HALF END-CELL GEOMETRY OF RFQ

Yoshihisa Iwashita and Hiroshi Fujisawa*
Accelerator Laboratory, Institute for Chemical Research, Kyoto University,
Gokanosho, Uji-shi, Kyoto-fu 611 Japan
*Nissin Electric Co., Ltd.
575 Kuze Tonoshiro-cho, Minami-ku, Kyoto-shi 601 Japan

Abstract

Half end-cell geometry of RFQ is suggested by showing the results of modified-PARMTEQ runs. In a particular example of the 33.3 MHz heavy ion RFQ, we have found that at the $10/16^{th}$ of the exit cell of the RFQ the beam phase-space parameter α becomes small and nearly identical in x-xp and y-yp plane.

Introduction

Since RFQ is considered to be a periodic focusing and defocusing acceleration structure, the beam phase-space ellipse at the end of each cell - especially in the acceleration section - exhibits focusing and defocusing characteristics which alternate in two orthogonal transverse coordinates as the beam accelerates through the RFQ cells. In some application, this characteristic is not desirable and more symmetric and less divergent beam - in transverse plane - is preferable for both economical and ion optical reasons. We sought such possibility using a PARMTEQ code which is partially modified for the present purpose [1]. The results of computer simulations and the applications of the half end-cell geometry of the RFQ are summarized in this brief report.

Table 1 Key parameters of the 33.3 MHz RFQ.

Frequency	33.3 MHz
Average bore radius	0.8 cm
Focusing strength	6.79
Inter-electrode voltage	54.9 kV
Charge to mass ratio	1/11 ~ 1/16
Injection energy	2.73 keV/u
Output energy	83.5 keV/u
Length of electrode	222 cm
Number of cells	93
Cavity diameter	60 cm

PARMTEQ Simulation

An added feature to PARMTEQ is called upon a new label HALFCELL. A number following after this label lets the code knows how many segments beam dynamics calculations are to be done for the last cell of the RFQ linac. By default one cell of RFQ is divided in 8 segments so that when one wants to simulate the half end-cell of an RFQ linac, he or she has to put 4 after the label HALFCELL. Simulation studies are done using the parameters of the 33.3 MHz RFQ which is designed for accelerating a heavy ion beam [2].

Key Parameters of the 33.3 MHz RFQ is listed in table 1. Figure 1 depicts a situation of an RFQ cell divided in 8 segments. Figures 2 and 3 show the plots of calculated beam phase-space parameters α and β as a function of number of segments in the last cell - the 93^{rd} cell - of the RFQ. Note that the beam parameter α is almost identical in x-xp and y-yp phase-space at the end of 10^{th} segment. In the calculations, one cell is divided in 16 segments and included no space-charge forces. The important parameters used in the simulation runs of the half end-cell geometry of the 33.3 MHz RFQ are listed in table 2.

Table 2 Important input parameters used in the modified PARMTEQ simulation runs of the half end-cell geometry of the 33.3 MHz RFQ.

Normalized emittance, x-xp	0.7 π mm-mrad
Normalized emittance, y-yp	0.7 π mm-mrad
Space-charge force	Not included
Inter-electrode voltage	54.9 kV
Number of segments in a cell	16
Number of particles followed	500
Ion species	$11B^{+}$

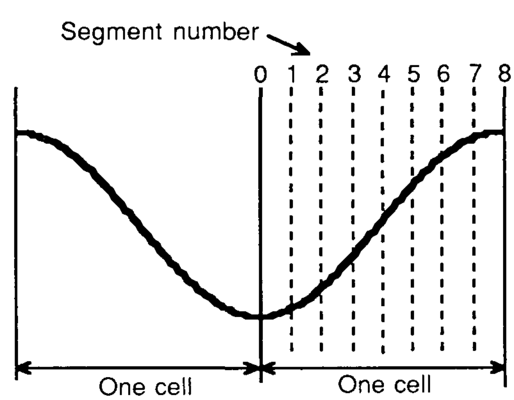

Fig.1 A schematic drawing showing a longitudinal profile of two RFQ cells. One cell is divided in 8 segments.

