AN ISOPATH ACHROMATIC BENDING SECTION FOR MULTI-CHARGE ION BEAM TRANSPORT AT ISAC-II

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Abstract

The ISAC-II post accelerator at TRIUMF has been optimized to allow the simultaneous acceleration of ions with multiple charge states after stripping in order to preserve beam intensity of the exotic species. Bending sections required to provide charge selection, fit building layout or to transport beam to the experimental station, are constrained to have equal path length (isohodous condition) for all charge states to maintain bunch structure. In addition they have to maintain a high order of achromaticity to prevent transverse emittance growth. An isopath system of four optics cells with proper symmetry conditions will fulfill the achromaticity condition to higher order. In the case of very low beam intensities such as for radioactive beams in which small losses are still acceptable, it is convenient to consider a system with only two cells, which don't give the exact solution, but still maintain a reasonable beam quality. We present here a first design result for a two cell system applied to the ISAC-II case in which the range of charges transported is $\pm$5% from the reference one.

1 INTRODUCTION

One of the most important features of the ISAC-II superconducting accelerator is the compatibility of multi charge acceleration [1] which allows the preservation of beam intensity after stripping, mostly at expense of longitudinal beam quality. Hence the acceleration cost can be reduced without compromising the beam intensity that is vital for RIB facilities. With such a feature the 90 degrees bending section after the first stripping stage planned for the ISAC-II accelerator has to be designed to be multicharge compatible. This means that beyond the achromat condition this section has to provide the same path length for different charges, so they arrive at the re-bunching position at the same time. The intrinsic difficulty in this kind of problem is the large chromaticity due to the different charges that make the matching to the following section difficult. A second order solution or higher is required in order to optimize the matching and hence minimize emittance growth along the rest of the accelerator.

1.1 The Isohodous section

The isohodous condition requires that all charges have the same path length. A small reverse bend dipole is employed to provide a negative path difference dispersion which is canceled by the path difference in the main dipole. The beam design parameters for the dipoles are listed in Table 1. The calculations were performed with the code COSY INFINITY [2].

Table 1: Beam design parameters

Reference A/q	10
Energy	400 keV/u
Transverse norm. emittance	0.2π mmmrad
Longitudinal emittance	2π keV/u ns

2 FOUR CELL SYSTEM

A common approach [3] to the problem of high order achromaticity uses symmetries. In this way all the properties of a complex system can be deduced by the properties of the single cell which constitutes the basic block of the system. In general each cell could have four symmetries: Forward (normal order, right hand), Reverse (reverse order, right hand), Switch (reverse order, left hand) and Combined (normal order, left hand). From the theory [4] the minimum number of cells required to achieve a high order achromat system is four, which means that a 90 degrees section will be composed of F,R,F,R cells where each of them has to provide a 22.5 degree bending angle.

A solution for a four cell system was obtained. Table 2 lists some of the parameters used. Cancellation of high order terms was achieved but costs and size of the system were thought be too high for the ISAC-II project. It was then decided to look into a 2 cell solution which is still a good approximation and a good compromise for low intensity beams.

Table 2: Elements in a four cell high order achromat

Element	**Num.**
Reverse dipole	4
Main dipole	4
Quadrupole	22
Sextupole	10

3 TWO CELL SYSTEM

The two cell system consists of a forward cell which has a net bending angle of 45 degrees and a reverse cell, which has the same elements as in the forward one, only reversed order. Fig. 1 shows the low energy transport section which focuses the beam in the stripping foil and then through the Isohodous achromat section that selects the charge states and injects the stripped beam into the superconducting accelerator.

The choice of the bending angle for the reverse dipole and the main one were done in order to have a small dis-

