ENGINEERING DESIGN OF HIGH-CURRENT 81.36 MHz RFQ WITH ELLIPTIC COUPLING WINDOWS

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Abstract

Four-vane high-current 81.36 MHz RFQ structure with elliptic coupling windows has been developed in ITEP for Tera Watt Accumulator (TWAC) accelerator/storage ring complex with the laser ion source [1]. As the electrodynamics simulations show, this structure combines the high efficiency with the operating mode stability against asymmetric detuning and vanes misalignment. A considerable reduction of structure diameter due to coupling windows becomes important for low frequency range which is necessary for heavy ion acceleration. At the same time, the vane configurations allow the high duty factor operation. This paper will discuss mechanical design of present RFQ.

1. INTRODUCTION

The RFQ structure with elliptic coupling windows has been originally developed in ITEP, being then adapted to cw operation for RIA project [2]. The basic parameters of the 81.36 MHz ITEP RFQ are given in the Table 1. The simulation of the beam dynamics were carried out by using elaborated in ITEP code "DYNAMION". The present design has been developed as a compromise of many parameters and factors: shunt impedance, mechanical stability of the construction together with the precise alignment ability, reliable RF contacts, fine tuning of resonant frequency during operation, assembling technology, efficient water cooling system etc. Fig.1and Fig.2 show the geometry of the regular and end cells calculated by using 3D OPERA code.

Table 1: Main parameters of the structure

Parameter	Unit	Value
Operating frequency	MHz	81.36
Charge to mass ratio		1/3
Input/output energy	MeV/u	0.02/1.566
Average radius	cm	1.0
Vane tip radius	cm	0.75
Voltage	kV	182.5
Input emittance (norm)	cm*mrad	0.32765
Input current	mA	70
Length of the RFQ vanes	m	6.258
Inner cavity diameter	m	0.564
Quality factor		14000

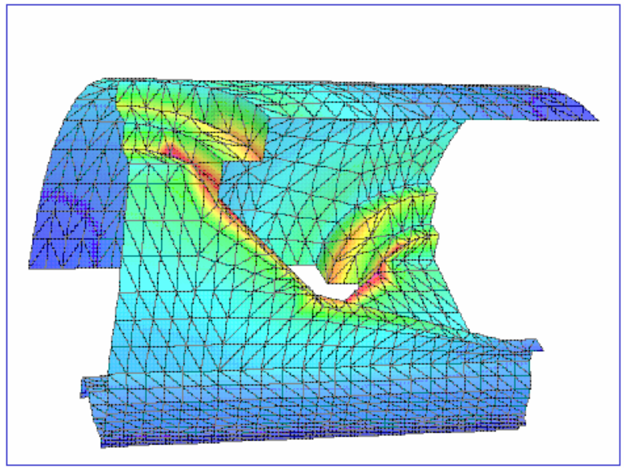

Figure 1: Finite elements model of the regular cell in "OPERA – 3D" code

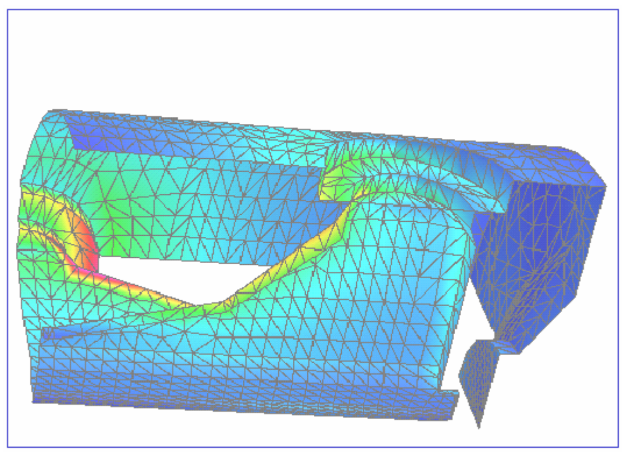

Figure 2: Finite elements model of the end cell in "OPERA – 3D" code

2. DESIGN OF THE STRUCTURE

An external general view of the RFQ (without vacuum and cooling systems) located on its support is shown at Fig.3. The whole accelerating structure is mechanically assembled from nine longitudinal elements (sections) and two end flanges. The typical section consisting of a vacuum tank and four vanes, everyone supplied with the alignment mechanism, is shown by Fig.4. The water cooled frequency tuners (plungers) have to be installed at every section of the structure in order to compensate the inaccuracy of calculation and manufacturing. The final plunger sizes will be defined by the tuning procedure and then fixed during operation.

