A 30 MeV LINEAR ELECTRON ACCELERATOR DESIGNED FOR NEUTRON SPECTROSCOPY


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A linear electron accelerator designed for neutron spectroscopy is described. For accelerated electron energies of 25-32 MeV, pulse durations are 0.6, 0.2, and 0.05 μsec, and pulse current is 160-500 mA. Pulse repetition frequencies up to 100 cycles are possible. Neutrons are produced in a U²³⁵ target located within a water moderator. Results are given for neutron spectra from the accelerator obtained for a flight path of 109 m and an energy interval of 4 eV to 30 keV.

Introduction

The methods of modern neutron spectroscopy, based as they are on the technique of selecting neutrons of a given energy by time of flight over a fixed distance, require the creation of powerful pulsed neutron sources. In 1949, Cockroft [1] noted that a linear electron accelerator, used as such a source, has a number of important virtues.

At the present time, a neutron spectrometer based on a 15 MeV linear electron accelerator is being operated at Harwell (England). Comparatively recently, it was reported that, for this same purpose, a new high-current 30 MeV linear electron accelerator with pulse currents of 300-400 mA had gone into operation [2]. Similar instruments have been built and are operating at Saclay (France) [3] and at Livermore (USA) [4]. In this paper, a description is given of the linear electron accelerator which is being used for neutron spectroscopy at the I. V. Kurchatov Order of Lenin Institute of Atomic Energy of the USSR Academy of Science. The planning and developing of the accelerator was carried out at the Radiotechnical Institute of the Academy. Further development and improvement of the various parts of the accelerator during the adjustment stages were accomplished by joint efforts of the two institutes.

The travelling-wave accelerator was designed for the production of a 30 MeV electron beam with pulse currents to 200 mA. Provision was made for three pulse durations (0.6, 0.2, and 0.05 μsec) and for pulse repetition rates to 100 cycles. The accelerator operates at a frequency of 2764 Mc with high field intensities (up to 150 kV/cm at the beginning of the diaphragmed waveguide). The efficiency for the transformation of the energy in the rf field into electron energy is 30-35%. A block diagram of the accelerator is shown in Fig. 1.

Accelerator Construction

Accelerating system and rf path. The following requirements were taken as a basis for the design of the accelerating system. The accelerator should successfully produce an electron beam with a 200 mA pulse current and a 30 MeV maximum in the energy spectrum. The maximum rf power input was to be 20 MW with the wave length $\lambda = 10.8$ cm and the field strength at the beginning of the accelerator 150 kV/cm.

The structure of the diaphragmed waveguide of the accelerator is shown in Fig. 2. The requirements which were assumed as a basis for the design of the accelerating system determined the following values for waveguide parameters, which were constant over the entire length of the accelerating system: $D = 27$ mm, $2a = 30$ mm, $a/\lambda = 0.14$. The waveguide diameter $2b$ was determined from the parametric curves of Ginzt "on [5], was experimentally made more precise by the use of the resonance method, and turned out to be 86 mm. From engineering considerations, the diaphragm thickness $d$ was chosen to be 6.4 mm. In order to increase electrical stability, the edges of the openings in the discs were rounded (with a radius of 3.2 mm). The length of the diaphragmed waveguide was made 400 cm in order to obtain the required electron energy. In this way, about half of the rf power passing along the waveguide was absorbed by the final charge. The values assumed for the initial field strength and the injection voltage (100-120 kV) assured the trapping of a considerable fraction of the electrons during the acceleration process without the use of a buncher. Thus the diaphragmed waveguide is a uniform system with constant phase velocity.
The diaphragmed waveguide was manufactured by electrolytically plating the external wall of the waveguide on an assembly made up of discs with aluminum spacers. The thickness of the wall was 7 mm. The aluminum spacers were dissolved out by an alkaline solution, and the outside surface of the waveguide was machined. The internal surfaces of the waveguide were polished electrolytically. In the manufacture of the waveguide, mechanical tolerances for all basic dimensions of the compartments were held to 10 μ. Six sections of the waveguide were connected together by means of attached flanges. Four copper tubes, required for cooling the waveguide, were fastened in special grooves. In each compartment of the waveguide, there are four openings 4 mm in diameter for the purpose of improving evacuation. These openings have not exhibited any noticeable effect on the rf properties of the waveguide.

Experience in use and rf measurements have shown that a waveguide manufactured in this way has parameters which are highly stable in time and which are unchanged after repeated disassemblies. At the joints between separate sections of the waveguide, no rf burning at contact points was detected, and repeated disassembly of the waveguide did not lead to the appearance of power loss or changes in phase velocity in the joint regions.

Rf power from the generator is fed to the accelerator input through a standard rectangular waveguide 34 × 72 mm in size. The total length of the guide, which passes through a channel in the accelerator shielding, is approximately 6 m. The supply waveguide is separated from the vacuum spaces of the klystron and accelerator by conical glass windows of circular cross section, and it is filled with a mixture of nitrogen and SF₆ in the ratio 10 : 1 at a pressure of 4-5 atmospheres in order to prevent breakdowns connected with the transmission of high power.

In order to improve pumping conditions around the windows installed in the accelerator, three rectangular pump-out openings were made in the broad side of the waveguide where it passes within the vacuum casing of the accelerator. They assured a 50 liter/sec pumping capacity, removing the difficulty connected with the creation of breakdowns in the glass of the window from the high-vacuum side, and had no effect on the rf properties of the line.