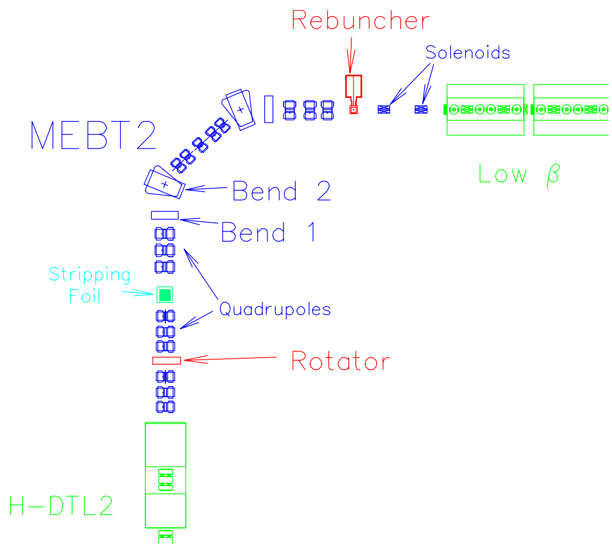

Figure 1: Schematics of the low energy transport section for ISAC-II. The figure shows the optics that transport and focus the beam up to the stripping foil, the isohodous section which select the ions with different charge states before being injected into the superconducting accelerator.

persion in the center region in order to reduce apertures of the optical elements and hence avoid non linear effects and reduce quadrupole cost. The dispersion calculated at the mirror plane is 5mm/% of different charge. The maximum dipersion is in the middle of the second quadrupole after the main bender and correspond to 8mm/% of $\Delta Q/Q$. For a $\pm 5\%$ of charge difference the full aperture of the quadrupoles in the dispersive region has to be bigger than 8cm.

Table 3 lists the optic parameters used in the forward cell.

The achromaticity condition to first order is achieved by fitting 6 quadrupoles so that at the symmetry plane the element of the transport matrix are D' = 0 and R11 = R22 = R33 = R44 = 0. This condition produces a unit matrix to the first order.

In order to compensate the second order terms it is necessary to superimpose sextupole fields in the quadrupoles in the dispersion region and to add a pure sextupole magnet between the reverse dipole and the main one.

The basic cell result then to be as follows: Q-Q-Q-D-S-D-QS-QS-QS where Q represent pure quadrupole, D are the rectangular dipoles, S is pure sextupole and QS are quads with sextupole coils inside.

A calculation of the matrix to second order was done and applied to beam ellipses in order to understand the effect of the chromaticity. The plots in Fig. 2 show the behaviour of the different charge states, so for example in the horizontal plane the non reference charges have a net divergence while in the vertical plane the higher charges are overfocused while the lower are not completely focussed.

As one can see the compensation is not perfect, in fact

Table 3: Optic parameters for the first half of the mirror symmetric iso-path for the design particle A/Q = 10, E = 400keV/u

Element	Length (mm)	Strength (T/m)
Drift	400	
Quadrupole	180	-6.008
Drift	300	
Quadrupole	180	8.042
Drift	300	
Quadrupole	180	-2.304
Drift	300	
Bend entr. angle	$\beta = 0°$	
Bend	R=-1000, g=60	$\theta = 5°$
Bend exit angle	$\beta = 5°$	
Drift	250	
Sextupole	100	0.02 T
Drift	250	
Bend entr. angle	$\beta = 25°$	
Bend	R=695.18, g=60	$\theta = 50°$
Bend exit angle	$\beta = 25°$	
Drift	300	
Quadrupole	180	2.99
Drift	300	
Quadrupole	180	8.082
Drift	300	
Quadrupole	90	-11.412

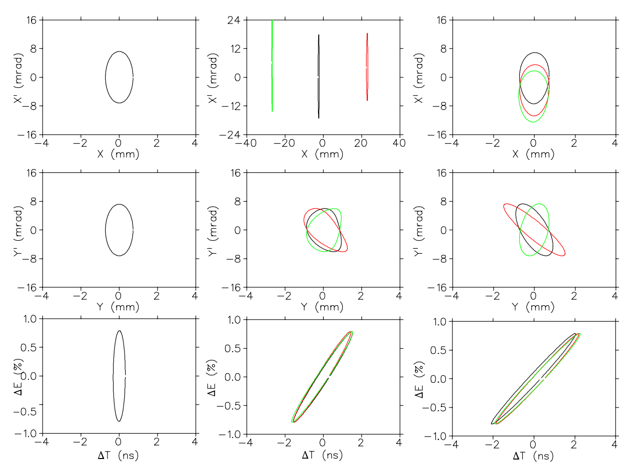

Figure 2: Beam ellipses for horizontal (top), vertical (middle) and longitudinal (bottom) planes for three charge states, $\Delta Q/Q$ = 0, +5%, -5% (black, red, green), at the stripping foil (left), mid-point (middle) and end(right) of the charge selection iso-path section.

at the end of the section the different charges have different Twiss parameters which means that the following section inherits a mismatched beam which can produce emittance growth.

