YEREVAN 120 MeV LINAC TEST-FACILITY*

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Abstract

The parameters and status of the Yerevan 120 MeV electron Linac (LUE-120) Test Facility (LTF) is presented.

Prime parameters of LTF beam are: energy from 15 to 30 MeV with average accelerated current 1.5 mA and from 30 to 50 MeV with current 0.3 mA. Energy spectrum of accelerated electrons ±2.5% (monochromator off) and ±0.3% (monochromator on).

The main nomination of LTF - stand for testing and optimization of the LUE-120 devices as well as for experimental research of beam-beam and beam-wave interaction in various structures and media.

The maintaining of essential part of LTF is completed and tuning is in process.

Introduction

In accordance with the R & D Program for the Yerevan Synchrotron [1], a new injector- electron linac LUE-120 [2] project was elaborated and construction has begun . At present a tunnel and 20 RF klystron stations have been constructed. For testing and optimizing of the LUE-120 systems equipment, as well as for experimental research of beam-beam and beam-wave interaction [3] a test-facility LTF is being constructed.

A few words about other application of LTF.

The beam of LTF with such parameters gives opportunity to generate neutron flow 10^{13} 1/cm^{2}sec and γ-quanta with intensity more than 10^{14} 1/sec.

However, on the base of LTF neutron-activated and γ-activated complex can be created in short time. This complex will give opportunity to analyze patterns with high resolution (10^{-5} - 10^{-10} % for neutrons and 10^{-4} - 10^{-7} % for γ-quanta); it will be possible to do some thousand analyses per year. This complex can serve in any region: Transcaucasia, North Caucasus and Middle East.

The second purpose - production of isotopes for medical use. For example, it is possible to produce more than 10 Curie of ^{123}J isotope per year, which is sufficient for all regions.

The third - sterilization of medical instruments and materials.

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Parameters, Layout and Set of LTF

The LTF is based on the three-section linac whose main parameters are given in Table 1.

TABLE 1
LTF Main Parameters

Parameter	*Parameter Value*
Electron Beam Parameters	
Nominal energy (MeV)	*30*
Nominal pulse current (A)	*1.0*
Energy adjustment range (MeV)	*15 - 60*
Current adjustment range (A)	*0.01 - 1.5*
Current pulse duration (μsec)	*0.5 - 7.5*
Pulse repetition rate (Hz)	*single mode 12.5;25;50;100*
Electron bunch repetition rate (MHz)	*2796.6*
Energy spread for 80% electrons	
(monochromator off) at 0.1A (%)	*±(1.5 - 2.0)*
at 1.0 A (%)	*±(2.5 - 3.0)*
Energy spread for 80% electrons	
(monochromator on) at 1.0 A (%)	*±(0.3 - 0.5)*
Current stability for energy spread ±0.3% (%)	*±(3 - 5)*
Accelerating System	
Accelerating section length (m)	*2*
RF power on accelerating section input (MW)	*18*
Electron efficiency of accelerating structure	*up to 0.6*
Total number of accelerating sections	*3*
Total number of klystron RF stations	
(including a reserve klystron training one)	*4*

A Layout of the LTF is shown in Fig.1. It comprises a system of preliminary beam formation (pre-injector), an injector and main sections unit, a unit of the main section and beam monitors. Final electron energy on the third section end is 30 MeV at a pulse current 1.0 A. Then the beam arrives at a fast-switching bending magnet (FSBM) which directs electrons to three channels: A, B and C. Using the system for beam parallel transport the A and C beams can be addressed to the corresponding consumers. The B beam arrives at a monochromator which narrows the beam energy spread to ± 0.5%.

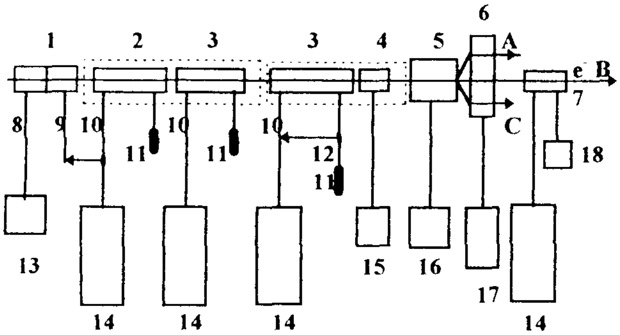

Fig. 1. LTF Layout: 1-pre-injector; 2-injector section; 3-main section; 4-beam monitors, 5-FSBM; 6-beam parallel transport system; 7-beam monochromator; 8-electron gun pulse power supply line; 9-pre-injector RF power supply line; 10-accelerating sections RF power supply line; 11-RF-load; 12-RF-power recuperation line; 13-electron gun pulse power supply; 14- RF klystron station; 15-beam parameters control; 16-FSBM power supply; 17- beam parallel shifting system power supply; 18- monochromator power supply.

