# STUDY OF SIMULTANEOUS ACCELERATION OF TWO BEAMS WITH OPPOSITELY CHARGED IONS

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## INTRODUCTION

The present work is devoted to the investigation of the simultaneous acceleration of oppositely charged beams in RFQ accelerator. It is obvious, that the accelerating and focusing channel with periodical quadrupole varying-sign focusing allows to accelerate oppositely charged ion beams with the same charge to mass ratio. In this case the centers of the bunched oppositely charged beams will be separated in phase by interval of 180° and the transverse phase portraits of the beams will be similar (phase portrait of positively charged beam in (x, $v_x$) plane will coincide with the phase portrait of negatively charged beam in (y, $v_y$) plane and vice versa).

Nevertheless in case if column forces are comparable with the bunching forces in the process of simultaneous bunching of two beams one can observe some new features. In case of one beam the phase interval between bunches is 360° and column fields from neighbor bunches encourage bunching, as they are directed to the center of middle bunch. But in case of simultaneous bunching of two beams with different charge signs the phase interval between bunches is 180° and column fields from neighbor bunches impede to bunching, as they are directed from the center of middle bunch.

The aim of the investigations presented in this work is to define how much the trapping of charged particles in acceleration diminishes in case of simultaneous acceleration of two oppositely charged beams with the same absolute value of current.

## 1. THE CODE LIDOS.RFQ.DESIGNER

For the presented investigations the modified code LIDOS RFQ DESIGNER [1] was used. As the result of modification it is possible to visualize the process of simultaneous acceleration of two beams.

