# PROGRESS WORK ON HIGH-CURRENT HEAVY ION LINAC FOR ITEP TWAC FACILITY

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### *Abstract*

The new heavy ion high current injector for ITEP-TWAC Facility is now under construction at ITEP for acceleration of ions with 1/3 charge to mass ratio up to energy of 7 MeV/u and beam current of 100 mA. The 81.5 MHz RFQ section based on 4 vane resonator with magnetic coupling windows is constructed for the beam energy of 1.57 MeV/u. The RF tuning of RFQ section has been presently completed and basically confirmed the expected parameters calculated by 3D OPERA codes. The windows improve both azimuthal and longitudinal stabilization of the operating mode by increasing the separation from parasitic modes. The second section of 163 MHz H-type resonator is designed and in progress for construction. Status of machine construction activity and beam dynamics calculation are presented.

## INTRODUCTION

The ITEP-TWAC facility is under operation since 2002 delivering proton and ion beams in several modes of acceleration and accumulation by using the multiple charge exchange injection technique [1]. Intensity of accelerated and stacked ion beams is limited now in this machine by operation parameters of ion injector I-3 such as low energy (4 MV) and high on-off beam ratio (>20) at low accelerating frequency (2.5 MHz). To increase machine intensity by factor of ten ore more a new high current ion injector I-4 is under construction for acceleration the ions with charge-to-mass ratio 1/3 with beam current up to 100 mA. The new injector consists of two acceleration structures such as RFQ and IH DTL

## RFQ STRUCTURE

The design of the 81.5 MHz RFQ cavity is based on 4-vane resonator with magnetic coupling windows which was originally developed in ITEP [2]. The windows improve both azimuthal and longitudinal stabilization of the operating mode by increasing the separation operational and parasitic modes. They also significantly reduce the transverse dimensions of the resonator. The windows on adjacent vanes have been displaced with respect each other in order to increase the magnetic coupling among quadrants. The operational mode of the structure is a combination of TE210 and coaxial modes, but the structure can not be considered as a split-coaxial RFQ structure, because the last one has electrical contact between each pair of the vanes and end flanges and completely different field distribution inside the resonator. Note that the displacement of the windows reduces a "ripple" of inter-electrode voltage along the resonator and improve mode separation in comparison with a symmetrical version (when the windows are not displaced) [3]. On other hand coaxial component of the operational mode creates an electric field ($E_z$) on beam axis in the gaps between end flanges and the vanes. The magnitude of the field depends on both displacement of the windows and diameter of the flange hole. As it was shown by simulation carried out using different codes this effect does not practically influence on beam dynamics. The simulations of the beam dynamics were carried out by using code "DYNAMION" elaborated in ITEP. The basic simulated parameters of the 81.5 MHz RFQ are given in the Table 1. Fig.1 and Fig.2 show the geometry of the regular cell calculated by 3D OPERA code.

Table 1: Main parameters of the RFQ structure

| **Parameter** | **Unit** | **Value** |
|---|---|---|
| Operating frequency | MHz | 81.5 |
| Charge to mass ratio | | 1/3 |
| Input/output energy | MeV/u | 0.02/1.57 |
| Average radius | mm | 10 |
| Vane tip radius | mm | 7.5 |
| Voltage | kV | 182.5 |
| Input emittance (norm) | cm*mrad | 0.327 |
| Output emittance (effective) | mm*mrad | 2.3*π |
| Input current | mA | 100 |
| Pulse repetition | Hz | 1 |
| Pulse duration | µs | 100 |
| Output energy spread | keV/u | +/- 20 |
| Length of the RFQ vanes | m | 6.258 |
| Inner cavity diameter | m | 0.564 |
| Quality factor of the resonator | | 11000 |

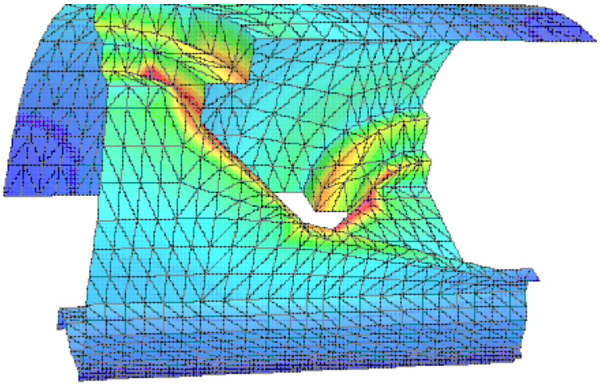

Figure 1: Finite elements model of the regular cell.

