THE NEW EBIS RFQ FOR BNL

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Abstract

A new RFQ is being built as a part of the new EBIS-Linac at BNL. The RFQ accepts highly charged ions from the EBIS ion source with energy of 17 keV/u and ion currents of up to 10 mA. The operation frequency will be 100.625 MHz. The design had been optimized to get a rather short structure with $L_{RFQ} = 3.1$ m with moderate electrode voltages of $U_Q = 70$ kV. The resonant insert has a cooled base plate and solid stems and vane-electrodes. The mechanical design is very stiff, with a precise base-structure. The top lid along the RFQ allows installation, alignment, inspection and maintenance.
After the mechanical alignment of the electrodes the longitudinal electrode voltage distribution will be adjusted with tuning plates between the stems. The properties of the RFQ, the results of the tuning and the status of the project will be discussed.

INTRODUCTION

Availability for beams for high energy heavy ion physics is limited by the properties and performance of the accelerator chain especially the low energy part, where beam intensities and emittances are set.

At RHIC the injector consists of a Tandem whose beam is transported to the AGS. The limitations of that injector, a combination of a dc, low beam current heavy ion machine, a long transport line with a typical pulsed proton high energy machine are obvious. Starting with negative ions, the mass range is also limited.

Plans for a new injector making use of the new developments of ion sources as well as rf-linacs have been discussed for a number of years. Now that modern injector scheme is being set up at BNL, which will lead to more reliable operation and improved capability especially for the RHIC and NSRL programs [1].

The EBIS ion source is perfectly matched to the operation pattern with its pulsed beam of highly charged ions. The RFQ accepts a low energy heavy ion beam, and bunches and accelerates it with high efficiency and low emittance growth [2]. The IH structure has been applied for heavy ion machines e.g. at GSI and CERN which have demonstrated operation with very high gradients resulting in a very efficient compact ion injector for a Synchrotron [3,4].

Figure 1 shows a layout of the new heavy ion injector linac with total length of appr. 12 m, which will provide ions with 2 MeV/u for a mass to charge ratio of up to A/q = 6.25.

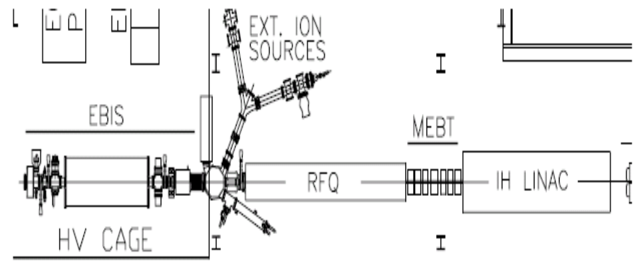

Figure 1: Layout of the EBIS Linac at BNL.

RFQ

The RFQ for the new EBIS-linac at BNL accepts highly charged ions from the EBIS ion source with energy of 17 keV/u and ion currents of up tp 10 mA. The operation frequency will be 100.625 MHz.

Beam Dynamics

The beam dynamics design does an adiabatic variation of the RFQ parameters to shape, bunch and accelerate the beam [5]. We optimized the design to get a rather short structure with $L_{RFQ} = 3.1$ m with moderate electrode voltage of $U_Q = 70$ kV.

Table 1: RFQ Beam Dynamics Design Parameters

Frequency	100.625 MHz
Input energy	17 keV/u
Output energy	0.3 MeV/u
Mass to charge ratio	6.25
Beam current	10 mA
Outp trans. emitt rms norm. 90%	< 0.38 π mm mrad
Output long. emittance 90%	< 220 deg keV/u
Transmission	98%
Electrode voltage	70 kV
RFQ length	3.1 m
Cell number	189
Aperture min - max	2.96-5.25 mm

Results of particle dynamics simulations show the RFQ output transmission and emittances for different beam input emittances and currents show low emittance growth and very high transmission also for I = 10 mA

*Work supported by the US Department of Energy and the National Aeronautic and Space Administration.

Table 2: RFQ Beam Emittances

$\varepsilon_{in}^{trans.,un., real}$ [π mm-rad]	Transm. [%]	$\varepsilon_{out}^{z, rms}$ [MeV-deg] 100%	$\varepsilon_{out}^{xy, rms}$ [π mm mrad] 100/90%
0.05790 I=0	99.2	0.284	0.064 / 0.0271
0.08685 I=10	96.7	0.243	0.09 / 0.038
0.11580 I=0	98.4	0.27	0.126 / 0.053
0.11580 I=10	98.7	0.33	0.15 / 0.060

Beam dynamics simulations have been done with Parmteqm Vers. 3.07. This allows applying a Crandall-Output cell with low divergence of the beam. The final design has good emittances in both axial and radial direction, a very high transmission.

