LUE200 LINAC. FULL-SCALE TESTING OF ACCELERATING SECTIONS

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Abstract

"LUE200" – a 200 MeV electron linac is being constructed at FrankLab of the JINR as a driver of the pulsed neutron source "IREN" [1]. The testing of the linac accelerating system consisting of two S-band accelerating sections is provided at the VEPP-5 preinjector mounted at BINP [2]. The energy of the electrons up to 120 MeV for the beam with the 1.5 A current and 240 nsec pulse duration was achieved after acceleration in two 3 m length sections.

1 FULL-SCALE TESTING SCHEME

1.1 Introduction

The test was carried out at the initial part of the VEPP-5 preinjector at the Budker Institute of Nuclear Physics (BINP, Novosibirsk) [2, 3]. The full-scale testing scheme includes a 200 kV thermionic electron gun, a subharmonic buncher, an S - band buncher, two accelerating sections, RF assembly on the basis of 5045 SLAC klystron, RF power compression system SLED, a focusing system, a beam diagnostic system and a wideband magnet spectrograph (see Fig. 1). The subharmonic buncher was out of operation in the experiments and was used as the beam transportation channel.

The aim of the present test series was to achieve the typical accelerating gradient for the electron beam with high current, close to the desired parameters of the accelerator project for "IREN".

The beam pulse current of the thermionic gun changed from 1.6 A up to 3.5 A for the pulse width of 220 nsec. The gun pulse current was measured by the wall current monitor located at the gun output. The shapes of the beam current pulse and of the gun high voltage pulse are shown in Fig. 2.

The repetition rate of the setup was limited up to 2 Hz due to radiation protection reasons.

1.2 Accelerating Sections

The traveling wave accelerating sections have been designed by BINP as a round disk-loaded waveguide of constant impedance. The structure and the parameters of accelerating sections were already explicitly presented earlier in the report at LINAC2000 conference [4]. The main parameters of the accelerating section are given in Table 1.

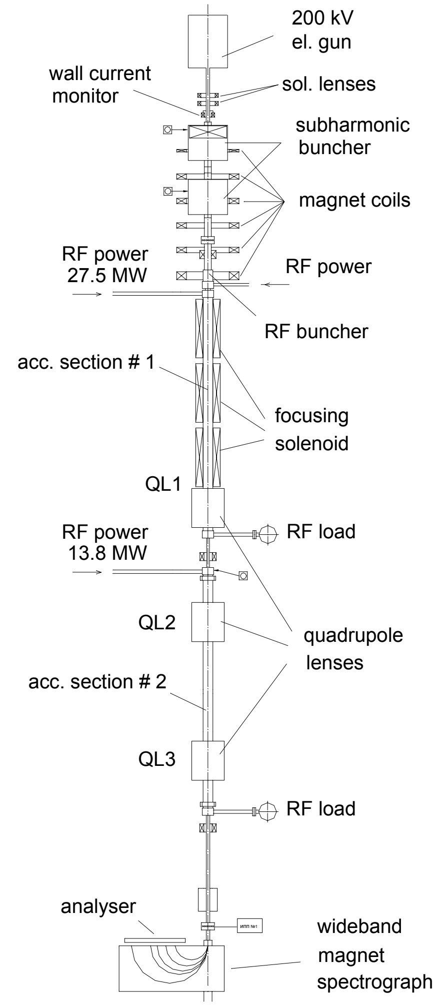

Figure 1: The scheme of the accelerating section testing.

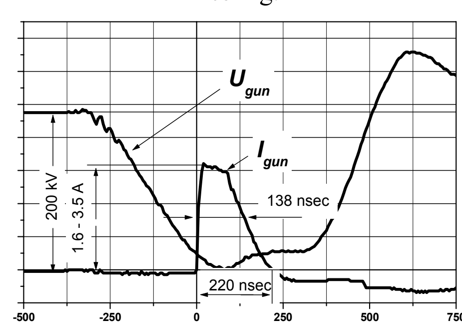

Figure 2: The shapes of the beam current pulse (I_{gun}) and of the gun high voltage (U_{gun}).

