"ISTRA-10" LINEAR PROTON ACCELERATOR START-UP

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ISTRA-10 linear proton accelerator was launched at ITEP. It consists of the initial part with RFQ sructure (see Fig.1) and the main part which is Alvarez tank with permanent magnet quadrupoles (PMQs). The Alvarez tank is excited at the frequency (297 MHz) double higher than the RFQ. Between the initial part and the main part the matching channel is mounted comprising the buncher and the drift part.

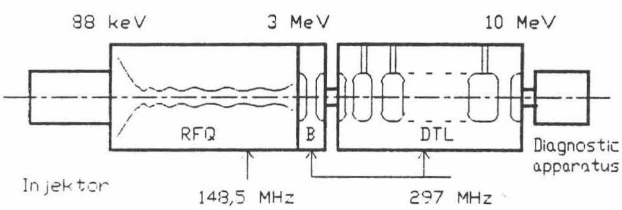

Fig.1. Block diagram of the Linac Istra-10.

ISTRA-10 linac is the first part of ISTRA-56 linac (56 MeV, 150-200 mA pulse current) [1-4] which will be used as the injector of ITEP proton synchrotron and also will serve as a pulse prototype of high current accelerators needed for radiopharmachemicals production, material irradiation tests and for solving of some nuclear power tasks. Main design parameters of ISTRA-56 linac are given in the Table. Bird's-eye view on the ISTRA-10 linac is presented in Fig.2.

In the RFQ launched a few years ago[5] the beam is accelerated from 88 keV to 3 MeV at the maximum current of 250 mA. In the output beam the share of particles accelerated to the energy of 3 MeV was 95%, in the current range of 0 - 100 mA the beam losses were negligible. The operating experience showed that the mechanical rigidity of the RFQ sructure was not enough. For ISTRA-56 linac the new RFQ section was manufactured. This RFQ is being under tests.

ISTRA-10 linac comprises the old RFQ, the matching channel with the buncher and 10 MeV Alvarez tank. The focusing channel of the linac has FODO structure and is formed by rare-earth magnet quadrupole lenses. Each lense consists of two layers of $SmCo_5$ rod magnets[6] fixed in duralumin cylinders (see Fig.3). The lense doesn't contain materials which could deteriorate vacuum quality. This fact allowed to open the interior of the drift tubes, where the lenses are mounted, to high vacuum of the tank chamber. The interior of the drift tubes is pumped through special holes drilled in the drift tube body. Thus it is possible to avoid vacuum-tight welding of the drift tube, because the presence of strong magnetic field in the welding area makes the task very complicated.

Each of 33 drift tubes contains 50 mm long lense. At the input of channel the gradient is maximum and is equal to 60 T/m. The rms deviation of the gradient values

TABLE

ISTRA-56 DESIGN PARAMETERS

Parameter	Unit	Initial part	Main part: Tank 1	Tank 2	Tank 3
Input energy	MeV	0.089	3	10	36
Output energy	MeV	3.0	10	36	56
RF field wave length	m	2.02	1.01	1.01	1.01
Wave type	-	H_{211}	E_{010}	E_{010}	E_{010}
Focusing	-	RFQ	*rare - earth*	*quadrupole*	*magnet*
Tank length	m	4.57	3.56	11.64	9.15
Tank diameter	cm	44.9	65.0	63.0	58.0
Drift tube diameter	cm	-	10.0	8.5	8.5
Number of drift tubes	-	-	1/2 + 33 + 1/2	1/2 + 54 + 1/2	1/2 + 29 + 1/2
Gap length factor	-	-	0.180-0.254	0.179-0.289	0.239-0.292
Modulation factor	-	1.00-1.74	-	-	-
Aperture diameter	cm	8.11-1.54	1.2	1.6	2.4
Quadrupole lense length	cm	-	5.0	10;15	15
Field gradient in quadrupole	kG/cm	-	6.0-5.6	3.23;2.56	2.36
Synchronous phase (absolute value)	degree	90-35	50-37	37-30	30
Time-of-flight factor	-	0-0.39	0.812-0.854	0.902-0.840	0.879-0.830
Momentum spread	%	2.32 output	4.00-1.86	1.86-0.84	0.84-0.65
Acceptance	cm mrad	1.28	0.63-0.83	1.48-1.73	3.91-4.00
Maximum pulse current at phase density of 1 A/cm mrad	mA	200	250	520	1490
Rated pulse RF power losses in copper	MW	0.44	0.43	1.11	1.07
Pulse RF power needed at beam current 150 mA	MW	0.44	1.09	3.90	3.00