LTF Systems Description and Basic Characteristics

Pre-injector

In order to obtain a relative width of energy spectrum ±0.5% on the linac end, it is necessary to provide on the output of the bunching (injector) section phase length of electron bunches about 10°. In that case the energy spread on the injector section end may be relatively large (± 2.5%). The phase duration required is provided both by the preset law of variation of electric field strength and wave phase velocity along the injector section and by preliminary electron bunching by a pre-buncher that provides phase length of electron bunches on the input of the injector section (of order of 30 - 40°). In order to get on the injector section input bunches of the required phase length there is provided beam modulation from electron source on the linac accelerating field frequency. To reach that, the pre-injector includes buncher-cavities at the linac frequency harmonics (Fig. 2)

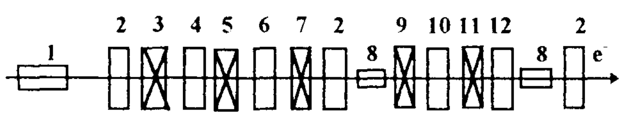

Fig. 2. Pre-injector: 1-electron gun; 2-beam monitors; 3-lens-1 with correcting coils; 4-vacuum gate; 5-lens-2; 6-chopper-1; 7-lens-3; 8-collimators; 9-lens-4 ; 10-chopper-2; 11-lens-5; 12-multifrequency buncher.

The electron source is made of glass insulator which allows one to easily perform its disassembly and assembly at cathode replacement.

Table 2 lists the main parameters of the electron source.

TABLE 2
Electron Gun Main Parameters

Parameters	Parameter value
Cathode pulse voltage (kV)	*150*
Voltage on control electrode (kV) (relative to cathode)	*0÷5*
Beam pulse current (A)	*2÷20*
Pulse duration (μsec) at ≤ 10 A	*≤ 10*
The same at beam current $10 \leq I_p \leq 30A$	*≤ 5*
Pulse repetition rate (Hz)	*≤ 100*
Cathode filament power (W)	*250*

A spherical pressed spongy cathode with indirect filament is used in the source. The control electrode represents a grid of tungsten filaments 0.2mm in diameter; the grid transparency coefficient is ≅0.9.

The electron optics of the gun and two first lenses form and maintain the necessary crossover of the beam in the plane that lies through the center of the chopper cavity. The beam diameter in that plane must be 6-7 mm.

Chopper-1 executes pulse interruption of the beam at the synchrotron RF system frequency (466.1 MHz). It consists of a toroidal cavity and two shifting magnets. Such construction permits to adjust the beam parallel shift. The cavity has a sufficiently good field homogeneity in the place of beam flight (≅ 1%) at admissible size (≅ 370 mm). The beam passes inside the cavity inductive part in the region of maximal homogeneity of RF magnetic field at the distance of 45 mm from the generatrix. The field strength is ≅ 80 Oe at RF power ≅ 15 kW supplied to the cavity. The shifting magnets operate under pulsed regime at frequency up to 100 Hz and induce magnetic field of a strength up to 180 Oe. The cutoff angle due to chopper-1 is 300°. Hence at least ≅ 80% of particles of the initial beam will dissipate on a first collimator. Further, with lens-4 the beam is focused in the place of location of cavity - chopper-2 which operates at 2796.6 MHz frequency. At overlap of the beam crossover with the cavity center the inhomogeneity of the vertical switching-off force over the beam cross-section may be 2-3%. The cavity - chopper 2 is rectangular (15·74·140 mm) being excited at TE_{102} type of oscillations. The beam cutoff angle due to chopper-2 is 180°. This means that nearly 70% of particles having entered chopper-2 will dissipate on collimator-2. Chopper-2 can be used to adjust the beam current by varying the cutoff angle. The RF power consumed by the cavity does not exceed 5 kW.

The particles that had passed through chopper-2 are focused by lens-5 and arrive at cavities of multifrequency (five harmonics) pre-buncher where they compress to bunches of low phase length.

The focusing lenses represent solenoids with focal distance 60mm and maximal strength of axial field about 500 Oe. The pre-injector total length is 1900mm.

Injector section.