The RFQ resonator consists of 9 sections. Each section contains a vacuum tank, made of double layer metal, and vanes. Both inner surface of the tank and electrodes are manufactured of oxygen free copper. Outer part of the tank shell is made of stainless steel. Electrical contact between each electrode and inner shell of the resonator tank has been provided by mechanical joint.

Fig.2 depicts view of the RFQ with open outlet flange.

Figure 2: view of the RFQ with open outlet flange

After assembling the structure the electrodes were optically aligned with respect to beam axis by means of telescope and an optical target as it is shown in Fig.3. The electrodes have a reference edges, manufactured with proper accuracy relatively beam axis. The target has a hole with a cross. The position of each electrode was corrected in order to install the cross on the beam axis. Orthogonality of the electrodes has been tested by means of precise teflon bar sliding between each pair of the electrodes.

Resonant frequency $f_0$ after alignment is 81.913 MHz. Nearest parasitic modes ( TE211 and TE110) are 85 MHz and 92 MHz respectively. Quality factor of the resonator Q is equal 7500. Normalized Inter-electrode voltage distribution V(z) along the structure for 4 quadrants of the RFQ is shown in Fig.4.

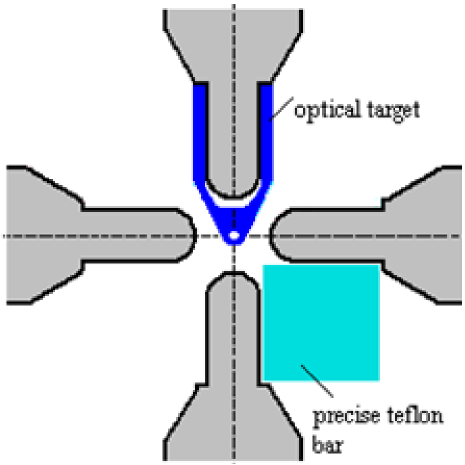

Figure3: Alignment of the electrodes.

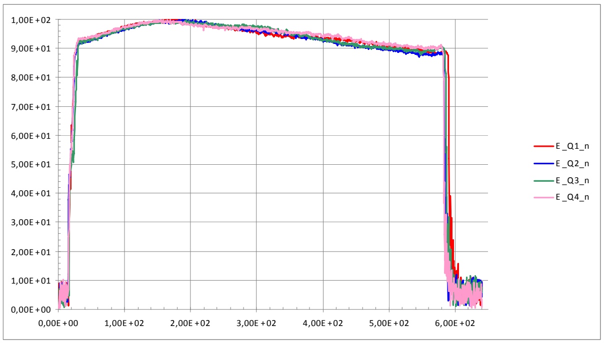

Figure 4: Inter-electrode voltage distribution V(z).

The azimuthal voltage unbalance among the four quadrants was measured to be within +/-1%. The longitudinal inter-electrode voltage distribution has a tilt of about 10%. It may be caused by both increasing average radius of the aperture to the end of the structure and detuning end cells of the resonator. Since the resonant frequency was found higher than 81.5 MHz no tuners were used to equalize V(z). We decided to start commissioning of the RFQ with present parameters. For the next test session, foreseen in this year, we plan to improve field distribution and find exact resonant frequency. Conditioning of the resonator has been accomplished in pulse regime at pressure of $2x10^{-7}$ mbar. Low multipacting levels were overcame very easily. Achievement of nominal inter-electrode voltage level (182.5 kV) is now under processing and will probably take a few weeks.

## IH DTL STRUCTURE

The IH structure is designed for the second acceleration section. Beam dynamics studies and layout of the IH DTL structure were reported in work [4]. The layout of the structure and 98% beam envelopes in both transverse directions are shown in Fig.5. The structure is based on separate resonators with KONUS scheme and focusing elements placed between resonators.