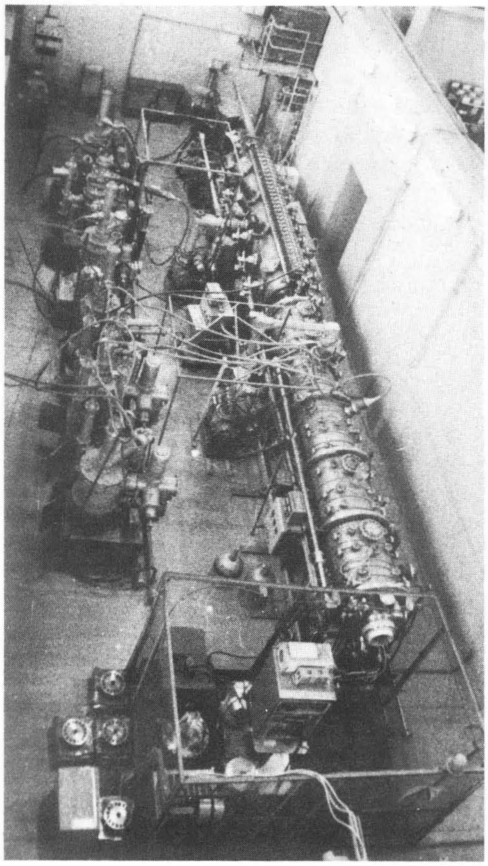

Fig.2 General view of the Istra-10 Linac

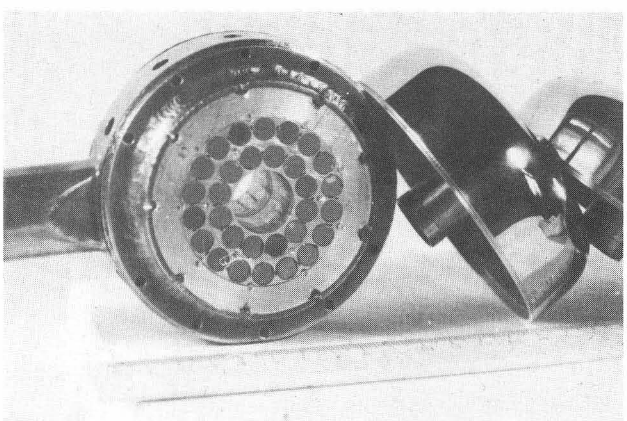

Fig.3 Open into vacuum the drift tube with PMQ (before assembling)

from the rated ones (over all lenses) is 0.6%, nonlinearity - 0.5%. Mean displacement between the geometric and magnetic axes over all lenses is 0.03 mm.

Increasing of frequency in the Alvarez tank allowed to decrease its dimensions that along with the decreasing of the drift tubes diameter permitted to reduce RF losses but didn't lead to beam current limitation. The Alvarez tank is fabricated of trimetal and at the same time is a vacuum chamber. The drift tubes were aligned with the rms displacement of 0.08 mm in transversal planes. The longitudinal alignment error is 0.05 mm. Quality factor of resonator is 33000. The difference between the operating mode and the nearest one is 1.8 MHz. Unflatness of the mean field level on the axis (the designed value E=30 kV/cm) is up to 5%. The cavity is excited by two loops, the loops being isolated from the vacuum chamber by quartz windows which have antimultipactor grooves. The training was carried out both at direct excitation and autoexcitation. As a result the field level achieved exceeds the designed value by 16%.

The one gap buncher is made as copper torus-like resonator, gap length is 22 mm and the aperture - 18 mm. Two rare-earth magnet quadrupoles mounted in its halftubes provide the gradient of 58.4 T/m. Intensive multipactor effects were observed during first excitation tests. Reliable operation of the buncher was achieved only after special antimultipactor measures were taken such as improving of contacts, cleaning of surfaces and so on. The gap voltage of 290 kV was achieved that exceded the design value by 30%.