This solution was tested also with the Monte-Carlo second order code LANA [5]. Fig. 4 shows the phase space

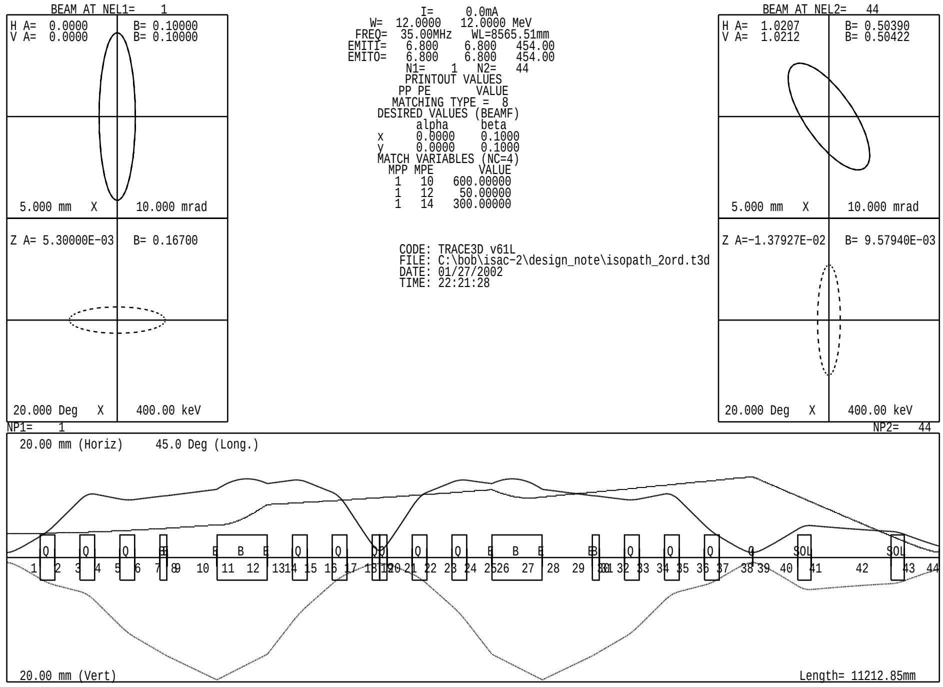

Figure 3: Beam envelopes for the iso-path transport bend section.

portrait in the dispersion plane in the center point of the system for ±10% of ΔQ/Q.

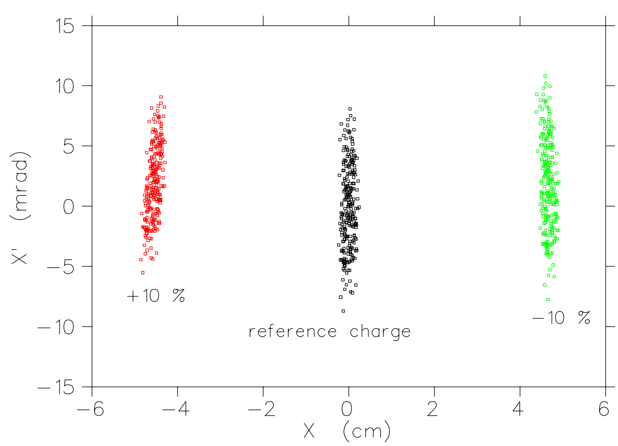

Figure 4: Phase space portrait of the dispersion plane at the center of the section for ±10% ΔQ/Q.

This section works also for a single charge state beam, and in this case the first order optics gives a completely symmetric system. In Fig. 3 are shown the beam envelopes with an initial Twiss parameters of $\alpha_{x,y} = 0$ and $\beta_{x,y} =$ 0.1mm/mrad.

4 CONCLUSION

High intensity driver linacs such as RIA that take advantage of multi charge acceleration will require isohodous transition sections corrected to high order. Conversely low intensity applications such as post acccelerators for RIBs where small losses are still acceptable, can utilize two cell systems that give a good compromise between cost and beam quality assuming the downstream linac has sufficient acceptance of mismatch.

5 REFERENCES

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