The beam dynamics design is very flexible; it allows rather large variations of the input beam parameters and has good output beam quality.

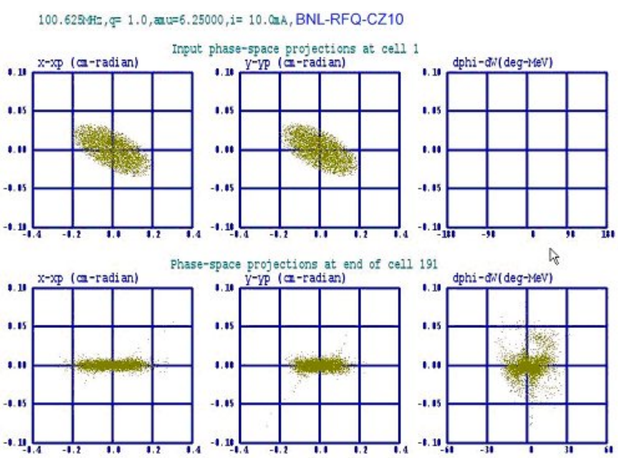

Figure 2: RFQ emittances for I = 10 mA.

4-Rod-RFQ-Structure

The 4-Rod-RFQ consists of a chain of λ/2 resonators which are operated in π-0-mode, to have opposite voltage on the adjacent electrodes and constant voltage along the RFQ. It is possible to describe the basic cell of the 4-Rod-RFQ as a capacitively loaded line, at which the electrodes are the capacity and the stems the inductivity resp. the short line.

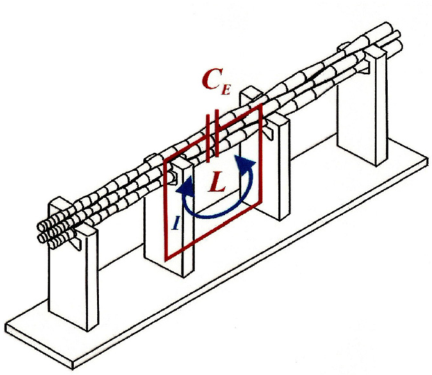

Figure 3: Basic cell of the 4-Rod RFQ structure.

Table 3: 4 Rod Structure Parameters

4-Rod-RFQ	100.625 MHz
Tank diameter	350 mm
Tank length	3100mm
Beam axis height	147 mm
Stem number	20
Stem distance / thickness	158 mm / 10mm
Aperture	5.2-2.96 mm
Modulation factor	1-1.99

Based on MWS-simulations and experimental results of similar RFQs the structure power for the EBIS-RFQ is P_S = 105 kW. Two inductive tuners will perturb the field in the plane between the stems. The 3-1/8" power line will be fed in by a central coupling loop.

The RFQ-cavity is made out of a 5 cm thick wall tube, copper plated, with inner diameter of 350 mm. The resonant insert has a cooled base plate and solid stems and sloped-electrodes. The support stand structure is 70 cm wide and allows horizontal adjustment.

The mechanical design is very stiff, avoids much welding for stress free, precise basic structure and by the use of the top lid allows rather easy installation, alignment, inspection and maintenance.

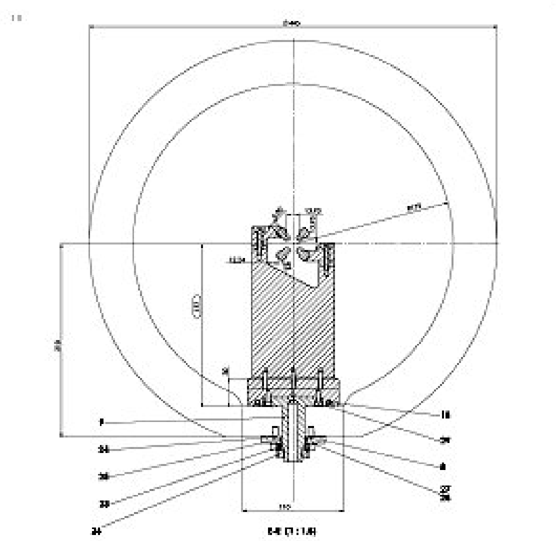

Figure 4: BNL 4-Rod RFQ Cross section.

