A NEW KIND OF EXTRACTION SYSTEM FOR A HIGH PERFORMANCE ECR ION SOURCE: A SHORT RFQ CHANNEL

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Abstract

Extraction systems typical of ECR ion sources are in general consisting of cylindrical electrodes used for extraction and focusing of beams. However, at low energies (10 kV to 30 kV) and intense beam currents (~ 10 mA), the focusing properties of these lenses are questionable and generally cannot be used due to various problems which causes downtimes for the source operation. An alternate and better option is use of a short RFQ channel coupled directly to the source to focus and accelerate these intense beams. Typical lengths of a short RFQ is ~ 0.5 m operating at 48.5 Mhz. For the heaviest ions, the beam blow up inside the RFQ is limited to within an average radius of 5 mm for a beam current of 1 mA. In order to limit the losses for a total beam current of 10 mA, the average radius should be increased to 8 mm. The closest distance of approach between the ECR source and the RFQ dictates a tolerable electric field of 35 kV/cm. The details of the coupling of the ECR source with the RFQ channel, simulations and applications will be discussed in detail.

INTRODUCTION

Today, high performance ECR ion sources are being operated at much higher frequencies, for ex., 28 GHz and therefore with higher plasma densities. Extraction systems coupled with these ECR ion sources face problems to extract intense beams of highly charged ions due to higher plasma densities and larger emittances. Various kinds of extraction systems are being used which utilise an accel-decel mode combination of lenses to extract and transport intense beams of highly charged ions. These kind of electrostatic extraction systems generally fail due to high voltage sparks and/or due to beam loading which eventually stops the ion source from smooth functioning and downtime of the accelerator. In order to circumvent this problem, an elegant solution is to couple a short radio frequency quadrupole accelerator directly to the ion source. The advantage is that the short RFQ channel can transport very intense beams without any problem to the downstream accelerators and at the same time accelerate to higher energies thereby avoiding the space charge blow-up effects normally encountered with electrostatic systems.

DESCRIPTION

In the past, a few accelerators have utilised the coupling of an RFQ to laser ion sources and this technique has been called the direct plasma injection scheme (DPIS). In

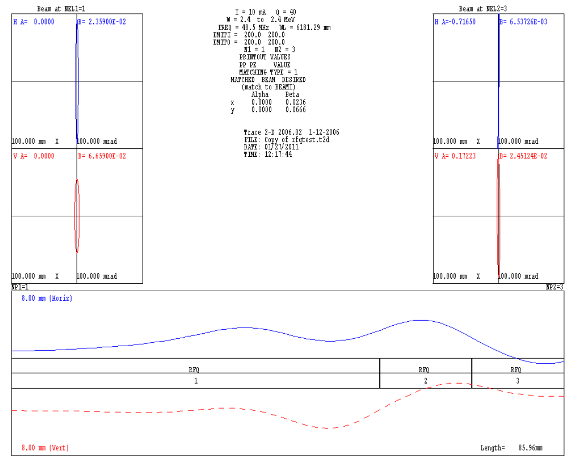

Figure 1: Optics in the radial matching section of the RFQ for a typical heavy ion, intense beam.

this case, the plasma expands to the entrance of the RFQ where the electrons get deflected in the fringe field of the RFQ and only the ions get trapped by the RFQ focussing force. Therefore space charge effects are completely ignored and has a great advantage to transport very intense beams. Some of the laser ion sources use an electrostatic or magnetic lens between the ion source and the RFQ. We propose to directly couple a typical high performance ECR ion source to the RFQ (using a short RFQ channel) entrance flange to minimise aberrations during the beam formation. Due to the space charge effects at very low energies and relatively higher beam currents, the ECR ion source is typically polarised to 60 kV to initially overcome the defocusing forces. Simulations using the TRACE 3D codes show that by directly coupling the RFQ to the exit of the ECR ion source, beam currents of the order of 10 mA can be accelerated, focussed and transported by a short RFQ channel to the downstream accelerators and further manipulation on the beam can be easily carried out. In this design, typical operating frequencies of 48.5 MHz was chosen to minimise the length of the structure and power requirements. The simulation of the beam optics of the heaviest beam U^{40+} with a typical beam current of 1 mA requires an average radius of 5mm ; for a typical beam current of 10 mA, the average radius needs to be increased to 8 mm and is shown in figure 1 & 2. Typical design parameters of a short RFQ channel is shown in table 1 and gives an idea of a possible structure which can be fabricated and used as an extraction system for a high performance ECR ion source and thereby minimising the cost of fabrication of this structure.