Table 1: Main parameters of the accelerating section.

Operational frequency	2855.5 MHz
Internal cell diameter 2*b*	83.75 mm
Iris diameter 2*a*	25.9 mm
Iris thickness *t*	6 mm
Period *D*	34.99 mm
Operational mode of oscillation θ	$2\pi/3$
Relative phase velocity β_p	1
Relative group velocity β_g	0.021
Section length *L*	2.93 m
Total number of cells	85
Unloaded quality factor Q_0	13200
Shunt impedance R_{sh}	51 MOhm/m
Time constant $\tau_{0a}=2Q_0/\omega_0$	1.471 µs
Attenuation (by field) $\alpha=1/(\tau_{0a}v_{gr})$	0.108 m $^{-1}$
Filling time $T_f=L/v_{gr}$	0.465 µs

The temperature control of the accelerating structure is provided by the thermostabilization system. The operational temperature of accelerating sections is 30°C. The accuracy of temperature stabilization is ± 0.1°C.

As shown in earlier experiments [3,4], in accelerating section powered about 50 MW RF power the accelerating electrical field can reach more than 45 MV/m, and the average acceleration rate reaches more than 30 MeV/m.

1.3 RF Power Supply

The shaping amplifier forms the RF pulse of ~3.5 µs duration and output pulse power $P \approx 200 \div 400$ W for 5045 klystron excitation. The phase shifter provides the phase inversion at the operational frequency at the given instant to ensure the power compression system operation. RF pulse of up to 50 MW power is directed from the klystron along the waveguide channel (72 x 34 mm) via the SLED-type power compression system to the accelerating section inputs. The unused power is dissipated in the dummy load that is located at the outputs of the sections.

The fraction of RF power after SLED system is directed to the RF buncher via the directional coupler with the attenuation. The RF pulse phase and amplitude can be varied by means of the attenuator and phase shifter.

In the presented series of experiments the 41.3 MW RF pulse power from one 5045 klystron was directed into the two accelerating sections: 27.5 MW into the first section and 13.8 MW - into the second one.

1.4 Magnetic Spectrograph

The beam energy spectrum measurements were carried out by the wideband 180º magnetic spectrograph. The error of the beam total energy is equal of ± 2 %. Energy spread was measured by means of a beam multiposition collector placed at the output of the spectrograph. The beam multiposition collector consists of 30 lead full beam stop sections and allows one to measure the total charge and energy contents of the beam. The beam energy contents was determined as sum of products of the charge, measured on each lamel, on the value of energy appropriate to the position of each lamel at the output of the magnetic spectrograph.

2 EXPERIMENTAL RESULTS

The following parameters of the electron beam were measured while testing the sections:

- gun beam pulse current,
- total charge of the accelerated beam, (total number of particles per one beam pulse),
- beam energy spectrum,
- beam energy content.

The observed data are presented in Figs 3 and 4. The energy spectra and energy contents of the accelerated beam were measured at increasing of a gun beam current from 1.6 A up to 3.5 A. Energy spectra of the beam after acceleration in two sections for three values of the gun beam current are shown in Fig. 3.

It is visible from Fig. 3 that at the increase of the current of the beam injected in the accelerating system, the energy of the beam and mean accelerating rate are reducing.

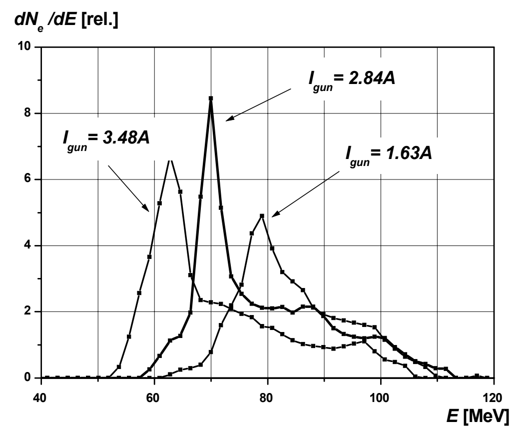

Figure 3: Energy spectra of the beam after acceleration in two sections at three values of the gun beam current. The bold line shows the spectrum of the beam with maximum energy content.

