Commissioning of the SIBERIA-2 Preinjector and First Beam Results

V.Korchuganov, G.Kulipanov, E.Levichev, O.Nezhevenko, G.Ostreiko,
A.Philipchenko, G.Serdobintsev, E.Shaimerdenov, V.Ushakov,
Institute of Nuclear Physics, Novosibirsk 630090, Russia,

A.Kadnikov, Yu.Krylov, S.Kuznetsov, V.Ushkov, Yu.Yupinov,
Kurchatov Institute, Moscow, Russia

Abstract

The DAW structure linac - the preinjector for the SIBERIA SR complex was commissioned on November 1, 1992 when the 62.5 MeV electron beam is obtained. A 6-m-long high impedance (92 MOhm/m) linac operates at 2.8 GHz. The paper describes the experimental RF characteristics of the linac structure and beam measurements obtained during the commissioning. The results of electron current, energy spectrum, beam profiles and emittance measurements are presented.

I. INTRODUCTION

A SR facility SIBERIA is being constructed at the Kurchatov Institute in Moscow. The injection part comprises a 80 MeV preinjector-linac operating in the stored energy mode. The paper reports the successful commissioning of the linac in November of 1992.

II. GENERAL DESCRIPTION OF THE LINAC

The 6.1 m linear accelerator (Fig. 1) consists of an electron gun, 6 regular accelerating sections (Fig. 2) and a power input unit which is housed in the center of the accelerator. Each section comprises 18 identical cavity cells spaced with the period equal to $\lambda/2$ [1],[2].

The linac design is based on the 2.8 GHz modified DAW structure. Each disk is supported by three radial stems, whose length is close to one quarter of the wave length. The DAW structure operates in the stored energy mode and enables us:

- to reach maximum accelerating voltage due to high shunt impedance;
- to accelerate the beam with a maximum number of particles due to large stored energy;
- to make an accelerating structure in the form of single resonance section with a single power input due to a high group velocity and, thus,
- to avoid phasing of separate sections and to simplify the requirements for the accuracy of manufacturing and tuning.

The DAW structure measured parameters are given in Table 1.

Table 1. The parameters of the accelerating structure

Operation mode	$TM02\pi$
Shunt impedance	92 MOhm/m
Frequency	2797.2 MHz
Quality factor	28000
Characteristic impedance	3.5 kOhm/m
Calculated overvoltage coefficient	5.6

The linac has a simple injection system without a special buncher. The longitudinal bunching and transverse size shaping of the electron beam are the effect of RF field in the accelerator only. The nonbunched 40 keV electron beam formed by a diode gun is injected directly into the first cavity cell of the structure.

Note that the first cell was made twice shorter than the

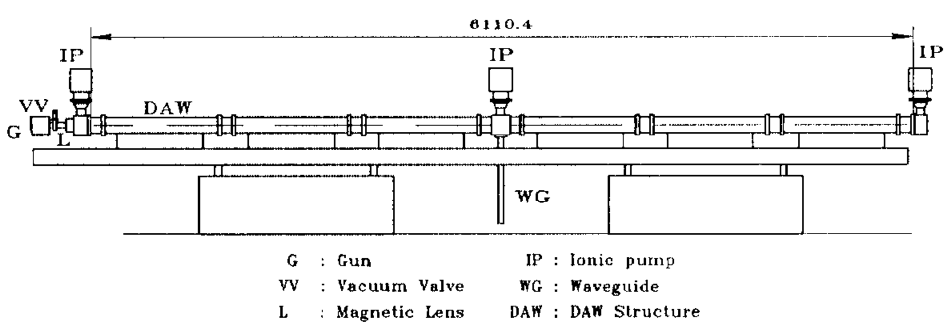

Figure 1: Fig.1: The preinjector layout

atm. This ceramic window is inserted because the klystron ceramic window of the cone type has not provided the reliable klystron operation with the vacuum waveguide in January of 1992, when training the waveguide and lattice a breakdown in ceramics was happened at a power of the incident wave 11 MW [3].

