OPERATION OF A 300 MEV ELECTRON LINAC IN THE SHORT-BEAM MODE

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Abstract

The 300 MeV electron linac was operated in conjunction with a versatile injector complex in the short (ns) beam mode. The operating conditions permitted a pulsed neutron source and spectrometer to be employed in the time-of-flight measurements of neutron spectra.

Medium-energy electron linacs have application in pulsed neutron sources which are now in widespread use as tools of solid state and nuclear physics research. Atomic energy programs particularly fast reactor and nuclear plant projects require that experimental techniques and instrumentation employed in neutron physics and material science be essentially improved and extended. Electron linacs as pulsed neutron sources have the advantage that the beam energy and current pulse length can easily be varied over a wide range. The largest electron-linac based neutron sources now in existence are ORELA (140 MeV; USA), HELIOS (136 MeV; Great Britain), FAKEL (60 MeV; USSR), and GELINA (120 MeV; Belgium).[1,2]

In 1976 it was proposed to modify the 300 MeV electron linac of the Kharkov Institute of Physics and Technology, creating an accelerator-based fast neutron source and selector.[3] As part of this program a versatile injector complex (VIC) was designed and built to produce nano- and microsecond electron beam pulses with a maximum energy of 40 MeV. Moreover, certain modifications were made with a view to improving the electrodynamic properties of the accelerator sections, modulator parameters and beam guiding system. The improved electrodynamic properties of four accelerating sections out of eight were obtained by making radial cuts on the diaphragms to reduce axially nonsymmetric oscillations excited by the beam.

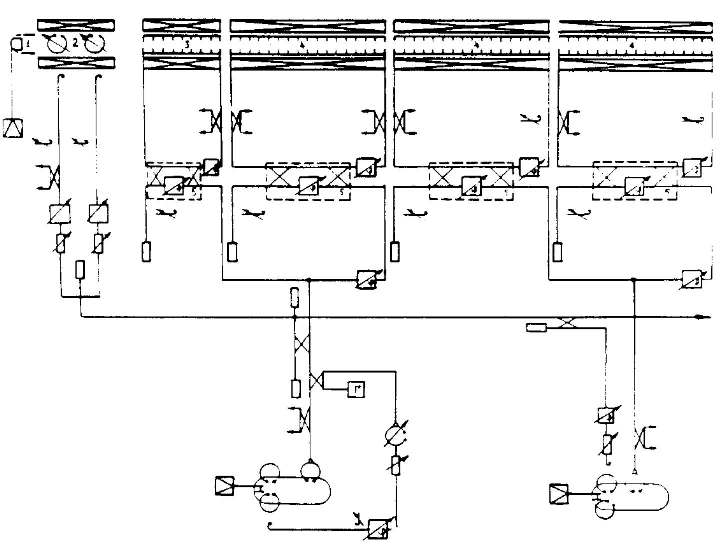

Fig. 1. Schematic of the 300 MeV electron linac versatile injector complex.

The VIC is an accelerator comprising four sections and a prebuncher, its distinguishing feature being that each section has a feedback circuit permitting the RF energy stored during the short-pulse operation to be increased. A schematic diagram of the VIC is shown in Fig. 1. As an electron source a three-electrode gun (1) is used with an impregnated cathode 20 mm in diameter. The gun provides 5 A of current with microsecond and 50 A with nanosecond pulse lengths at a maximum electron energy of 180 keV. A prebuncher (2) consists of two toroidal cavities, each fed by a 100 kW pulsed power supply via a directional coupler and two double T-bridges.

The VIC has a buncher (3) and three accelerating sections (4) with resonance rings to recuperate RF power. The buncher has a length $L_1 = 83$ cm, the accelerating sections $L_2 = 172$ cm. In order that as large a fraction as possible of the beam should be accepted the wave phase velocity is reduced to 0.96 c in the buncher by heating it to 108°C. To suppress the transverse axially nonsymmetric waves excited by the beam the diaphragms have radial cuts. The adjustment of each ring is accomplished by a phase shifter. Each pair of sections is fed via a double T-bridge by the same RF power supply. A distinguishing feature of the RF system is the use of a variable input directional coupler (5) to provide optimum RF power supply to the rings.[4,5] The prebuncher and accelerating sections have solenoids to produce a magnetic field of 0.25 T.

The VIC was first started up in September 1983. In the short-pulse mode of operation the output pulsed current (I) was 12 A with $\tau = 3 + 4$ ns ($W = 35$ MeV, $\Delta W/W = 40\%$). In September 1984 the 300 MeV linac with the new-made injector (VIC) was put into operation. Under steady-state operating conditions, the following output parameters were obtained: $I = 4.5$ A, $\tau = 3 + 4$ ns (Fig. 2: horizontal scale division $t = 2$ ns, vertical one $I = 1.6$ A) and $W = 310$ MeV, with $\Delta W/W \sim 5\%$.

The beam current pulses were measured with a nano-second stripline-base beam monitor[6] positioned at the entrance to the last section. The maximum accelerated current recorded

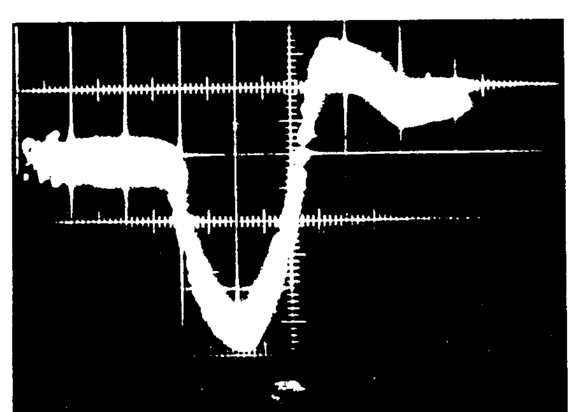

Fig. 2. Current Pulse Oscillogram.

here was 6.3 A. In this case, however, beam blowup was observed. The detailed studies of this phenomenon revealed the beam blowup in the last section to be of threshold nature and to occur in the VIC-300 MeV linac structure at currents of 4.7 A.