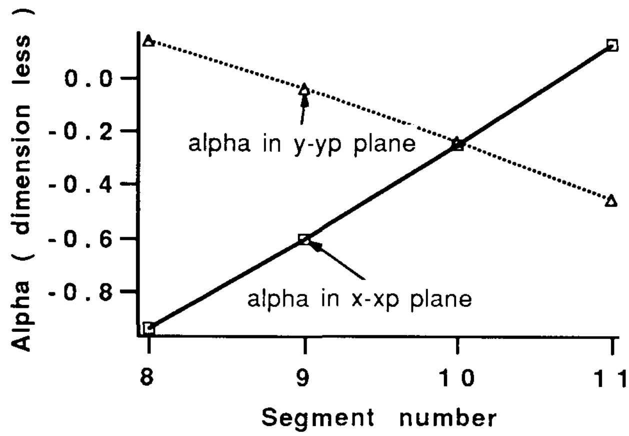

Fig.2 Plots of calculated beam phase-space parameter α at the end of segment as a function of segment number at the 93rd cell of the 33.3 MHz RFQ. The parameter is computed from 90 % of transmitted particles.

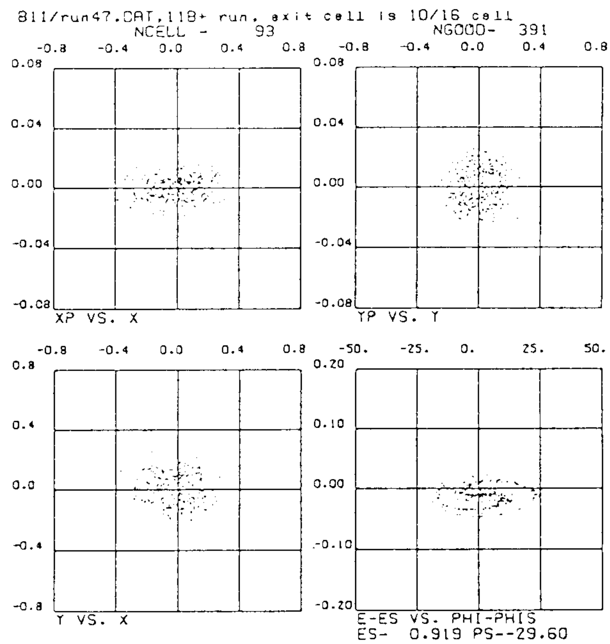

Fig. 4 A calculated beam phase-plot at the 10/16th cell of the 93rd cell of the 33.3 MHz RFQ.

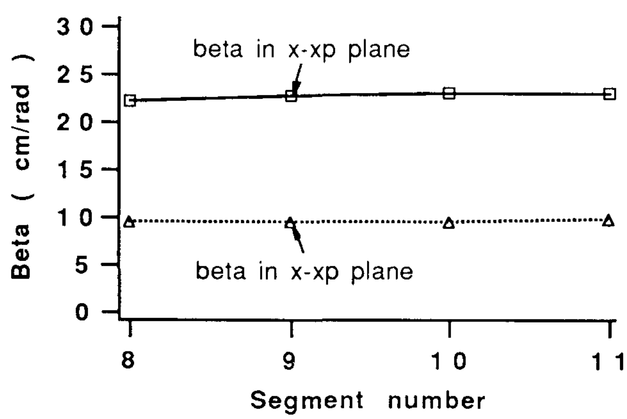

Fig.3 Plots of calculated beam phase-space parameter β at the end of segment as a function of segment number at the 93rd cell of the 33.3 MHz RFQ. The parameter is computed from 90 % of transmitted particles.

Figure 4 is the calculated phase-space plots at the end of 10th segment of the 93rd cell of the 33.3 MHz RFQ, where the beam parameter α is approximately identical in x-xp and y-yp phase-spaces.

Applications

The idea of the half end-cell geometry would be used in a variety of applications where symmetric and less divergent beam is required. The application is also found in simultaneous positive and negative ion acceleration since the beam phase-space depends only on the RFQ exit geometry but not on the charge polarity of a beam. Let us describe such applications in more details.

Descriptions

There is a situation where the orientation of RFQ electrodes is rotated by 45° with respect to the horizontal plane for some mechanical requirements. When the field of a dipole magnet is set either in the horizontal or in the vertical directions, the output beam from such an RFQ should be properly transformed to that of the dipole magnet if one is to avoid any extra emittance growth that occurs in the magnet. This problem can be removed by using the proposed half end-cell because the output beam from the RFQ becomes symmetric: thus no coordinate transformation is necessary.

The output beam from an RFQ is usually focused by magnetostatic or electrostatic Q-lenses. Whether an ion beam diverges or converges after going through such lenses depends on the charge polarity of a beam. In simultaneous acceleration of positive and negative charged particles, this property presents some difficulties in output beam matching design without rf Q-lenses. Thus by applying the proposed half end-cell, we can expect that a matching between an RFQ and a DTL will become much easier. For instance, a symmetric beam of either charge polarity can be readily matched by static Q-lenses to a DTL - with the focusing Q-lenses in its drift tubes - even when the azimuthal orientation of the static Q-lenses is different from that of the RFQ.

