DESIGN AND STATUS OF THE RFQ FOR REX-ISOLDE*

T. Sieber, D. Habs, O. Kester, A. Kolbe, LMU München, Am Coulombwall 1, Garching, Germany
A. Schempp, J.W.Goethe Universität, Robert Mayer-Str. 2-4, Frankfurt/Main, Germany

Abstract

The first module of the REX-ISOLDE-Linac is a 4-Rod-λ/2-RFQ-structure, which is - together with the REX- IH-DTL - built up and tested at Munich.

In this Paper, the electrode design and the mechanical characteristics of the REX-RFQ are presented. Furthermore, the results and the principle of our low-level rf-measurements are discussed, and PARMTEQ-calculations for several measured voltage distributions are shown.

1 INTRODUCTION

At CERN a new concept for the efficient post-acceleration of radioactive ions will be realized with REX-ISOLDE [1]. REX-ISOLDE is a compact experiment, at which neutron-rich isotopes from the online mass separator ISOLDE are firstly accumulated, cooled and bunched in a Penning-Trap, afterwards charge breeded in an Electron-Beam Ion-Source (EBIS) and finally accelerated by a Linac to energies between 0.3 MeV/u and 2.2 MeV/u [2].

The Linac consists of a 4-Rod-RFQ and an Interdigital-H Drift-Tube-accelerator, followed by three seven-gap resonators for energy variation from 1.1 MeV/u to 2.2 MeV/u. The RFQ will accelerate the radioactive ions (design-ion: $^{36}Na^{8+}$) with an A/q of 3 - 4.5 from 5 keV/u to 300 keV/u. The according electrode-voltage is 28 to 42 kV, which will require an rf-power of about 30 to 40 kW. It has a total length of 3 m (18 stems) and operates at a resonant frequency of 101.28 MHz (duty-cycle: 10%).

Table 1: Parameters of the REX-RFQ, theoretical values are marked with ‘*’.

frequency	101.2 [MHz]
Input energy	5 [keV/u]
Final energy*	300 [keV/u]
duty-cycle	10 %
q/A	1/3 - 1/4.5
Electrode voltage	28 – 42 kV
rel. field deviation	≈ 1%
Transmission*	98%
max. input emittance	200 πmmmrad
phase	-90° to –13°
Energy spread*	±1%
Rp (pert.cap.)	171 [kΩm]
Quality-factor Q_0	3894
accelerator cells	233
electrode length	2925 [mm]
tank length	3000 [mm]
tank diameter	320 [mm]
stem height	189 [mm]
number of stems	18

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2 ELECTRODE DESIGN

The calculations for the electrode-design of the REX-RFQ were made with a modified version of the multi- particle code PARMTEQ. For the input, an in both phase planes convergent beam (α=0.66) with emittances of 200 π mmmrad and a distribution with a randomly filled transverse phase-space, uniform phase and no energy spread was assumed. Because of the very low beam-currents at REX-ISOLDE (10000 particles per 100µs-EBIS-pulse), a zero-current electrode design could be generated, which was optimized to a high transmission (98%) and - due to the small longitudinal acceptance of the following IH-0°-synchronous phase structure - small energy spread (±1%).

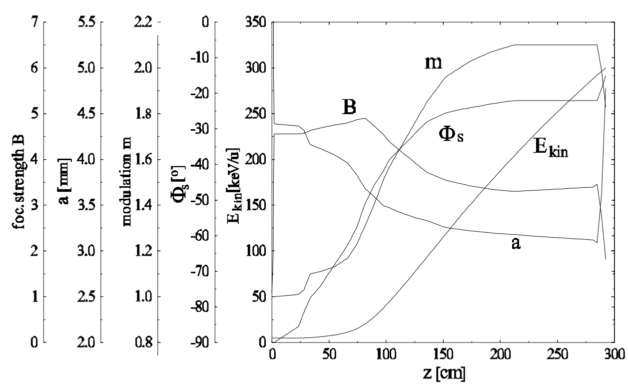

Figure 1: Electrode parameters calculated with the code PARMTEQ.

Figure 1 shows the electrode-parameters charted as a function of the accelerator-length. The strongly reduced focusing strength in the last three cells (which is the result of the increasing aperture: $B \propto 1/a^2$), corresponds to the matching-out section of the RFQ. By decreasing the phase in this section from -22° to -13° the energy spread could be kept constant. The simultaneous reduction of the modulation has simply mechanical reasons. Because of the increased aperture, a continuous modulation would have reached to close to the cooling channel inside the mini-vane profile (see below) of the electrodes.

The matching out section produces a decreased divergence of the output-beam, which reduces the required field strength of the following magnetic quadrupole lenses and avoids particle losses during the beam transport from the RFQ to the IH-structure. Fig. 2 shows the calculated output-emittances with (below) and without (above) matching-out section.

