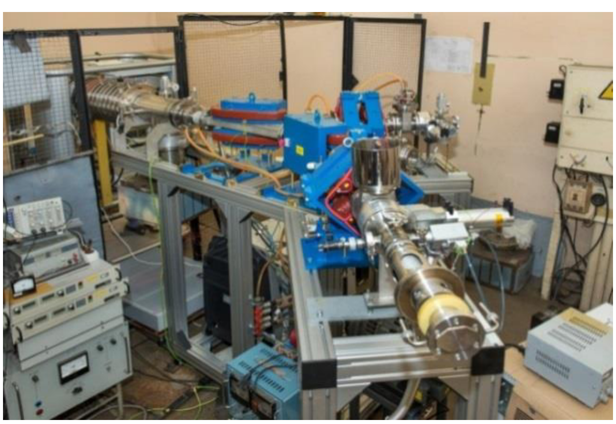

Figure 2: Neutron generator at a test facility.

VACUUM SYSTEM

The vacuum system of generators is based on the HMD-0.4 ion pump. A dry forevacuum pump is used for preliminary pumping. The HMD-0.4 pump is separated from the vacuum volume of the accelerator with a fast gate valve. The target device is connected to the accelerator vacuum system through a fast vacuum valve, which allows replacement of targets without the vacuum break in the accelerator. All vacuum valves are pneumatically driven; the process is controlled from the operator workstation. Necessary pressure in the pneumatic line is provided with a compressor, a part of the facility.

A set of targets devices, in which targets with diameter of 10, 16, 18, 23 mm can be used, was designed for the generators. Targets with the 45 mm diameter, which can be used at a high beam power, are installed in a special target device, which performs circular travel of a target relative to the ion beam.

AUTOMATIC CONTROL SYSTEM

The automatic control system performs acquisition of the data on the status of the neutron generator and its separate devices and systems and their display on the operator workstation as well as solves routine tasks of setting operating modes of the accelerator and tuning of the working parameters of separate devices. The automatic control system consists of a control cabinet, units for data receiving and transfer and operator workstation. The control cabinet houses controller blocks with expansion modules, input/output analog modules, transmitter-receiver of the optical channel for data transfer and power supply units for electronics. The unit for data receiving and transfer houses a controller with expansion modules, galvanic isolations of analog signals and transmitter-receiver of the optical communication link. The operator workstation consists of a personal computer with a monitor. The automatic control system allows the generator interaction with systems for measuring the neutron flux parameters.

The automatic control system of the neutron generator is built on the basis of the Fastwel CPM713 controller, which is the master of the Modbus TCP network, three Fastwel IO CPM713 controllers operating in the slave mode and a personal computer. All key units of the system are networked through an Ethernet switch HP 1410-16G. The software of the automatic control system consists of the five following programs:

- Program of the master controller (Fastwel CPM713).
- Program to control the injector (Fastwel IO CPM713).
- Program to control the vacuum system of the neutron generator (Fastwel IO CPM713).
- Program to control the neutron generator (Fastwel IO CPM713).
- Program of the computerized operator workstation (PC).

The Fastwel CPM713 controllers programs are developed in a special IDE Codesys v 2.3. The computerized operator workstation functions under operational system MS Windows 7. Fig. 3 shows the architecture of the automatic control system.

Controllers’ programs are automatically loaded and are not directly controlled by the operator. Information about their states and control commands are transmitted in the network based on the Modbus TCP protocols via the

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computerized operator workstation program. The ion source controller is placed in the high-voltage terminal cabinet, therefore an interface media converter SF-100-11S5 is used for galvanic isolation. Vacuum in the system is measured with the Meradat-manufactured measuring instrument VIT19IT2.

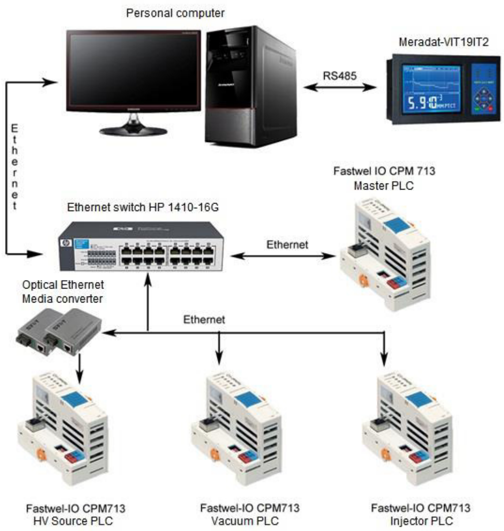

Figure 3: Architecture of the automatic control system.

The computerized operator workstation program is intended for:

- Setting the operation mode of the neutron generator.
- Control and preventing of accidents when the neutron generator is brought to its operating conditions and in the process of its operation.
- Keeping constant output parameters of the neutron generator in the process of operation.

The program is loaded automatically after the loading of the computer operational system or, if necessary, by an icon located on the desktop of MS Windows 7. General view of the user interface is given in Fig. 4.

Figure 4: The main window of the program.

The main window of the program consists of two sections. In the upper part of the window there are a panel to change-over pages of the control systems, setting buttons, unlocking buttons, buttons for logbook and exit. In the lower panel are located digital indicators of the main parameters of the neutron generator and indicators of the door and water interlocks. The most part of the window is occupied by the panel with switched-over pages of the NG sub-systems.

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