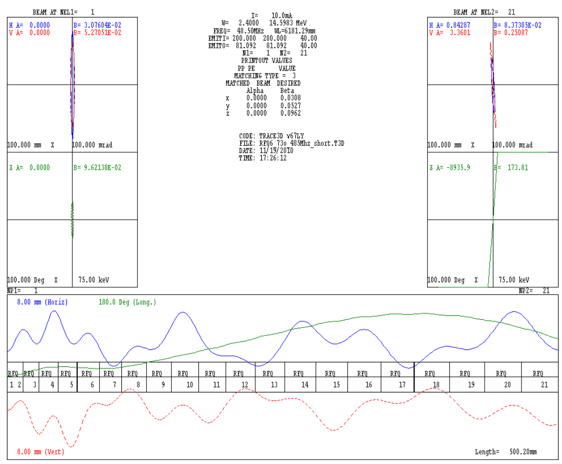

Figure 2: Transverse and longitudinal optics for a short RFQ channel for a typical heavy ion, intense beam

Table 1.Design parameters of a short RFQ channel

Operating frequency	48.5 Mhz
Injection beam energy	10.084 kev/u
Design Ion (A/q ~ 6)	$^{238}U^{40+}$
Design beam current	10 mA
Input beam emittance	200 π mm mrad
Final beam energy	61.26 kev/u
Total length	0.5 m
Average radius	8 mm
Intervane potential	25 kV
Final RMS emittance	4.173 cm mrad

The simulations using TRACE 3D gives a first order design optimization. A ray-tracing simulation using IGUN can further elucidate the design especially in the extraction region of the ECR ion source and in the radial matching section of the RFQ. The IGUN code can handle the rf focussing of the non modulated part of the RFQ and can also handle the DC fields in the injection region of the RFQ. Figure 3 shows the detailed view of the beam trajectories in the extraction region between the ECR ion source and the radial matching section of the RFQ. Due to the weak electric field between the ion source and RFQ, the beam emerges parallel at the entrance of the RFQ. The closest distance of approach dictates a tolerable electric field of 35 kV/cm. An additional magnetic focussing element can further focus the beam into the RFQ. The emittance diagram (shown in figure 4.) close to the radial matching section of the RFQ shows a slightly distorted shape of the emittance ellipse indicating small aberrations which are mostly at the tail end. These aberrations could worsen when an additional focussing element is used before injection into the RFQ. Therefore, a judicious use of a focussing element may be required depending upon the beam requirements.

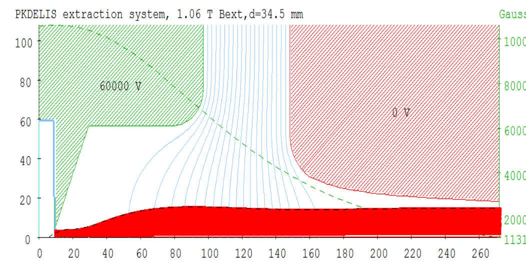

Figure 3: Beam trajectories emerging from ECR ion source and entering the radial matching section of the RFQ.

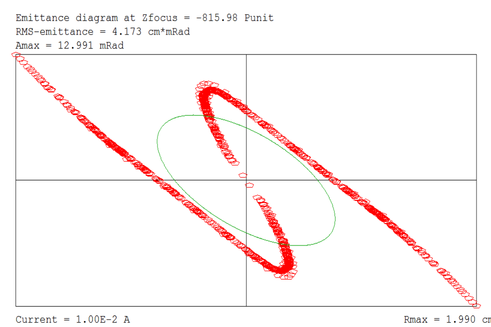

Figure 4: Emittance diagram close to the radial matching section of the RFQ.

CONCLUSIONS

It is shown that a highly performing ECR ion source can be efficiently coupled to a short RFQ channel to transport intense beams of highly charged ions without any problem of space charge beam blow-up and/or sparking problems in the extraction region. It is more economical to fabricate a short RFQ channel for further acceleration.

REFERENCES

[1] R.Becker, Proceedings of EPAC 1992, Berlin