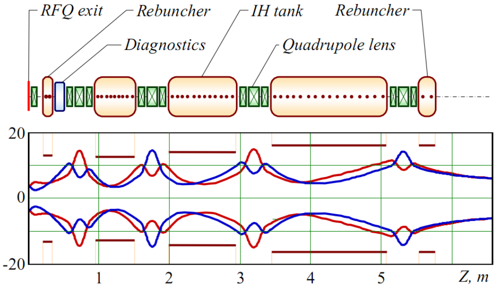

Figure 5: The structure layout and transverse beam envelopes at full current of 100 mA.

The calculated parameters of the IH structure are given at Table 2.

Table 2: General parameters of IH-DTL

| | | |
|---|---|---|
| Operating frequency | MHz | 163 |
| Beam current | mA | 100 |
| Input/output energy | MeV/u | 1.57/7.04 |
| Final energy spread | % | +/- 0.5 |
| Transverse emittance (norm) | mm*mrad | 3*π |
| Longitudinal emittance (norm) | AkeV*ns | 16.2 |
| Transv. Rms emit. Growth | % | 40 |
| Long. Rms emit. Growth | % | 22 |
| Total length | m | 5.75 |
| Number of RF tanks | | 3 |
| Number of RF bunchers | | 2 |
| Total gap number | | 41 |
| Aperture diameter | mm | 25-38 |
| Gap / cell ratio | | 0.48-0.4 |
| Effective gap voltages | | 370-700 |
| Maximum on-axis field | MV/m | 14 |
| Lens aperture diameter | mm | 40 |
| Magnetic field gradient | T/m | 48 |

Fig. 6 shows the phase of RF field seen by the center of the bunch when crossing the gap middle plane.

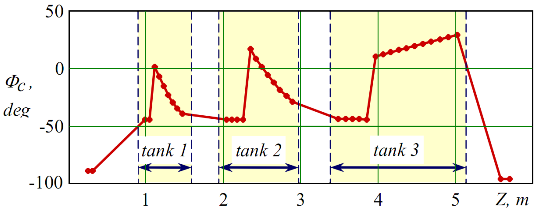

Figure 6: Phase pattern of the bunch center along Z .

The longitudinal emittance at the phase-energy plane along the structure is shown in Fig.7.

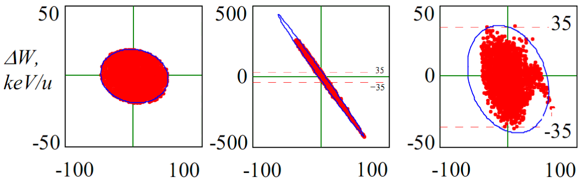

Figure 7: Longitudinal emittance at the RFQ exit, at the exit of tank 3 and after the external buncher.

The energy spread at the exit of 3rd tank is minimized by the external buncher and does not exceed the value of +/- 35 AkeV, satisfying requirements for synchrotron injection. The accelerating gap length variation and effective gap voltage along the structure are shown in Fig.8 and Fig.9.

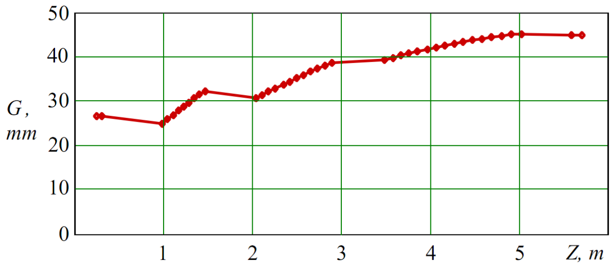

Figure 8: Gap length variation along IH structure.

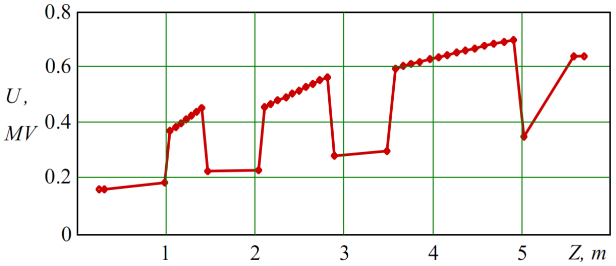

Figure 9: Effective gap voltages along IH structure.

## CONCLUSION

The work on construction of the new injector for TWAC facility is going on at ITEP. Commissioning of the RFQ has been started. Preliminary design of IH DTL structure has been practically completed and we are planning to start its specification and construction in this year taking into account experimental results of the RFQ section beam tests.

## REFERENCES

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