Beam Matching in the Transition Region between DTL and DAWL of the INR Linac

Yu.V.Bylinsky, S.K.Esin, A.V.Feschenko, L.V.Kravchuk,
P.N.Ostroumov, S.I.Scharamentov, V.L.Serov
Institute for Nuclear Research of the Russian Academy of Sciences
Moscow, 117312, Russia
A.P.Fedotov, A.I.Kvasha, B.P.Murin
Moscow Radiotechnical Institute
Moscow, 113519, Russia

Abstract

The method and the results of the 100 MeV proton beam transition from the drift tube linac (DTL) operating at a frequency of 198.2 MHz to the disk and washer structure linac (DAWL) operating at a frequency of 991 MHz are presented. The special features of the longitudinal and transverse matching are discussed.

1 INTRODUCTION

The INR linac, which accelerates protons and H^- ions to an energy of 600 MeV with an average current of 0.5 mA consists of two parts with the transition between two occuring at a beam energy of 100 MeV. The drift tube linac operating at a frequency of 198.2 MHz, is at this point replaced with the disk and washer structure linac operating at a frequency of 991 MHz. The focusing FODO channel with 1.3 m period turns into a FDO channel with 2.3 m period, giving rise to the problem of longitudinal and transverse matching of the 100-MeV beam. The initial results of the commissioning of the 160-MeV linac are presented in the report [1].

2 LONGITUDINAL MOTION

The main feature of the longitudinal matching consists in the fact that the operating frequency of the second part of the linac is 5 times as high as that of the first part and, consequently, its longitudinal acceptance is 5 times as small. Adiabatic damping of the longitudinal oscillations of particles in the drift tube linac is not strong enough to fit the bunches into the longitudinal acceptance of the DAWL. Therefore the final (fifth) resonator of the DTL is a quarter of a longitudinal wavelength long which makes it possible to reduce the bunch phase length by a factor of 1.4 and thus fit them safely into the acceptance of the DAWL.

To carry out the longitudinal matching it is necessary to study the longitudinal parameters of the 100-MeV beam at the output of the DTL: the phase spectrum, the momentum spread, and the longitudinal emittance.

The phase spectrum is measured with a phase analyzer [2], placed at the output of the fifth tank. The phase spectrum, measured at 10 mA current with the buncher being turned off, is shown in Figure 1. The bunch phase length is about 11 deg. The spectrum is integral.

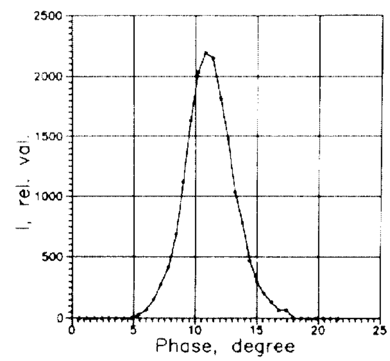

Figure 1: The integrated bunch phase spectrum downstream DTL

A succession of instantaneous phase spectra, measured within 1 μs with the intervals of 5 μs between them, is shown in Figure 2. The width of the instantaneous spectrum is 8°. It is seen a background due to γ-radiation. A coherent shift of about 3° of the spectrum along the current impulse is caused by beam loading of the field in the tank. In the system of the automatic control of the field amplitude, the feedforward compensation of the beam loading effect was not realized. Later this coherent shift will be removed.

The momentum spread of the particles was measured with the aid of a magnetic analyzer placed downstream of tank #9. It contains two vertical slits, each of 1mm width, the bending magnet and a current receiving plate of 1mm width. The resolution is 0.11%. The measured 100.1 MeV beam energy spectrum with the buncher turned off is shown in Figure 3. The momentum spread of $\pm 0.8\%$ slightly exceeding the calculated value practically coincides with the vertical dimensions of the bucket of the DAW.

The elliptically shaped longitudinal emittance is reconstracted according to the three measurements of the bunch phase length at the output of matching section with a certain matrix [3]. The fifth tank and following drift space serve as the matching section. The bunch length was measured with the phase analyzer placed at a distance of 1.5 m beyond the output of the fifth tank. First the phase ellipse is reconstracted at the fifth tank input according to

