DEVELOPMENT OF RFQ ACCELERATOR FOR THE MMF LINAC

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Abstract

The 750 keV RFQ accelerator section is under development in order to install it upstream the first drift tube cavity of the MMF Linac instead of 2-gap buncher. The using of RFQ allows to decrease accelerating tube voltage to 400 kV and to increase pulse duration two times without pulsed transformer saturation. Main features of RFQ section are discussed: sufficiently high capture efficiency (up to 67%); reasonable length of 1.3 m; beam bunching without longitudinal halo.

Introduction

The upgrade program of the Moscow Meson Factory linac [1] includes the increase of average beam current up to 1 mA by lengthening of the pulse duration up to 200 μs. This is possible if a voltage of pulsed transformer will be decreased to the 400 kV. The transportation and funneling of H^+ and H^- allows to use a whole set of channel equipment, including H^- beam chopper. If the scheme with two RFQ resonators for each type of ions in the energy range of 50 keV to 750 keV would be used there will be a complicate problem to transport and to funnel high intensity bunched beams. Therefore the RFQ booster accelerator on the frequency of 198.2 MHz is proposed to accelerate simultaneously 400 keV H^+ and H^- ions with the total peak current of 100 mA up to Alvarez tank injection energy of 750 keV.

Choice of RFQ Parameters

For the proper value of normalized acceptance of the focusing channel V_k = 1.2 π·cm·mrad, the aperture radius and the voltage between adjacent pole tips are equal to a = 16 mm and U_2 = 150 kV accordingly. A calculated value of the transverse oscillation phase advance μ_0 is 0.6 for zero current. Taking into account space charge parameter h [2] phase advance μ could be estimated as:

$$\mu = \mu_0\left(\sqrt{1 + h^2} - h\right)$$

For example, for the normalized beam emittance ε = 0.4 π·cm·mrad the ratio μ/μ_0 is sufficiently high: μ/μ_0 = 0.835.

The semi circumference pole tips with the constant radius of R_e = 8 mm is foreseen along the whole length of electrodes. A maximum value of rf field on the electrode surface is expected 265 kV/cm which corresponds to 1.8 of Kilpatrick limit and does not exceed the value normally used in accelerator practice.

Transverse matching of the axially symmetric beam being injected in RFQ is provided with using matching section of 177_2 mm long. The square of focusing rigidity k^2 is changed by the law:

$$k^2 \sim \sin^2\left(\frac{\pi \cdot z}{8 \cdot \beta\lambda}\right)$$

For the phase density of j = 150 mA/(π·cm·mrad) the matched injected beam envelope is:

$$\sigma_x = \sigma_y = 2.774; \; \sigma'_x = \sigma'_y = -.75$$

More than 90% of the particles are contained inside an area of the phase space ellipse which overlaps with instantaneous Floke envelope. In order to match the output bunched beam consisting of approximately 60° bunches with the static quadruple channel of the Alvarez tank the output matching cell with the length of 0.33βλ is proposed. The electrode shape in this cell provides the proper changing of focusing rigidity which results to essential dropping of a time-dependence of the phase space ellipses.

Unusually high injection energy, small energy gain as well as limited RFQ size cause certain difficulties in the choice of the accelerating channel parameters. With consideration of mentioned features the accelerating channel consist of

1. A section of particle velocity modulation consisting of 4 half periods of longitudinal modulation of electrodes. The synchronous phase is equal -90°;
2. Drift section with the length of 2βλ;
3. A section of momentum spread depression with the length of 1.5 βλ. Synchronous phase is +90°. Apart the momentum spread decreasing this section allows to shorten the drift space as well as to transform the particle distribution in longitudinal phase space in such a way that in further acceleration the maximum momentum separation would be achieved for particles being inside and outside of separatrix.
4. The section of acceleration has 14βλ cells. The synchronous phase is changing from −45° to −28° along this section and the

momentum width of the separatrix of ±4% is keeping practically constant.

The RFQ parameters are presented in the table.

