NEW 15 MEV ELECTRON ACCELERATOR FOR NON-DESTRUCTIVE TESTING

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A 15 MeV accelerator with the dose rate from 80 to 120 Gy/min at 1m from the target has been designed and manufactured in NPK LUTS, the D.V.Efremov Institute, NIIEFA. The accelerator is intended for nondestructive testing (radiography, introscopy, tomography) of large scale products.
Under tests an X-ray beam with the boundary energy of 15-16 MeV and dose rate of 100 Gy/min has been produced. When operating with longer pulse lengths of the accelerated electron current, the beam power was up to 140 Gy/min; with lower currents the 18 MeV energy was attained at a dose rate of 40-50 Gy/min.
Biperiodic accelerating structure with axial coupling cells is applied in the accelerator. The accelerating structure buncher provides RF-focusing of the electron beam, therefore there is no need for focusing the solenoid. The focus spot diameter is no more than 2mm. To provide the electron beam stability, the accelerator is equipped with a system for automatic frequency tuning (AFT). The AFT system ensures both coarse tuning of the driver frequency against the temperature of the accelerating structure and fine tuning - against the minimum reflected power. The anode voltage of the klystron amplifier is stabilized by using a de-Q-ing system.
A charging choke and pulse forming network (PFN) are located inside the irradiator unit to increase the distance between the modulator and irradiator up to 100m and to reduce losses when high-voltage high-current pulses are transmitted.
The low-voltage klystron (anode voltage up to 55 kV) applied in the accelerator allows reducing the machine weight and dimensions (1100 kg and 2040x880x920mm).
The accelerator is equipped with a PC-based automatic control system.
In the accelerator intended for the radiographic inspection there is an external collimator with movable diaphragm jaws for testing small fragments of an inspected product.
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A new linear accelerator for a nominal energy of 15 MeV and X-ray radiation dose rate of 80 Gy/min at 1m from the target has been designed and manufactured in NPK LUTS. The accelerator is intended for radiographic, introscopic and tomographic inspection of articles of a large thickness.

Under tests of the accelerator with a tantalum target, X-ray radiation with the boundary energy of photons of 15-16 MeV and dose rate of 100 Gy/min was obtained at an average current of 110 μA. In this case the pulse current was 140 mA at a pulse length of 8μ and pulse repetition rate of 100 Hz. When operating with 10μs current pulses of accelerated electrons, the radiation dose power amounted to 140 Gy/min; with the 30 mA pulse current, 18 MeV energy and 40-50 Gy/min dose rate were attained.

A biperiodic accelerating structure 2.05 m in length with axial coupling cells is applied in the accelerator. The buncher of the accelerating structure comprises accelerating cells providing RF focusing of the electron beam, as a result of which no focusing solenoid and centering coils are used in the accelerator. In this case the measured diameter of the focus spot is no more than 2-3mm.

One of the distinctive features of the accelerator is long pulse of accelerated current and reduced pulse repetition rate, due to which the detrimental effect of transient processes occurring at the pulse front on the energy spectrum of accelerated electrons is reduced.

A klystron amplifier KIU-111 with a pulse power of 6MW and average power of 6 kW operating at the anode voltage no more than 55 kW is employed in the accelerator. Application of the klystron operating at a low anode voltage made it possible some reduction of the weight and dimensions of the irradiator unit (1100 kg, 2040×880×920 mm).

The klystron driver is equipped with a system for automatic frequency control (AFC), comprising a stable self-excited oscillator, an AFC unit and amplifier of RF oscillations. A transistor self-excited oscillator operating in the quasi-continuous mode is used in the accelerator. Short-time stability of the oscillator frequency is ± 7.5 kHz without the AFC system.

Frequency is controlled by changing the control voltage at the input of the self-excited oscillator. Three control channels are provided: voltage can be changed by an operator from the PC control console, by using a potentiometer located on the face panel of the klystron driver and by using the AFC system.

A signal from the self-excited oscillator is applied at the input of the klystron power amplifier, which can generate a power more than 200 W per 15 μs pulse at a pulse repetition rate of 50, 100 and 150 Hz. Range of the output power manual control is no less than 10 dB.

Relative instability of the preset frequency over the working part of the pulse is no more than 3×10^{-6} with the AFC system.

The AFC system allows for the temperature of the accelerating structure walls, thus implementing pre-tuning of the driver to the resonance frequency. Fine tuning is performed against the reflected wave pulse. The acceptance time of the fine tunia ng system is no more than 2sec, therefore rather small time is needed to reach the steady-state irradiation mode after the klystron turn on.

High-voltage pulse at the klystron cathode is generated by a linear modulator with a thyratron switch. The voltage across the 5-cell pulse forming line with mutual inductance of the cells is stabilized by using a de-Q-ing system in the charging circuit. High uniformity of the pulse peak contributes to the better energy spectrum and higher yield of X-ray radiation.

The charging circuit and PFN are located inside the irradiator unit thus allowing larger distance, up to 100 m, between the high-voltage rectifier and pulse units of the modulator as well as lower losses and lower level of electromagnetic noise generated by high-current high-voltage pulses.

A real-time distributed automatic control system applied in the accelerator is built on the basis of PC-compatible industrial controllers and industrial panel computer networked via interface RS-485. A host computer, located on the operator's site, is made as an industrial panel computer with a color TFT LCD and touch screen. A functional keyboard is displayed on the screen. Initial setting of separate sub-systems (doser, collimator, etc.) is implemented in the dialogue windows. Parameters of subsystems to be measured are also visualized in these windows.

The operator's workstation software is implemented in the "DELPHI" visual object-oriented development environment.

A real-time PC-compatible controller Octagon 6020, running under the MS-DOS operating system, serves for direct controlling the accelerator. To improve the capabilities of the controllers in input/output of analogue and discrete signals, special ISA expansion cards are used. The controllers are connected to the controlled object via galvanic isolation interface modules. For acquisition and transfer of a small body of data from remote subsystems (signalling, blocking key, door interlocks, etc) processor modules of RIO-7000 (or ADAM 4000) type are used. The built-in processor means make possible normalisation of signals, analogue and discrete input/output, data transfer to the main controller of the network. To protect from environmental effects, the controllers, RIO-7000 (ADAM 4000) modules, the expansion cards and interface modules are placed inside special shielding boxes of high-noise immunity. Additional measures to provide electromagnetic compatibility of high-current devices of the accelerator and computer control system have been taken too.

The accelerator intended for radiography is equipped with an external collimator with movable diaphragm jaws for inspection of small segments of objects. If necessary, the irradiator comes complete with an automatic manipulator ensuring its rotation in two planes.