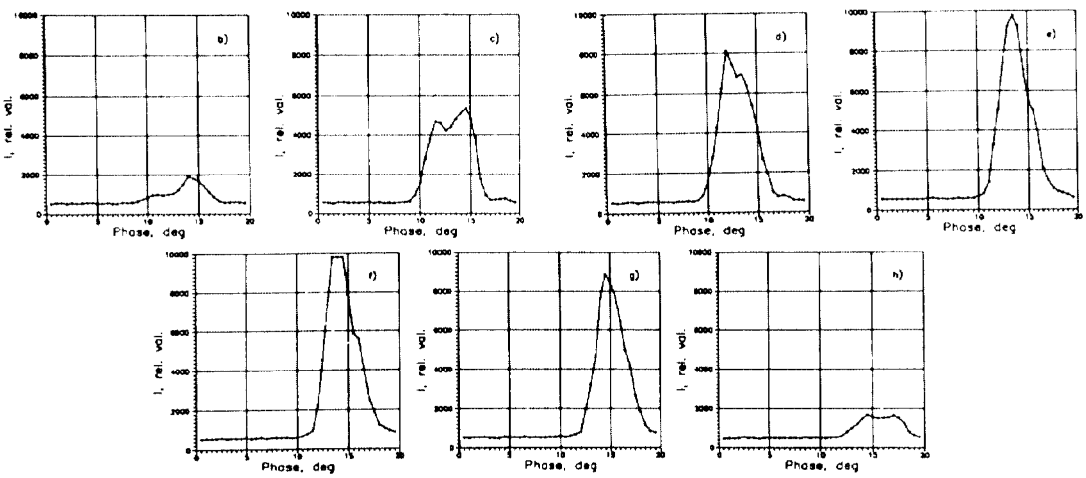

Figure 2: Stroboscopical bunch phase spectrum downstream DTL for a beam current of 10 mA

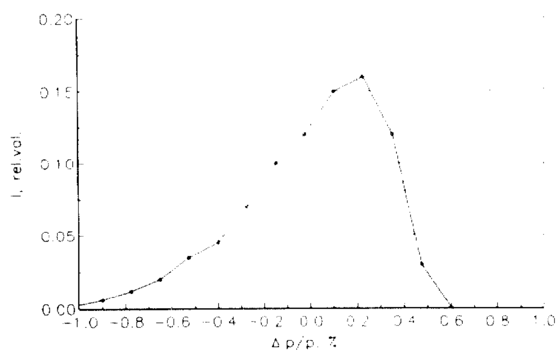

Figure 3: The measured momentum spectrum downstream DTL

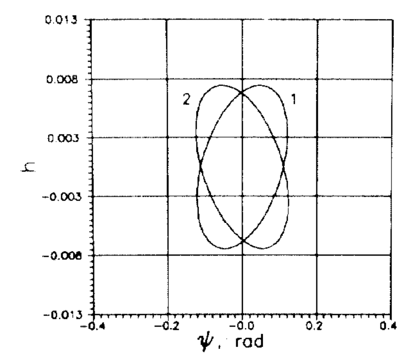

Figure 4: Longitudinal beam ellipse on the transition region input (1) and output (2)

the phase length measurement result at following accelerating field amplitudes: $E = 0$; $E = 0.7E_n$; $E = 1.3E_n$, where E_n is its nominal value. The transformed ellipse at the output of tank #5 and at the input of tank #6 are shown in Figure 4. The longitudinal emittance of beam (0.75π MeV$\cdot$ rad) is smaller than the bucket of the following linac (1.04π MeV$\cdot$ rad).

The calculated energy at the input of the high energy part of the linac was set by varying the phase of the fifth tank field and fixed with the aid of the Δt procedure with an accuracy of $\Delta\beta/\beta = 5 \times 10^{-5}$ [4].

3 TRANSVERSE MOTION

The transverse matching of the beam in the transition region downstream of the FODO focusing structure with a period of 1.3 m is carried out according to the original design with the aid of the four magnetic quadruple lenses (two doublets) fed from separate power sources. In the tuning under way now only two lenses are used, the two others are replaced with beam monitors. Matching is accomplished with the aid of the two matching lenses and the final three lenses of the FODO channel.

One may evaluate the quality of the beam transverse matching by the measured beam transverse parameters (the beam profile shape, its rms dimensions $X_{\rm rms}$, $Y_{\rm rms}$, the centre of weight location $X_{\rm pos}$, $Y_{\rm pos}$). The aforenamed parameters are measured at each of the sixth tank's four sections output.

In the module tuning regime (Figure 5) amplitude of the coherent oscillations of the beam centre of weight did not exceed 4 mm in each plane. In the accelerating regime on the 30.01.91 (Figure 5,6) an especially good matching of the beam with the focusing channel was achieved in the X-plane; $X_{\rm rms}$ was 2.3 mm.