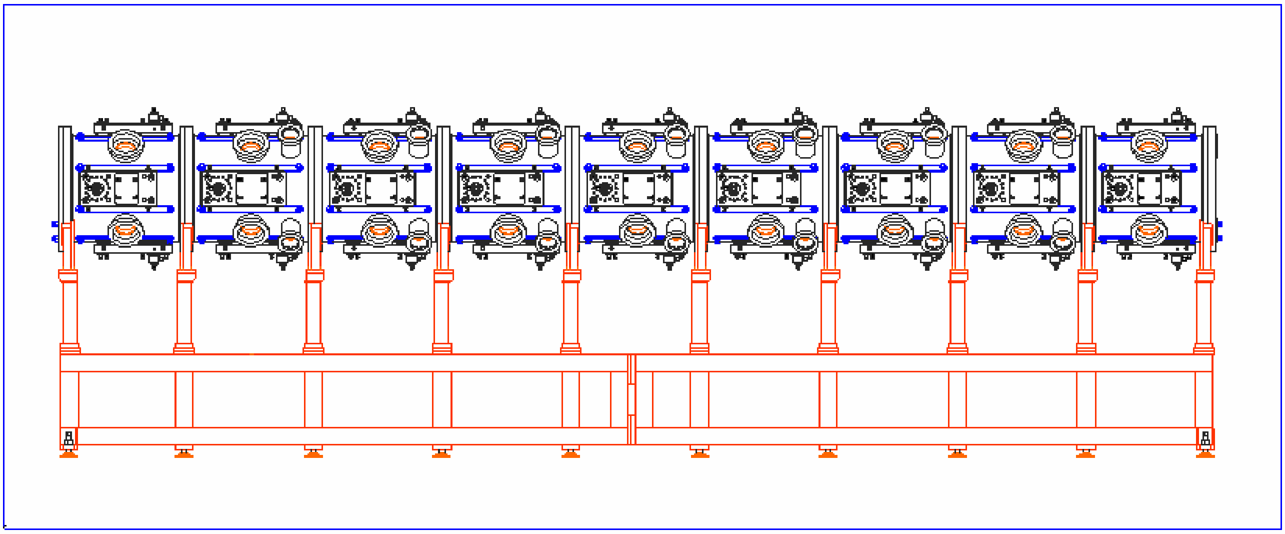

Figure 3: An external general view of the RFQ

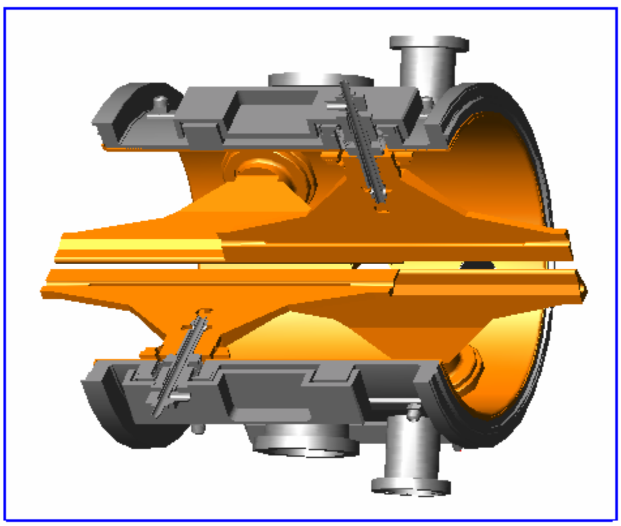

Figure 4: The regular cell of the RFQ.

The tuners are designed as cylindrical plungers introduced from the wall between the vanes in the middle or every cell. Calculation shows that the plungers of 65 mm diameter and 80 mm depth give the total frequency shift around 0.8 MHz. An operating frequency can be maintained by a manipulation of water temperature in the cooling system. The pick-ups are mounted at the centre of the bottom of some fixed frequency tuners. The distributed vacuum system consists of several different pumping.

Vacuum tank and end flange

The cylindrical shell of the vacuum tank consists of two metal layers joined by using hot diffusion technology. The internal layer is fabricated from 4mm oxygen free copper (100% OFE copper) sheet. The external layer made from 12 mm Stainless Steel sheet provides good mechanical stability and stands atmospheric pressure. Eight cooling channels are machined in the same steel layer. Each end flange also consists of two metal layers (SST and 100% OFE copper) and these layers are joined by using hot diffusion technology. Fig.5 shows these different layers. Four frequency tuners, pick-ups, RF-coupling and vacuum pump ports are located at the tank.