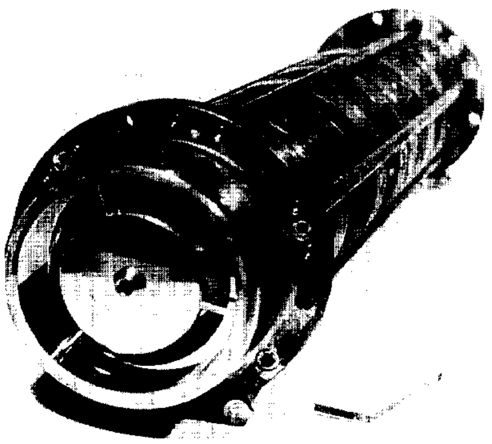

Figure 2: The regular accelerating section

regular one with the aim to obtain a uniform distribution of the accelerating field amplitudes in the cavity cells, to reach the required emittance and the conditions for the longitudinal bunching. There is a grid to exclude the defocussing effect of RF fields on the low energy electrons at the entrance of the first cell. The linac aperture is 8.7 mm in diam.

The linac has a minimum necessary and sufficient set of devices for the initial transverse focussing of the beam and its following tracking along the structure, namely:

- the x,z-correctors are placed at the accelerating structure entrance in the region of a 40 keV electron beam crossover,
- a single short axial-symmetry focussing lens is installed after x,z-correctors for matching the beam emittance and accelerator acceptance,
- the four pairs of windings of the long distributed correctors with separate power sources are spaced at the first and second halfs of the linac structure to compensate the influence of the small parasitic magnetic fields in the vicinity of the linac axis.

The structure exitation is reached by means of a special co-axial cavity. It is installed in the middle of the structure and splits it into two equal parts. The proper choice of the dimention of a coupling hole in this cavity matches the structure and the RF generator.

The linac is feeded by an industrial RF S-band generator which is based on the 18 MW klystron.

The klystron and the accelerating structure is connected by a 90×45 mm^2 rectangular waveguide whose length is a multiple of $\lambda/2$. This permits us to have minimum overvoltage during the unstable operation. The waveguide consists of gas and vacuum sections and a ceramic window between them. The gas part of the waveguide which is adjacent to the klystron is filled with nitrogen at about 6 atm.

III. Commissioning

The stable, 9 MW level of RF power in the linac was achieved by October 28, after a week training of the lattice and waveguide with the nitrogen-filled insertion. We want to note that the multipacting in the vacuum section of the waveguide was overcame during 8 hours by training and increasing the power level from 0.3 MW to 5.5 MW. Fig. 3 shows the oscillograms of: 1) the incident wave voltage in the waveguide; 2) the reflected wave voltage in the waveguide; 3) the voltage in the linac structure.

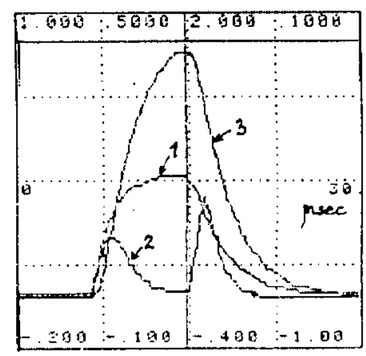

Figure 3: The oscillogram of RF signals

On November 1, 1992 we first emitted the electron beam from the linac to a transfer line. The current measurement, the beam position monitoring and beam collimation are performed by a movable pickup at the first accelerating cell entrance. The emitted beam parameters are measured in the transfer line.

Fig. 4 shows the elements of the magnetic and diagnostic

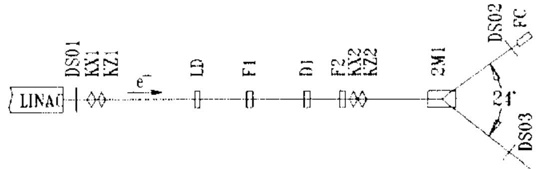

Figure 4: The magnetic and diagnostic system of the transfer line

systems of the transfer line. The electrons come out the linac in horizontal plane and move along an about 4-m-long straight section to the 12° vertical bending magnet (2M1). This bending magnet deflects the beam downwards to the septum magnet of the SIBERIA-1 or upwards in the diagnostic section and the Faraday cup (FC).

The three secondary-emission wire monitors are intended to observe and measure the intensity, the center-of-mass position, the transverse dimensions of the beam. The first one (DS01) is placed behind the linac, two others are installed after (2M1), at the end of the diagnostic section (DS02), and in the injection straight section before the septum magnet (DS03). A step between the wires of the monitor is as much as 1 mm in both directions and the charge sensibility is equal to 2×10^{-15} C.