The injector section is intended to accelerate the electron beam with initial energy of 150 keV up to 10 (20) MeV on the section end at the value of current 1(0) A respectively

Initial prerequisites in the development of the injector section were:

- provision of high acceleration rate at initial stage in order to avoid the bunch spread under the action of space charge forces;
- maximal acceleration efficiency in the section at all values of accelerated current;
- taking measures to prevent from pulse break at beam high currents;
- designed overall dimensions of the injector and main sections.

In the constructed section the first condition is satisfied, since the accelerating field strength is 90 kV/cm, and the wave phase velocity on the initial part is close to the velocity of light.

To compensate the influence of unconsidered factors, which may result in the shift of the bunch phase relative to the accelerating wave phase, temperature correction using the independent water cooling system for the initial part of the injector section is provided. To avoid the electron current pulse break-up the geometry of the section is optimized.

Table 3 presents main parameters of the beam on the injection section end for two different values of accelerated current.

TABLE 3

Beam parameter	Parameter value at	
	I_b=0.2 A	I_b=1.5 A
Energy (MeV)	*20.27*	*9.65*
Energy spread (%)	± 1.4	± 1.6
Bunch phase length (degrees)	*10.5*	*12.5*
Bunch effective radius (mm)	*4.3*	*5.8*
Maximum value of focusing magnetic field (Tesla)	*0.45*	*0.58*
Beam radial emittance (m rad)·10^6	2.5π	4.4π

Main Accelerating Section

Pulse current ≅1.5A acceleration at pulse length ≅10μsec in traveling-wave electron linac is a complicated problem, since it requires a number of measures to avoid pulse break-up. These measures, first of all, reduce to realization of such a structure in which a hybrid mode HEM_{11} will be maximally suppressed. The beam break-up must be taken into account when choosing the value of strength of accelerating electric field and length of the accelerating section. It is generally known that the value of limiting pulse current is directly proportional to accelerating gradient and inversely proportional to section's length. With account of that, a maximum value of accelerating electric field strength is chosen 120 kV/cm, and a length of each accelerating section - 2m.

The level of RF power, both pulse (18 MW) and average (18kW) is sufficiently high. At low currents considerable part of this power will absorb in the walls of the section, and the heat release along the section will be sharply nonuniform. This requires a special thermostabilization system which allows to substantially reduce temperature gradient along the section under conditions when energy release in the wall essentially depends on the value of accelerated current.

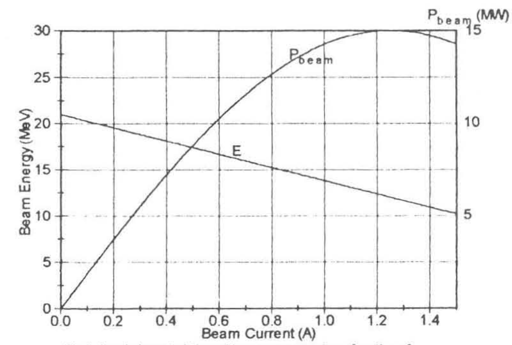

Fig 3. Load characteristic and beam power gain as function of accelerated current in a main section

Conclusion

In conclusion a few words about LTF status.

All equipment is mounted except the third accelerating section. Tests have been performed for the electron source, pre-injector and injector section. The preliminary results corroborate the possibility to provide the design parameters. Despite the difficulties caused by the total crisis in Armenia as well as in the FSU we hope to start the works with the LTF beam at the end of 1994.

References

[1] A.Ts. Amatuni, A.S. Alexanian, R.O. Avakian et al., "The Prospects of Improvement and Development of Accelerator Installations at Yerevan Physics Institute", Proc. of EPAC'88, Rome, June 7 - 11, 1988, vol. 1, p.p. 305 - 307, (1988).

[2] Yu. G. Basargin, V.P. Belov, E.M. Laziev et al., " The Principal Scheme and Main Parameters of a Recirculating Linac as an Injector for the Yerevan Electron Synchrotron", Trudi V Vsesojuznogo Soveschania po Uskoriteljam Zarjazhennykh Chastitz, (Dubna, 5 - 7 Oktjabrja 1977g.), vol.2, p.p. 127 - 131, (1976), (in Russian).

[3] E.A. Begloyan, E.D. Gazazian, H.H. Haroutjunian, M.I. Ivanian, V.G. Kocharian, E.M. Laziev, G.G. Oksuzian and A.D. Ter-Pogossian, " R&D Program on Yerevan Linac Test Facility", (Submitted to the LINAC'94).