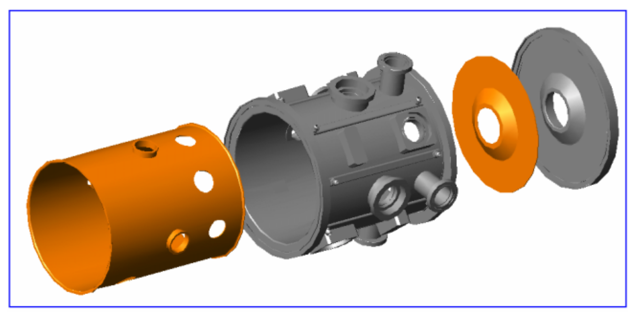

Figure 5: The different layers of the vacuum tank and end flange

Vanes

Three vanes of different length have been designed for the structure, 420 mm (half-vane), 720 mm and 780 mm long. All of them are made as oxygen free copper solids. The view of vane of the regular cell is shown at Fig. 6. Each vane is assembled of two elements joined by using electro-arc welding. These elements are the vane itself (or electrode) and the connecting unit, which has to provide the structure with the reliable rf contacts (see Fig.7). The electrode consists of three parts joined by using hot diffusion technology. The fabrication process begins with machining of the cooling channels, channel for alignment procedure into three plates and performing a hot diffusion welding. The connecting unit includes also three pieces: the top plate, flexible conducting insert and bottom flange joined by welding. A top plate of the connecting unit is welded to the electrode. Then the vane is machined to its final condition. This includes the finishing of all surfaces including the modulated vane tip.

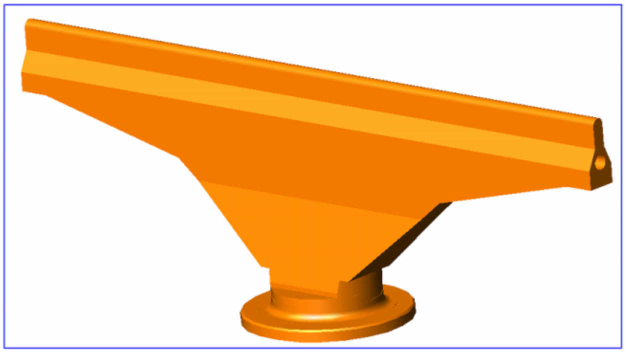

Figure 6: Vane of the regular cell

A bottom flange of connecting unit is fastened by screws to the internal shell of the tank during assembling procedure. A flexible conducting insert is necessary to make the vane movable in small limits at different directions for final alignment and to keep the rf contact at the same time.

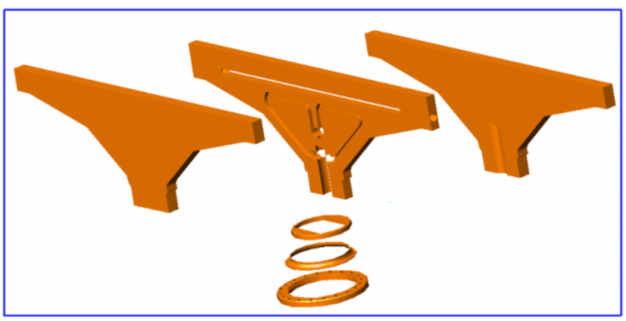

Figure 7: The parts of the vane

The channels in the vanes have been machined taking into account the power dissipation in the structure which peaks near the junction from the electrode to the connecting unit in the elliptical vane openings. Fig.8 shows a configuration of the cooling channels (blue colour) and a channel for alignment procedure (grey colour). All four vanes in one section are cooled in parallel to minimize the distortions and frequency shift.

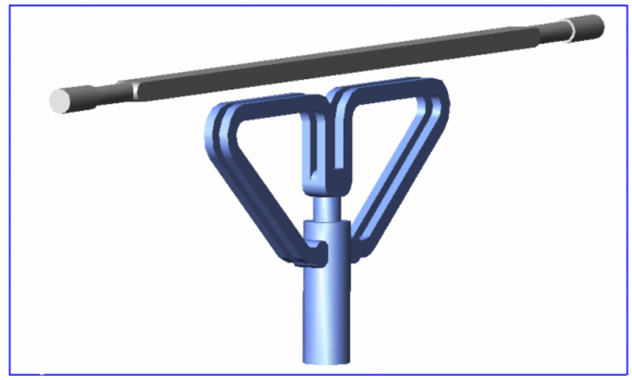

Figure 8: Vane channels for cooling and alignment

Each vane is mechanically assembled separately to the cylindrical shell by using a special alignment mechanism, which ensures the successful arrangement of the vane tip with necessary accuracy concerning a beam axis.

3. CONCLUSIONS.

In order to define the final dimensions of elliptic windows of the vanes and the depth of the plungers, we plane to construct a low power prototype – “half-cold model” in the nearest future. This model will consist of the real vacuum tanks, real end flanges, but including prototypes of both vanes and plungers fabricated from aluminium alloy. The whole setup is in manufacturing now.

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[2] D.A. Kashinsky at al. “Design of 57.5 MHz CW RFQ for Medium Energy Heavy Ion Superconducting Linac”. Physical Review Special Topics - Accelerators and Beams. Vol.5, 060101 (2002).