Table

Parameters of the RFQ resonator and beam

Parameter	Symbol	Input	Output
Energy	W_s (keV)	400	750
Relative velocity	β	0.029	0.040
Average distance from electrode to the axis	R(mm)	41	8
Radius of aperture	a(mm)	41	6.85
Electrode length	l_e(mm)	1199	
Tank diameter	D(mm)	325	
Radius modulation parameter	m	1.00	1.34
Transit time factor	T	0.0	0.189
Defocusing factor	γ_s	0.00	0.061
Transverse phase advance per period in the accelerating section	μ_0	0.609	0.593
Phase width of bunches	Φ(deg)	360	60
Maximum momentum spread	$\pm\Delta p/p$(%)	0.1	3.5

A computer simulation using the code [3] has been done for injection currents in the range of 0÷100 mA. In fig. 1 the beam phase portraits along the RFQ accelerator for peak injection current of 100 mA are presented. Initial specifications result to the unusual acceleration efficiency which is equal to 67% and 60% for injection currents of 0 and 100 mA accordingly. The normalized output rms emittance on the level of 90% is 0.45 π·cm·mrad for injection current of 100 mA and emittance of 0.38 π·cm·mrad at the input of RFQ.

The rf Aspects

On the full-scale model (Fig. 2) the radio technical parameters of the RFQ have been corrected as well as the field tuning procedure has been carried out. A bead pull technique has been used. A bead has been pulled in the gap between adjacent electrodes where the electric field is more uniform than in the aperture. Therefore the errors connected with an uncertainty of the bead position are decreased.

An influence of the coupling loops installed on the resonator end plates, ring-loops electrically connecting opposite electrodes, copper plates placed perpendicular to the direction of magnetic flux as well as tuning plungers movable into the resonator volume have been studied.

It was found that design value of the rf frequency, accelerating field uniformity and satisfactory dispersion curve can be obtained if the pair of the coupling loops (on the input and output end plates) as well as tuning plungers are used.

In accordance with calculation the dissipated rf power, quality factor and shunt impedance are equal to P_m = 150 kW, Q = 6900, R_{sh} = 75 kOm accordingly. Supposing that the actual rf losses can exceed calculated value and taking into account beam loading the total rf power is estimated equal to 260 kW. Average dissipated rf power does not exceed 7 kW for 3% of duty factor.

Four driving loops are foreseen, one in each quadrant. The driving loops will be inserted in a vacuum trough the insulator disk window.

The resonator is made from three-layer metal (oxygen-free copper, steel, stainless steel), the electrodes are made from oxygen-free copper. The cooling channels and longitudinal holes near the aperture for alignment are foreseen in the electrodes.

References

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3. I.A.Vorobjev et al. Computer simulation of the beam dynamics in RFQ. Preprint ITEPh No 52, Moscow, 1986.

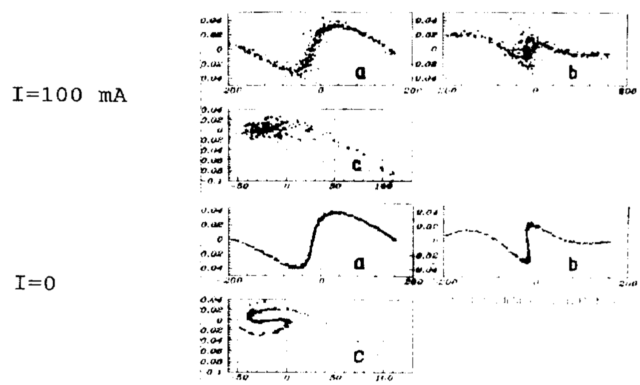

Fig. 1. Beam phase portraits at the exit of drift section (a), momentum spread depression section (b) and accelerating section (c) for peak currents of 0 and 100 mA.

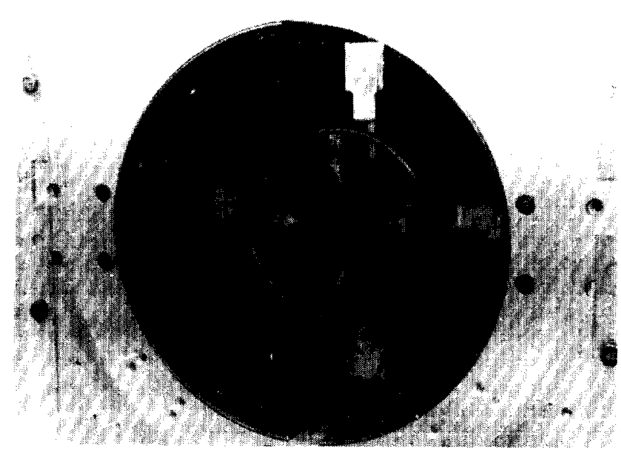

Fig. 2. Entrance view of the full-scale resonator model.