An Example

We are going to show one of the examples of the half end-cell : the 33.3 MHz RFQ with $10/16^{th}$ end-cell is followed by a 200 mm drift space and a two-gap rf accelerator [3]. The width of the two-gap resonator is 120 mm and the gap to gap separation is 54 mm. A schematic layout of the RFQ and the post-accelerator system is shown in fig. 5. No matching element is used in the transport line. A TRACE 3-D result of the beam optics calculation is shown in fig. 6 where 80 keV/gap energy gain is allowed in the calculation [4]. The input beam parameters in the optics calculations are the same as those shown in the PARMTEQ Simulation section.

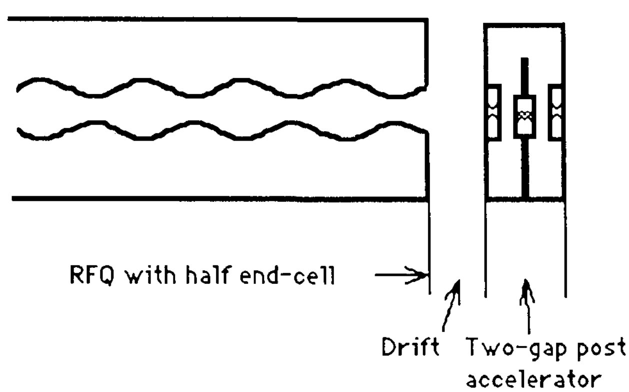

Fig. 5 A schematic drawing of the 33.3 MHz RFQ with half end-cell and a two-gap rf post-accelerator.

Concluding Remarks

As far as the beam parameter β is concerned, the output beam becomes symmetric in x-xp and y-yp planes at the $10/16^{th}$ of the exit cell of the RFQ; not exactly half of the exit-cell. So we may generalize the idea of the half end-cell to a use of any arbitrary number of segments to get prescribed phase-space profiles in the two transverse planes. In addition, we can include the other parameters - possibly the aperture radii of the exit end of an half end-cell - to be varied along with the number of segments in the computations so that we may obtain a truly symmetric beam with respect to both α and β.

To understand more about the RFQ half end-cell geometry, detailed fringing field calculations are going to be followed after this simulation works. Experimental confirmation is also planned in the near future.

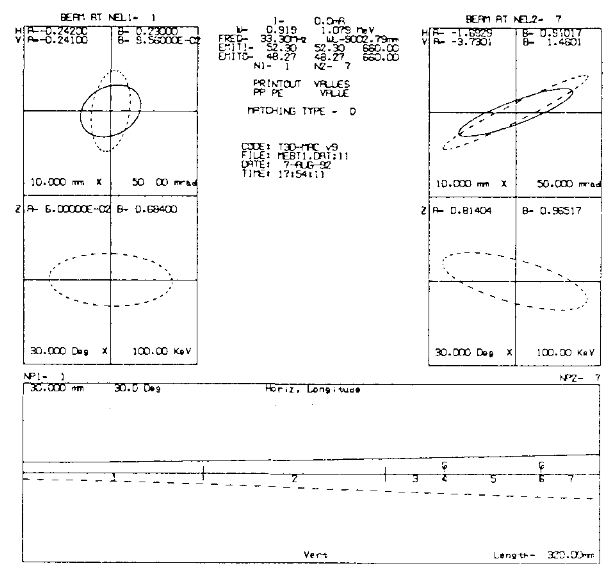

Fig. 6 A TRACE 3-D result of a matching section between an $10/16^{th}$ exit-cell of the 33.3 MHz RFQ and a two gap rf post-accelerator.

References

[1] K.R. Crandall, R.H. Stokes, and T.P. Wangler, "RF QUADRUPOLE BEAM DYNAMICS DESIGN STUDIES", BNL 51134, P.205-216 (1979).
[2] H. Fujisawa, et al, "RF CHARACTRISTIS OF THE 33.3 MHZ 4-ROD RFQ", this conference.
[3] H. Fujisawa, et al, "DESIGN STUDY OF A HEAVY ION RFQ LINAC FOR MeV IMPLANTER", Proc. of 1990 Linac Conference, LA-12004-C, p.241-243 (1991).
[4] K.R. Crandall , revised by D.P. Rusthoi, "TRACE 3-D Documentation", Second Edition , LA-UR-90-4146 (1987).