At first the beam current and beam sizes were measured by means of the Faraday cup specially mounted at the initial part of the transfer line. The DS01 monitor current measurements were calibrated with the FC. After that, the movable remote-controlled vertical probe (lead cylinder-LD) was installed instead FC, and FC was positioned behind the vertical bending magnet (2M1). The beam was then led to the SIBERIA-1 input straight section.

The transversal distributions of the electron density which are reached by the secondary-emission wire monitors DS01, DS02, DS03 have shown very small angle spreads of the electrons. The measured transverse profile of the electron beam at the linac exit has standard sizes of $1.1 \div 1.3$ mm, the standard angle spread is 2.4×10^{-4} rad. When supposing the Gauss distribution we estimate the beam emittance as large as 3×10^{-5} cm-rad. The beam profile images are presented in Fig. 5.

We note that the transverse sizes of the beam measured

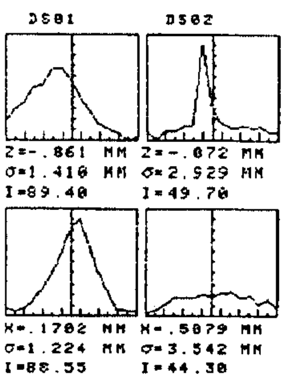

Figure 5: The beam profile images.

with FC and the movable remote-controlled probe after the linac were in good agreement with those of the wire monitor DS01 (Table 2).

Table 2.

	DS01	FC	Probe	DS02	FC
σ_x, mm	1.22	1.3	1.23	2.5	2.3-2.8
σ_z, mm	1.41			3.6	

The Faraday cup with a slit collimator before it and a vertical bending magnet 2M1 serve as a spectrometer intended for electron energy spectrum measurements. When changing the deflection angle of the magnet 2M1 the electron beam scans the slit of the collimator and the beam

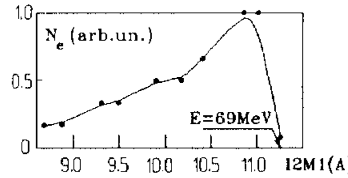

Figure 6: The energy spectrum of the linac electron beam

current selected by the slit is measured by the Faraday cup. The achieved dependence of FC current versus deflection angle is converted to the energy spectrum, Fig.6. Taking into account the geometry of the dispersion part of the transfer line, the width of the slit (3 mm), the transverse beam size at the slit (about 3 mm at one half level), and subtracting the background of the scattered electrons the relative width of the energy spectrum distribution is no more than 7 %.

The measured parameters of the electron beam at the exit of the linac are in Table 3:

Table 3.

Maximum energy	E = 69 MeV
Energy spectrum width	$\Delta E/E_{max} \leq 7\%$
Electron current	I = 370 mA
Pulse duration	τ = 18 ns
Pulse repetition frequency	$f_{rep} = 2Hz$
Electron beam emittances	$\varepsilon_x = \varepsilon_z \simeq 3 \times 10^{-5}$ $cm \times rad$
Beam transverse size at 1600 mm apart from linac	$2\Delta r_{1/2} = 3$ mm

The measured parameters of the beam enable us to take up the works with SIBERIA-1. The circulating electron beam at SIBERIA-1 was first generated using the new injector in December, 1992. The energy of the injected beam was 67.7 MeV. In March, 1992 the work was continued with the electron energy equal to 70 MeV at the injection in SIBERIA-1. Now SIBERIA-1 operates at a designed 450 MeV. The one-time capture current is up to 20 mA at the equilibrium orbit that sufficiently agrees with the expected current at this energy. By the end of 1993 the works on linac are assumed to be focused on increasing the energy up to 80 MeV and the current of the emitted beam

REFERENCES

[1] M.M.Karliner et al. Proc. of the EPAC, Rome, June 7-11, 1988. Vol.1. pp 602-604.

[2] O.A.Nezhevenko et al. IEEE Part. Acc. Conf.San Francisco, Cal., May 6-9, 1991. Vol.5, pp.935-937.

[3] V.N.Korchuganov, M.M.Samorukov. Proc. of the EPAC 92, Berlin, March 24-28, 1992. Vol.1, pp.474-476.