THE REX-ISOLDE LINAC

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Abstract

The linear accelerator of the **R**adioactive beam **Ex**periment (REX-ISOLDE) [1] at ISOLDE/CERN is under progress and the first RFQ-structure is ready for some low level tests. The radioactive ions from the online mass separator ISOLDE will be cooled and bunched in a Penning trap, charge breeded in an electron beam ion source (EBIS) and finally accelerated in a short LINAC to a target energy between 0.8 and 2.2 MeV/u. The LINAC consisting of a Radio Frequency Quadrupole (RFQ) accelerator, which accelerates the ions up to 0.3 MeV/u, an interdigital H-type structure (IH) with a final energy between 1.1 and 1.2 MeV/u and three seven gap resonators, which allow a variation of the final beam energy in the range mentioned above [2,3]. In this paper the design of the LINAC, the status of the structures and the beam dynamics are described.

1 INTRODUCTION

REX-ISOLDE is a first generation Radioactive Ion Beam (RIB) project to explore the possibilities of an effective post acceleration of exotic ions due to charge breeding and with dedicated state of the art maschines. The low intensity of the radioactive beams of the rare very neutron rich isotopes (N=20-28) make great demands on the transmission of the REX-ISOLDE LINAC. Hence the structures are optimized to high transmission of about 95% and provide a large transverse acceptance compared to the typical EBIS emittance. To get a high bunching efficiency in the RFQ a rather low injection energy of 5 keV/u has been chosen.

The frame parameters of the LINAC are an operation frequency of 101.28 Mhz which is the half frequency of the CERN proton LINAC II. The timing of the extraction and a repetition rate of up to 50 Hz require a maximum duty cycle of 10%. To be flexible in the kind of experiment and for different ion species the exit energy has to be variable between 0.8 and 2.2 MeV/u. The minimum charge-to-mass ratio of the ions is 1/4.5.

The used structures are a 4-rod RFQ similar to the first RFQ of the Heidelberg high current injector [4] using mini-vanes as electrodes. In addition an IH-structure is used as a booster structure which is a small version of the tank1 of the lead LINAC-IH-structure at CERN [5]. For matching the phase spread of the ion beam out of the RFQ to the longitudinal phase acceptance of the IH-structure a three gap split ring resonator is used. The energy variation is done by three seven-gap spiral resonators similar to the stuctures used at the Heidelberg high current injector [6]. The complete LINAC is shown in Fig.1 including the beam optics and the target region.

More details about the RFQ and the seven-gap resonators are presented elsewhere on this conference.

2 PARTICLE DYNAMICS

The beam dynamics in the structures has been calculated assuming an injection emittance of the RFQ which is typical for electron cyclotron resonance ion sources. The calculated emittances and the acceptances are sumarized in Table 1.

Table 1: Design parameters of the REX-ISOLDE LINAC. The shown entrance emittances are the limits for 95% transmission.

Para-meter	RFQ	Buncher	IH-structure	7-gap resonators
E_{inject} [MeV/u]	0.005	0.3	0.3	1.1-1.2
β_{inject}	0.0033	0.0254	0.0254	0.049-0.051
E_{exit} [MeV/u]	0.3	0.3	1.1-1.2	0.85-2.2
β_{exit}	0.0254	0.0254	0.049-0.051	0.043-0.069
$\varepsilon_{xx'}$, ε^n [πmmmrad]	200 (0.66)	---	25.3 (0.643)	21 (1.03)
$\varepsilon_{yy'}$, ε^n [πmmmrad]	200 (0.66)	---	25 (0.636)	52 (2.55)
Q	3400	3500	8500	5370
R_p, Z_{max}	120 kΩm	4.5 MΩ/m	197 MΩ/m	58 MΩ/m
U_{max}	42 kV	50 kV	5.04 MV	1.75 MV

The values of the quality factor Q and of the shunt impedance Z are derived from model measurements which have been done for the buncher, the IH-structure and the 7-gap resonators. Due to the fact that the mass separator between the EBIS [7] and the RFQ can not handle such an emittance with the required resolution the whole system has been calculated with a realistic EBIS extraction emittance of 7.5 π mm mrad (0.0246 π mm mrad normalized). Some beam calculations of the different section will be shown now.