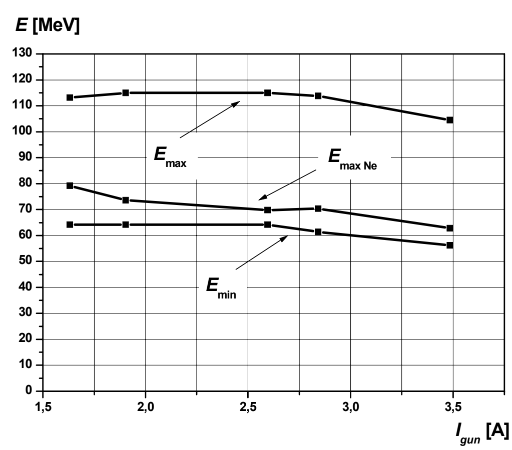

Figure 4: The energy of beam particles vs the gun beam current. E $_{max\ Ne}$ – maximum of the energy spectrum.

Fig. 4 shows the changes of the beam energy at the output of the accelerating system depending on the current of the injected beam (the load characteristic of the accelerating system consisting of two accelerating sections).

3 CONSIDERATION

The maximum energy content of the accelerated beam reaches 28 J at the injection of the beam with the gun current 2.84 A. The position of the maximum of the energy spectrum is ≈ 70 MeV, maximal energy of particles ≈ 117 MeV and minimal energy ≈ 60 MeV.

The maximal total charge of the electron beam, accelerated in two accelerating sections, reaches 327 nK. The number of electrons in one pulse reaches $2.04 \cdot 10^{12}$ particles, that is the equivalent to the current of the beam ≈ 1.3 A at the design pulse duration of 250 nsec.

The measured energy characteristics of the accelerated beam allow to make estimations for the situation with the main project parameters of the designed LUE-200 linac:

- RF pulse power - 60+60=120 MW from two 5045 klystron.
- Current pulse duration 250 nsec.
- Repetition rate 150 Hz.
- Electron gun pulse current 1.5 A.

Table 2 shows these experimental and estimated parameters.

Table 2: The experimental and estimated parameters according to the beam acceleration in two sections

	Experiment	Estimation (= Project)
RF power	41.3 MW	2x60 MW
Repetition rate	2.5 Hz	150 Hz
Beam pulse current	1.3 A	1.5 A
Beam pulse duration	250 nsec	250 nsec
Average electron beam energy	70 MeV	200 MeV
Beam energy content	28 Joule	76 Joule
Average beam power	-	10 kW

Thus, as a result of the experiments, the feasibility of accelerating sections in the mode of acceleration of the beam with large current has been confirmed.

4 REFERENCES

[1] A. Kaminsky, et al., "LUE200 - Driver Linac For Intense Resonant Neutron Spectrometer (IREN)", Proceedings of the XVIII International Linear Accelerator Conference., 26-30 August, 1996, Geneva Switzerland, CERN 96-07, 15 November 1996, Vol. 2 pp. 508-510.

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[3] http://arxiv.org/abs/physics/0008079. S.N. Dolya et. al. “Linac LUE200. First Testing Results”. LINAC2000 Conference. Monterey, California. August 21-25, 2000.

[4] http://arxiv.org/abs/physics/0008100. VEPP-5 Team (Budker INP, Novosibirsk, Russia) “Test of accelerating structure for VEPP-5 preinjector". LINAC2000 Conference. Monterey, California. August 21-25, 2000.