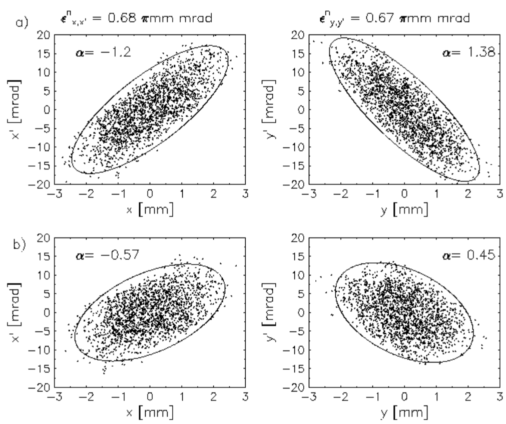

Figure 2: Output-emittances for $\varepsilon_{n,in}$=0.65 π mm mrad.

PARMTEQ calculations with the output emittance of the REX-ISOLDE mass-separator used as input emittance of the RFQ showed, that - due to the large acceptance of the given electrode design - the (in x-direction divergent) beam from the separator is matched and accelerated with the same excellent transmission and energy-spread as the design beam. Figure 3 shows the resulting RFQ-in- and output emittances. The separator output emittances have been calculated to third order with the COSY infinity code for an EBIS emittance of 14 πmmmrad [3].

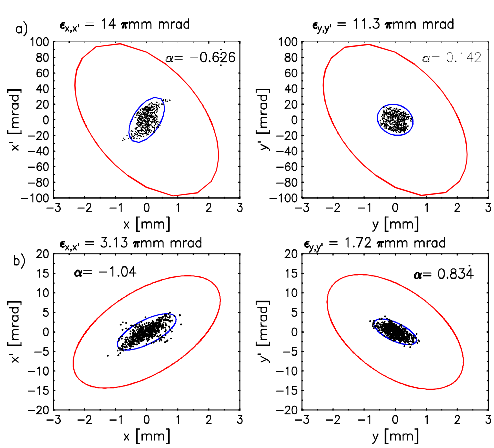

Figure 3: In and output emittances for the design beam (large ellipses) and the separator beam (small ellipses with α and ε specified).

3 MECHANICAL CHARACTERISTICS OF THE RESONATOR

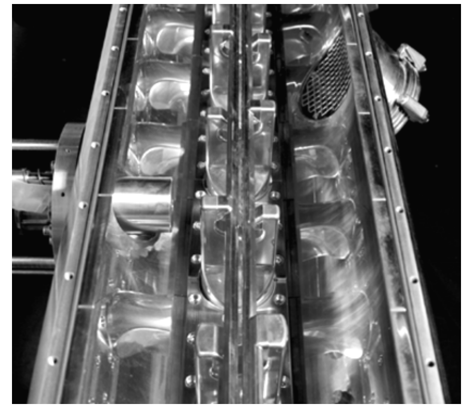

Figure 4: The inside of the RFQ tank (view from the low-energy end).

The resonator of the REX-RFQ is similar to the GSI High Charge-State-Injector- and to the Heidelberg High-Current-Injector-RFQ. Figure 4 shows a photo of the structure. The stems have a total height of 180 mm, the stem-foot (with circular cross-section) has a height of 40 mm, what defines the maximum thickness of the plates for frequency and Flatness tuning. For the quadrupole electrodes so called 'mini-vanes' with a cooling water channel inside (see Fig.6) were used. The mini-vanes allow a very good cooling of the electrodes, what avoids misalignment caused by heating.

The Flatness tuning is done with single plates, which are mounted between neighbouring stems. The plates are contacted to the stems by silver plated springs lying in a groove at the edge of the plates. The advantage of this principle is, that the deformation of the contact springs during operation of the resonator is reversible. Fig. 5 shows a tuning plate and the way it is contacted to the stems.

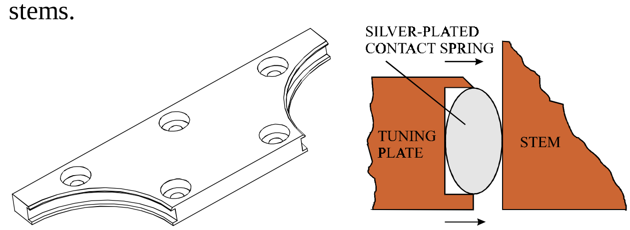

Figure 5: Tuning plate and contacting.

The channels for the water supply of the electrodes are drilled inside of the six waterleading stems. This design, which was developed for the Heidelberg High-Current-Injector-RFQ, avoids the (former used) little tubes on the outside, which turned out to be sensitive to corrosion and mechanical resonances. Figure 6 shows a Pro/E-Plot of a waterleading stem and a cross section of a stem with mounted electrodes. The electrode alignment is (because of the O-Ring between electrode-holder and stem) only possible in the range ±1/10mm horizontally and ±5/10mm vertically.