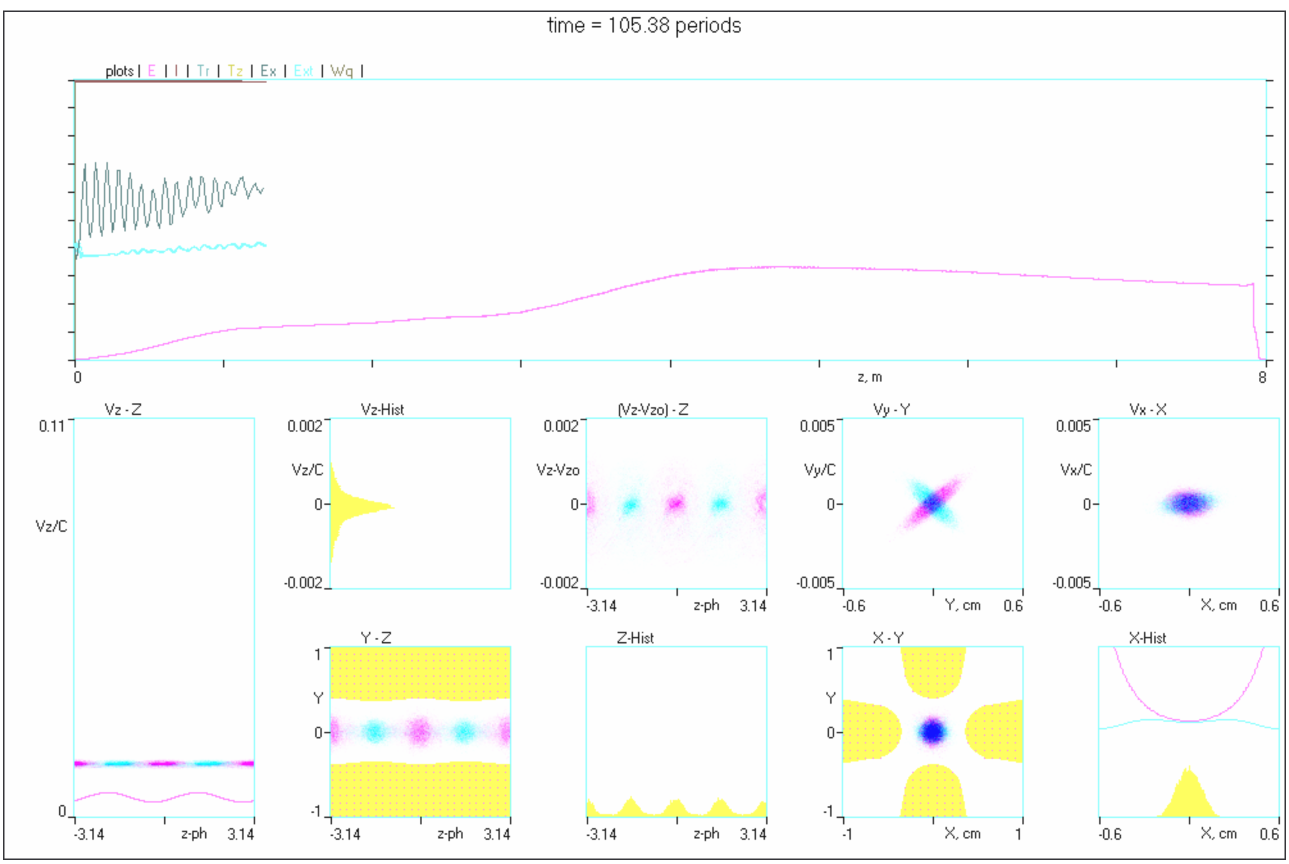


Fig. 1. Cartoon screenshot example

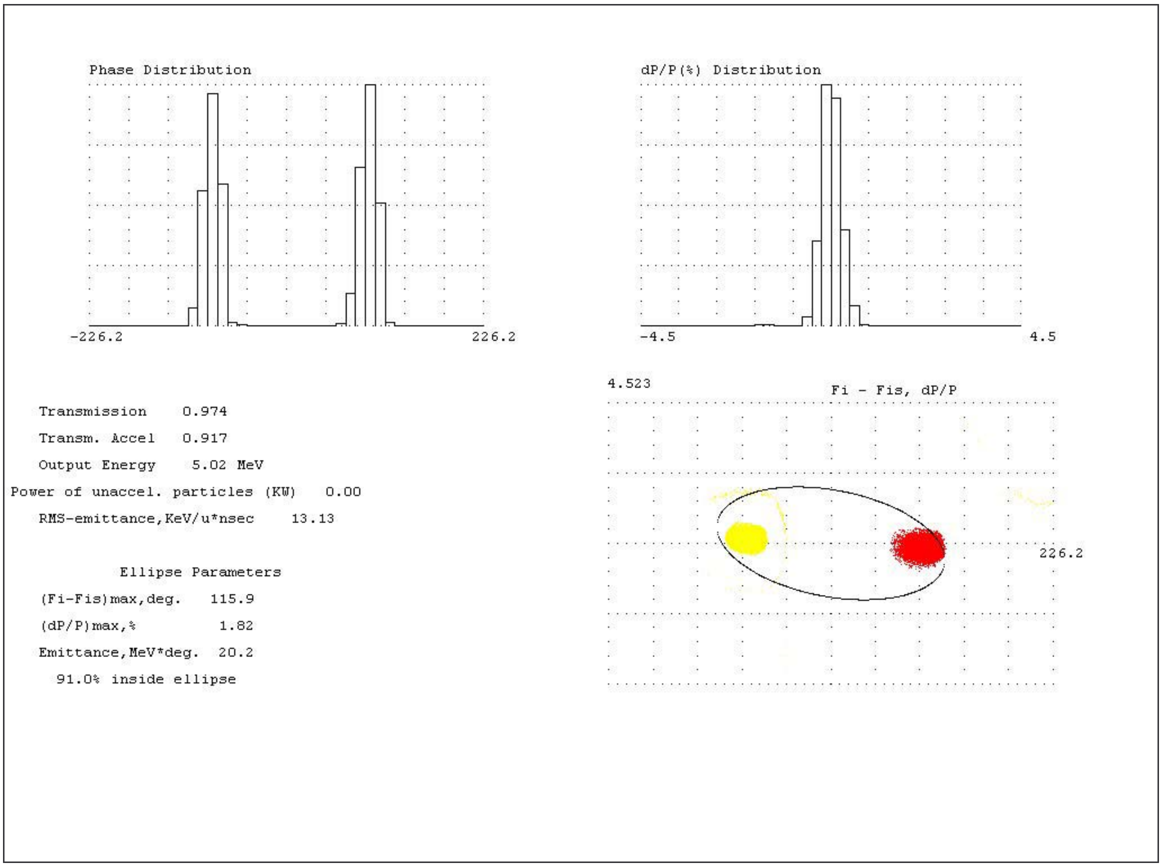
Phase Distribution
-226.2
226.2
dP/P(%) Distribution
-4.5
4.5
Transmission 0.974
Transm. Accel 0.917
Output Energy 5.02 MeV
Power of unaccel. particles (KW) 0.00
RMS-emittance,KeV/u*nsec 13.13
Ellipse Parameters
(Fi-Fis)max,deg. 115.9
(dP/P)max,% 1.82
Emittance,MeV*deg. 20.2
91.0% inside ellipse
4.523
Fi - Fis, dP/P
226.2