The beam parameters obtained permitted a prototype of a pulsed fast neutron source and spectrometer to be constructed and to perform time-of-flight measurements of the neutron spectra from the Ta and Pb targets 2.6 and 1.8 rad. lengths thick, respectively.

The measurements were made with a deflected (40°) electron beam using a secondary emission monitor.[7] At a distance of 37.5 m from the target two scintillation detectors were placed to detect neutrons and observe a gamma-flash. To protect the detectors against the gamma radiation we used lead filters 4 and 8 cm thick and pulsed power supply to the photomultipliers.[8] The beam current time distribution was controlled by visual inspection of gamma-flash pulses from the photomultiplier operated "suppressed" mode (suppression factor 250), the gamma-flash duration being 3 to 4 ns.

The neutron spectra were measured in series for 4 to 6 hours, each series at an average beam current of 0.1 μA and energies of 175 and 250 MeV. The time-of-flight spectrometer was triggered by an accelerator advance pulse. Figure 3 represents the recorded time-of-flight spectrum. Figure 4 shows the experimental neutron spectra corrected for the detector efficiency,[9] attenuation due to the filters, etc., in comparison with the cascade-evaporation model calculations.

On the whole, the operation of the accelerator-injector complex has proved to be stable enough, making it possible to use the complex as a basis for construction of an intense fast neutron source.

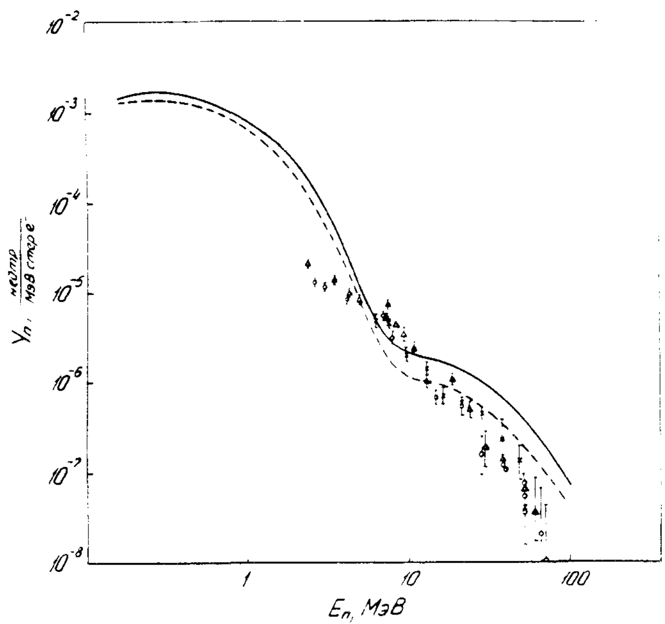

Fig. 4. Experimental and calculated neutron spectra. Ta Target: beam energy W = 175 MeV. Experimental spectra: Φ-Pb filter 40 mm thich, $\bar{\Delta}$-Pb filter 80 mm thick, - - - calculations. Beam energy W = 250 MeV. Experimental spectrum: Ī-Pb filter 80 mm thick, — calculations.

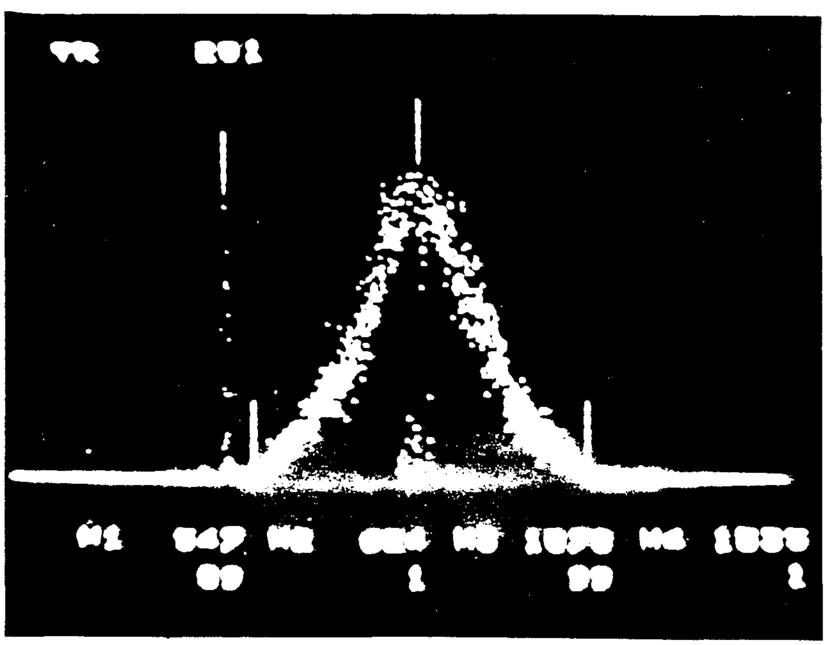

Fig. 3. Time-of-flight spectrum. Pb target; Pb filter 80 mm thick. M1: γ-flash position, M2 and M4: spectrum beginning and end, respectively. Horizontal scale: 3.8 ns/channel.

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