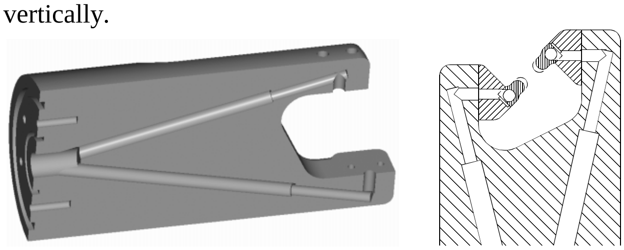

Figure 6: Waterleading-stem used in the REX-RFQ (see also Fig. 4 in the foreground).

4 MEASUREMENT OF THE RF-PARAMETERS

The measurement of the frequency and the quality factor resulted (with a distribution of tuning plates as seen in Fig. 7) in f=101.2 MHZ and Q=3894.

The theoretical description of the RFQ-resonator as a resonant circuit tells us, that the pertubation capacity, which is used for the measurement of the Rp-value must be small in comparison to the rod-capacity (≈190 pF). In this case $Rp=2Q\Delta f/\pi f^2\Delta C$, with ΔC being the pertubation capacity. Only if *all* values in this formula are kept constant, the electrode voltage is (because of the definition of the Rp-value: $U^2=Rp/N$) proportional to the square root of the frequency difference caused by the additional capacity.

To find out the upper limit of usable capacitors, and to investigate wether there is a convergence to the real voltage distribution when steadily smaller capacities are used, we measured the Flatness with three different pertubation capacitors.

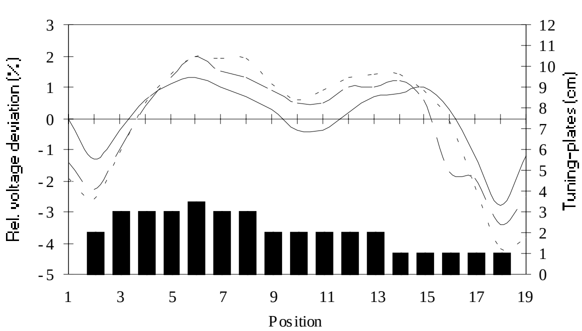

Figure 7: Voltage distribution of the REX-RFQ measured with 1.2pF (solid line), 2.2pF (dashed line) and 3.3pF (dotted line). The bars indicate the thickness of the Tuning-plates.

Figure 7 shows the expected steady increase of the 'Unflatness' at smaller capacitors. With an average Δf of the 1.2 pF measurement, the Rp-value of the REX-RFQ amounts to 171 kΩm.

In this context it is important to mention, that a Flatness and Rp-value measurement with the often used crocodile-clip-capacitor arrangements does not fit exactly to the theory. Because of the arrangement's own capacity (switch etc.), not the real Flatness is measured but the relative difference between f. ex. a 0.5 pF and a 1.2 pF measurement (analogue to Fig. 7). For the determination of the Rp-value this method provides strictly speaking no constant f in the above mentioned formula. The most accurate way of measurement is to contact the smallest available capacitor (≤ 1pF) directly to the electrodes and to determine its capacity as exact as possible (f. ex. with a capacity measurement-bridge).

The measured voltage distributions were used to calculate the influence of the Unflatness on the particle dynamics in the RFQ. Table 2. shows the results of the PARMTEQ-calculations. Note (from Fig. 7), that the maximum field deviation refers only to the end cells! On the average, the field deviation (except for the the untuned measurement) is around ±1%.

Table 2: Transmission and energy-spread for the untuned voltage distribution and for the tuned distri-bution measured with three different capacitors.

	max. field deviation	ΔE (90%)	Trans-mission	x,y-output-emittances ε_n
(untuned)	±20%	5.3%	97.9%	0.648; 0.659
3.3 pF	±2.8%	2.5%	97.3%	0.648; 0.659
2.2 pF	±3.4%	2.52%	97.15%	0.647; 0.658
1.2 pF	±4.2%	2.54%	96.95%	0.651; 0.656

5 PRESENT STATUS

Currently the REX-RFQ is on its test stand at the Munich accelerator lab ready for vacuum testing and final alignment of the electrodes. Two of the three piston tuners have been mounted (see Fig. 4), and provide (from a middle position) a frequency shift of ± 200 kHz. The vacuum test will take place after mounting of a cooled ground plate, which is the last missing component of the resonator. The electrode alignment was measured after mounting in the range of 1/10 mm, With the final alignment after the vacuum test, we want to reach an accuracy of 5/100 mm.

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