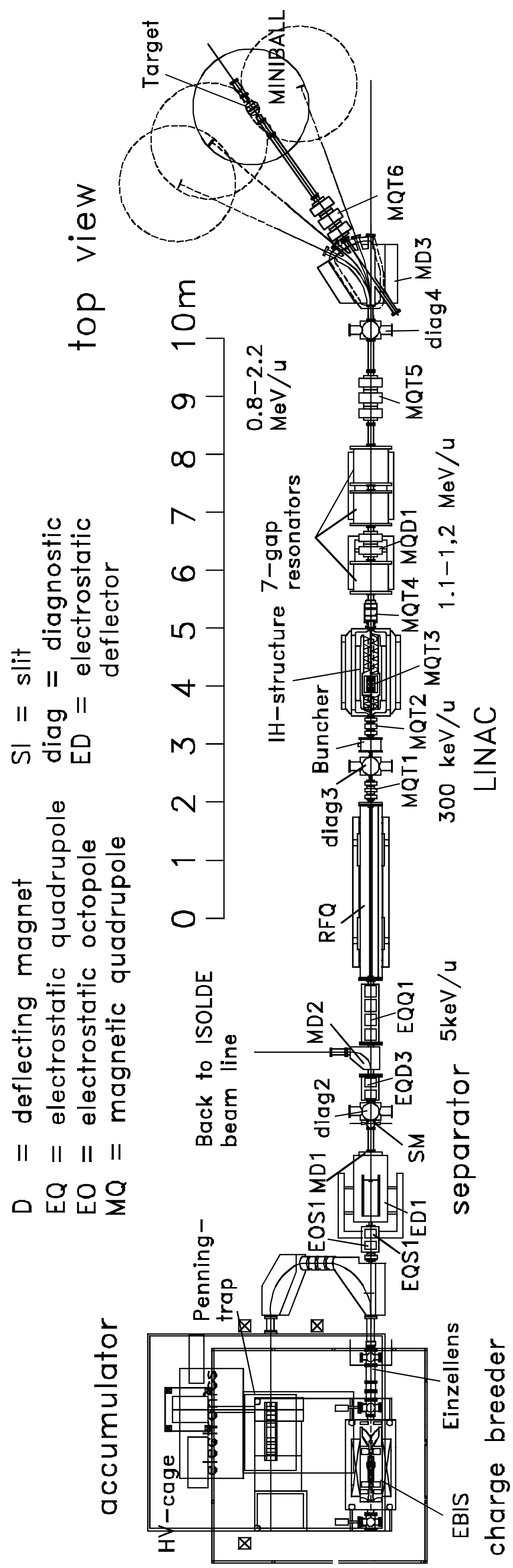

Figure 1: Layout of the REX-LINAC.

2.1 *Calculations for 0.8 and 2.2 MeV/u*

For all beam calculations of the LINAC the phase spaces of the beam out of the RFQ are of interest. Fig.2 shows the x and y phase spaces at the RFQ entrance and exit if a realistic beam from the mass separator is injected.

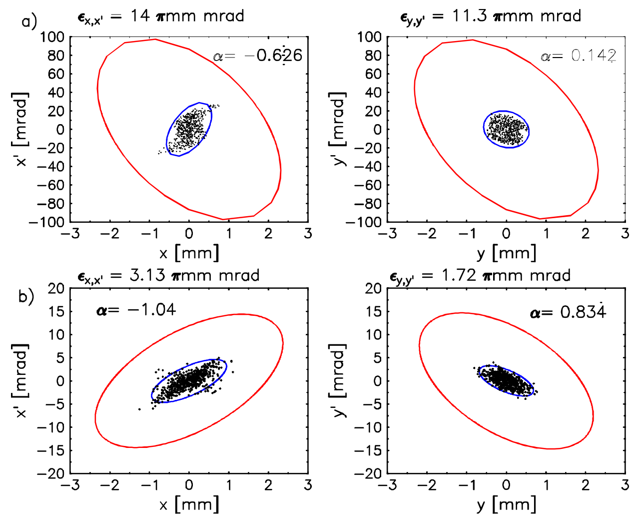

Figure 2: Emittances at the entrance and at the exit of the REX-ISOLDE-RFQ concerning a real beam from the mass separator. The emittances given in Table 1 are the larger ellipses. The emittance values in the graphic are represented by the small beam ellipses.

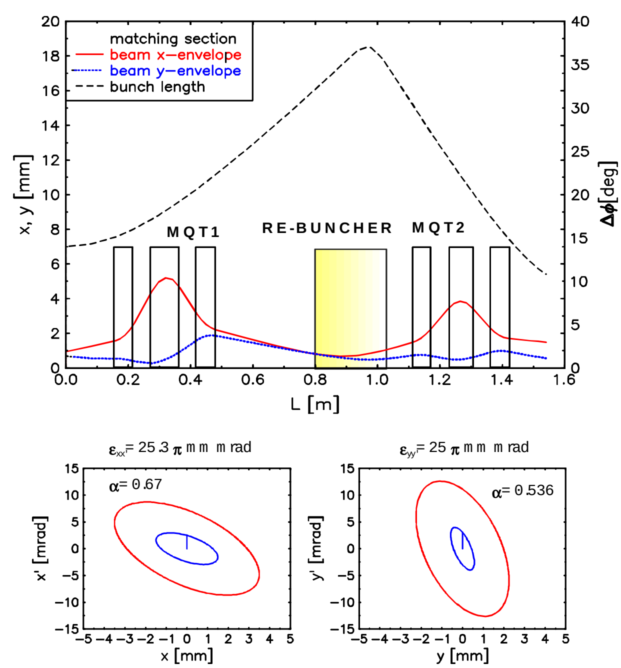

Figure 3: Calculation of the matching section between the RFQ and the IH-structure. The transverse emittances of the real beam are in comparison to the design emittances at the entrance of the IH-structure.