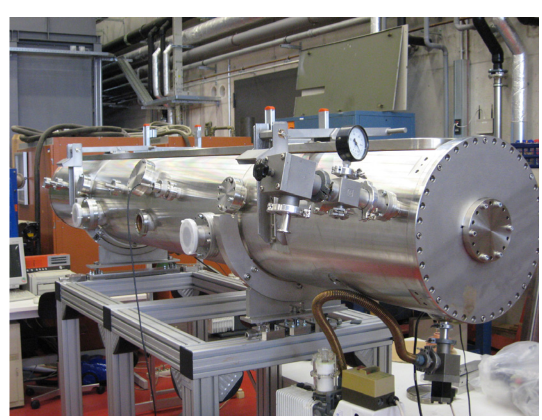

Figure 5: BNL 4-Rod RFQ set up.

Mechanical Alignment and Tuning

The first step for the mechanical alignment is to mount the stems onto the base plate and insert this set-up into the cavity. For alignment in the tank, measurements of the distance between the backsides of the electrode bridge heads and the minima of the aperture are needed. This is done with a Tesla meter in vertical and horizontal plane. Afterwards the electrodes are attached on the stems in the tank. To align them silver plated shims with a size of 4mm up to 6mm are fixed between the electrodes and the stems. They can easily be changed in order to adapt the proper vertical position. To align the electrodes horizontal we can change their position by shifting them. The top flange of the tank serves as reference for these measurements. Our measurement equipment for the alignment in the tank is the FARO Gage plus meter with which we can quantify distances of planes easily. The results of measurement show, that the positions is better than ±0,03 mm.

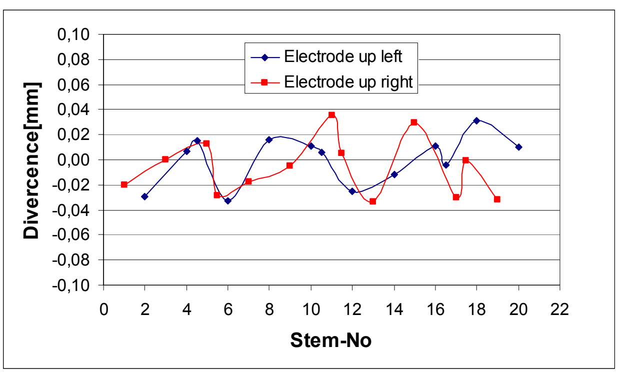

Figure 6: Results of Alignment.

A constant voltage on the electrodes of the RFQ is required for correct operation according to the beam dynamics design. For electrodes with no modulation and constant capacity a simulation of the whole structure was done. In structures with length design of 3,1 meters, the voltage difference from the mean voltage ranges between +11,8 % and -5,4 %. To balance this unflatness, tuning plates are inserted between the stems. They will change the local eigenfrequency of about 15 kHz per mm and correct the voltage differences, what is measured with a network analyzer. So each tuning plate is positioned at an individual height. As results of our tuning the quadrupole voltage (flatness) is better than ± 2 %.

Table 4: Position of Tuningplates in the BNL-RFQ

Cell No.	Height	Cell No.	Height
1	48.4 mm	12	23.3 mm
7	36 mm	13	38.3 mm
8	30 mm	19	44.2 mm

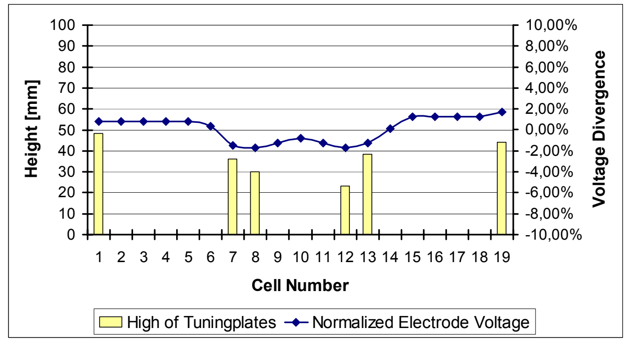

Figure 7: Results of Tuning.

The tuning plates change not only the local eigenfrequency but also the general one. For the precise adjustment of the resonance frequency, two inductive piston tuners are used. They enhance the resonance frequency up to 0.4 MHz dependent to the depth of the tuner.

STATUS

The resonant structure is inserted into the cavity. We have done the alignment with a precede of ±0.03 mm and the flatness is better than ±2 %. Leak tests have been done and the EBIS- RFQ will be prepared for transport to BNL in the week before LINAC 08.

REFERENCES

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