The beam rms dimensions measured with the five wire scanners are used for its emittance restoration according to an elaborate method. The method is based on the joint solving of the equation of the beam envelope with the phase ellipse equation described by

$$\gamma x^2 + 2\alpha x x' + \beta x'^2 = \epsilon$$

, for five measured points. Here $x' = dx/dz$; α, β, γ — are the ellipse parameters, ϵ — beam emittance. For the emittance restoration a program, Beampar, was worked out. Results of the reconstraction of the phase ellipse paramaters at the input of tank #6 (in the wire scanner

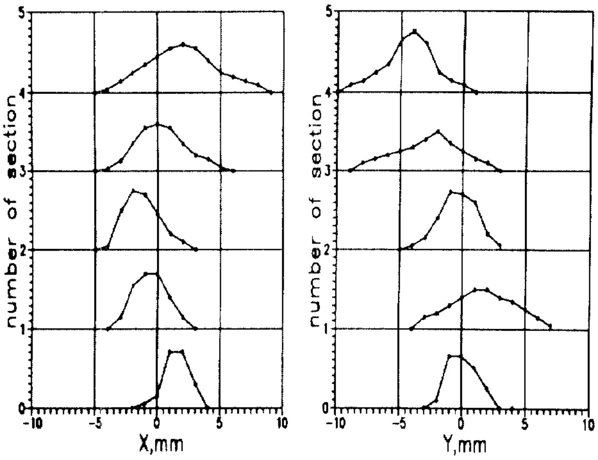

Figure 5: Measured beam profiles along sixth tank

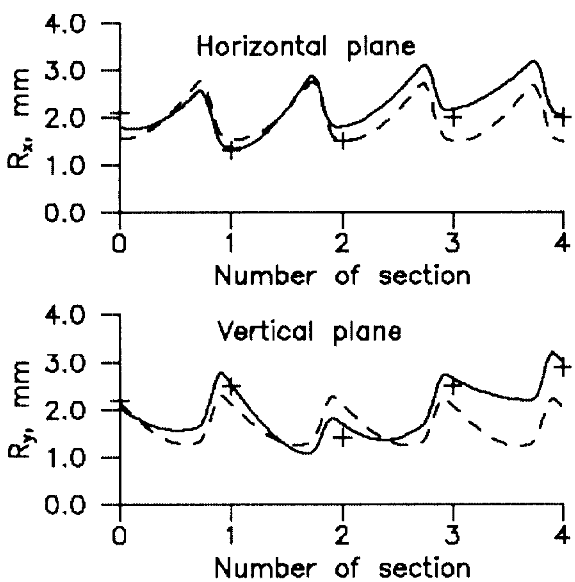

Figure 6: Beam envelopes along sixth tank

cross-section) for a certain run are given in Table 1.

The beam profiles in the X and Y planes, measured along the sixth tank, are shown in Figure 5. After the ellipse parameters for each phase plane were calculated, the beam envelope was restored (Figure 6, solid line). The dotted line corresponds to a matched beam. The rms beam dimensions measured in this run are marked in points. The measurement accuracy is not worse than 0.2 mm.

4 CONCLUSION

The measured longitudinal and transverse emittance of the 100-MeV proton beam (0.75π MeV$\cdot$ rad, 0.45π cm $\cdot$ mrad) fit safely in the longitudinal and transverse acceptances of the high energy linac part (0.9π MeV$\cdot$ rad, 3.8π cm $\cdot$ mrad). So one may hope to complete successfully the commissioning of the next linac part.

Table 1: Phase ellipse paramaters

Plane	β cm/mrad	α	ϵ_n $\pi \cdot$ cm $\cdot$ mrad
X	0.14	0.19	0.11
Y	0.26	0.91	0.075

5 REFERENCES

[1] G.I.Batskich et al. Bulletin of the American Physical Society. Abstracts of the 1991 PAC, v.36, N.5, 1991, p.1651.

[2] A.V.Feschenko, P.N.Ostroumov. Proceeding of the 1986 Linac Conf., Stanford, June 2-6, 1986, p.323.

[3] A.M.Tron, A.V.Feschenko. Problems of atomic science and technology. Technique of physical experiment series, 1983, Issue 3(15), pp. 51-53.

[4] S.V.Dvortsov, A.V.Feschenko, S.G.Garylkapov, P.N.Ostroumov, "The Δ-t Procedure Application at the INR Linac", in this Proceeding.