The ray tracing in the RFQ has been calculated with PARMTEQ. The results show that the aberrations from the mass separator optic does not influence the transmission of the RFQ. The comparison of a realistic beam with the design beam in Fig.2 and 3 shows that a high transmission of the whole LINAC is given due to the fact that only a small part of the design phase space is filled. In Fig. 3 the matching of the RFQ beam to the transverse and longitudinal phase space of the IH-structure is calculated with TRANSPORT to the third order. Fig. 3 shows obviously the good matching of the transverse phase spaces of the real beam and the design injection phase space.

2.2 Experiments with 0.3 MeV/u beams

For some experiments the energy of the ion beam coming out of the RFQ is of interest. For these reasons a ray tracing of the 300 keV/u beam through the other cavities and the beam line to the target is of interest. Fig.3 shows the calculations of the beam transfer with the COSY infinity code [8] in third order. The problem is to reach a small spot size at the target and a small beam slope, because at this low energy the beam angles are much more bigger than in case of the dedicated energies of more than 0.85 MeV/u.

Using the emittances shown in Fig.2, the calculations with COSY in third order give a final round spot with an radius of 1.7 mm. Thus fullfilling the requirements of small slopes and small spot sizes at the target for energies of about 300 keV/u. The beam at the target is slightly diverging with a maximum slope of about 2 mrad.

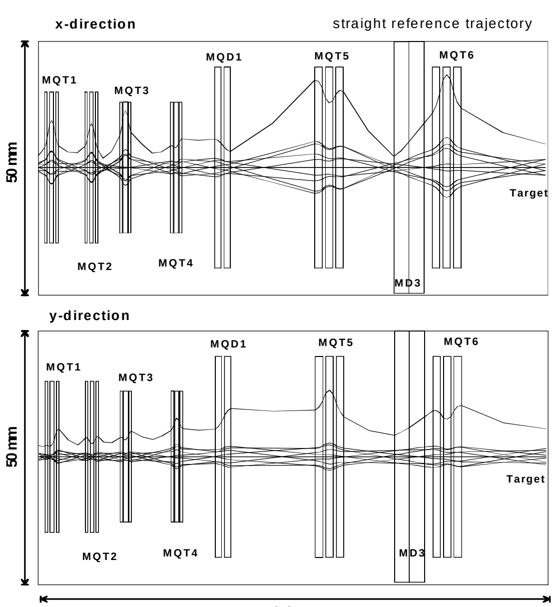

Figure 4: Calculation of the beam transport of a 300 keV/u beam out of the RFQ to the target of REX-ISOLDE concerning the exit emittances from the RFQ.

3 STATUS OF THE STRUCTURES

The built up of the REX-RFQ is almost completed. The rods and the stems are present, the plungers are assembled, the vacuum system and all components of the cooling system are delivered. The last missing parts are the water cooled ground plates, which will be ready in the beginning of June [9]. First low level measurements have been performed and an injection beam line is build up consisting of a duoplasmatron ion source, the prototype of the REX-ISOLDE diagnostic box and an electrostatic quadruplet quadrupole lens. After additional low level measurements and vacuum tests of the RFQ vacuum tank, power tests and beam tests are foreseen with 1 μA He^{1+}-ions. An emittance measurement system using the slit grid method is in production to measure the transverse phase space of the injected beam and the exit beam of the RFQ. This system is flexible in a large range of current and particle energy, so that measurements with beams extracted out of the EBIS can be performed as well as measurements at the final energy of the LINAC with a resolution of 5%. The re-buncher is in production at the university of Frankfurt. The buncher will be included in the test beam line when the measurements with the RFQ have been completed. The vacuum tank of the IH-structure is in production and the frequency measurements which determine the final half shell size are just finished. The tank will be copper plated and then delivered in October. The inner tank triplet quadrupole lens is in production and will be delivered in August. The stems and the drift tubes are produced, the vacuum systems is delivered. The 7-gap resonators are developed and built at the MPI für Kernphysik in Heidelberg. The vacuum tanks of the 7-gap resonators and the spirals of the resonant structures are completed [10]. First low level measurements will be done in August and first power and beam tests at the Heidelberg tandem accelerator are foreseen at the end of September.

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