At the drift part of the matching channel (421 mm long) six electromagnetic quadrupoles are mounted, but by the moment of linac start-up this part of the channel wasn't optimized for maximum beam transmission.

The total volume of the linac vacuum chamber is 3.5 m^3, the operation pressure was 10^{-6} - $6 \cdot 10^{-6}$ Torr.

RF power of 1.3 MW at the frequency of 148.5 MHz is supplied to RFQ by two-cascade generator based on GI-27AM triode. The Alvarez tank is excited by three-cascade generator (two cascades on GI-27 and the third on GI-50A triode) providing 1.7 MW at the frequency of 297 MHz. The modulators connected to RF generators include step-up cable transformers, thyristor rectifiers, optical control lines, etc. Automatic control systems sustain resonant frequencies of the cavities with the accuracy of ± 200 Hz and the phase difference between them with the accuracy of 1.5 phase degree.

The assesement of the influence of the buncher on the accelerated by the RFQ particles movement (before the Alvarez tank was mounted) showed that in the case of proper established RF field level and phase in the buncher the momentum spread grew by a factor of two and the phase length at the output of the drift part (at the first gap of Alvarez structure) decreased up to 80 phase degree (for frequency 297 MHz) that corresponded the designed value.

During the start-up of ISTRA-10 linac the proton energy at the output was measured by the magnetic analyser. The calibration of RF fields in the cavities was carried out by determining their threshold levels. Enough acceptance of the focusing channel in the Alvarez tank provided transportation of 3 MeV beam from the RFQ to the measuring channel through the Alvarez tank in the absence of RF field in the tank.

In September 1989 10.3 MeV proton beam was registered at the output of the Alvarez tank, output current being 15 mA, pulse length - 5 μs, repetition rate

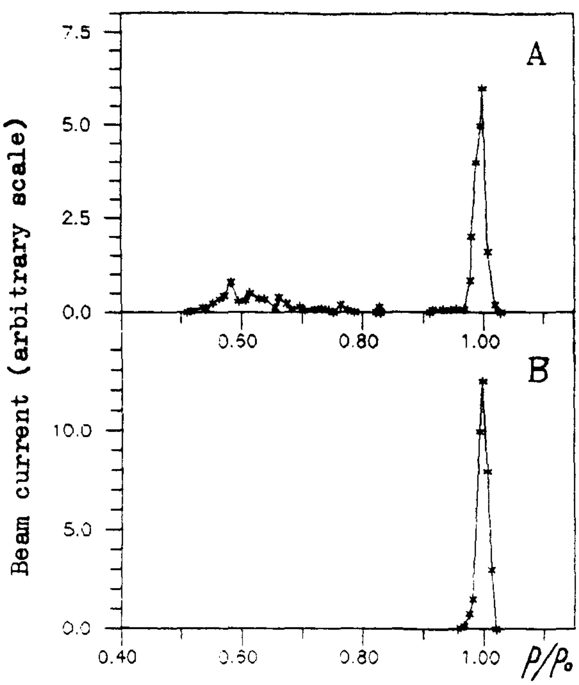

Fig.4. Spectrum of the output beam at the buncher off (A) and on (B)

- 1 Hz. Such a beam had no significant influence on the RF field level but provided enough intensity for reliable measurements.

Beam spectrum, measured at the designed level of RF field in the RFQ and the Alvarez tank at the optimum phase difference between them (the buncher was switched out), is presented in Fig.4a. Capture factor, defined as the ratio of accelerated to the designed energy protons current to the total output current, in this case was 68%. Protons of the designed energy were considered as those which momentum differs from the rated not more than by value of halfspan of the separatrix in the Alvarez tank.

In the case of switched on buncher it provided almost full overcapture of particles at their transfer from the RFQ to the Alvarez tank. Momentum spectrum for this case is presented in Fig.4b, capture factor being close to 1.

Now the efforts are aimed at the increase of beam current.

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