Fig. 2

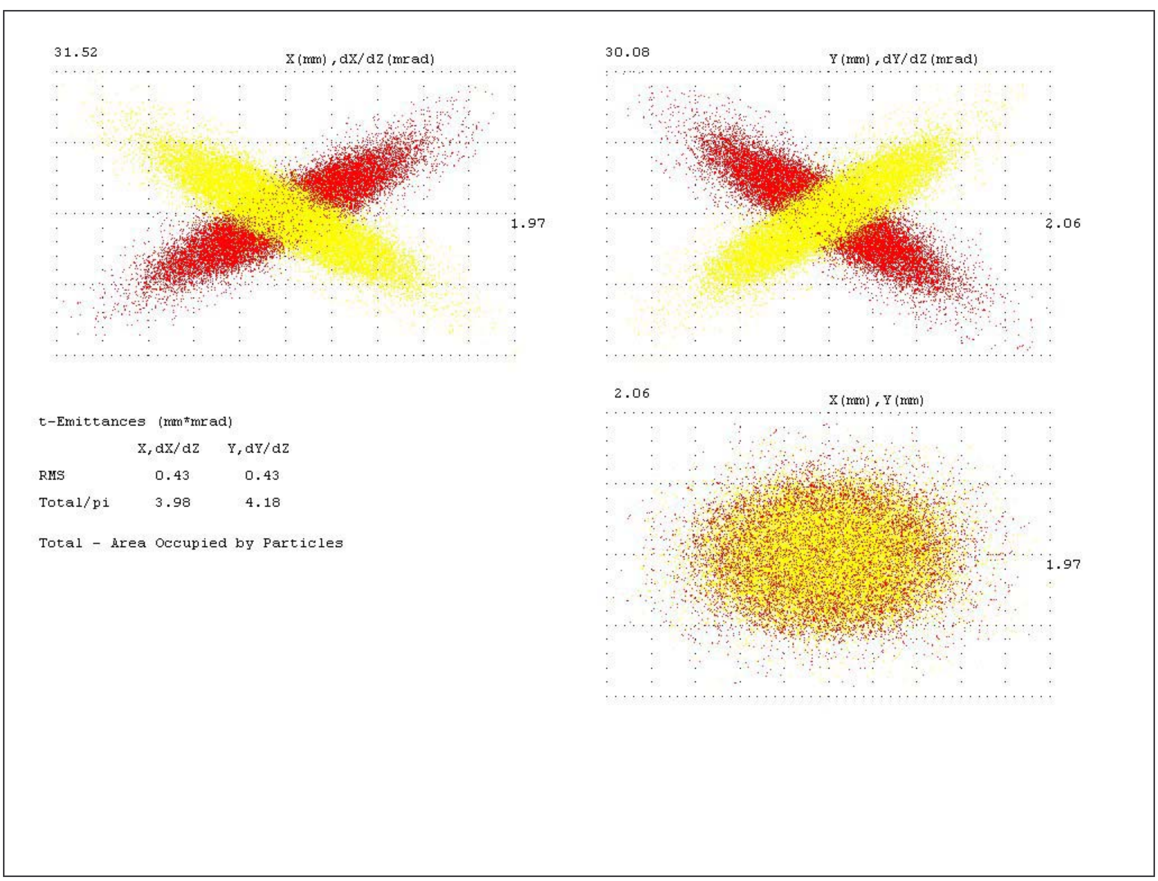
31.52
X(mm),dX/dZ(mrad)
1.97
30.08
Y(mm),dY/dZ(mrad)
2.06
t-Emittances (mm*mrad)
X,dX/dZ Y,dY/dZ
RMS 0.43 0.43
Total/pi 3.98 4.18
Total - Area Occupied by Particles
2.06
X(mm),Y(mm)
1.97

Fig. 3

One of the forms of the modeling results presentation is a cartoon that shows the dynamics of phase portraits, charge density and other beam characteristics variation (see screenshot example on Fig. 1). Ions of different sorts are denoted by points of different color and during the cartoon demonstration one can easily observe all the peculiarities related to the simultaneous bunching of oppositely charged beams.

For the investigations there was calculated a variant of RFQ channel with frequency 352 MHz accelerating protons $H^+$ and negative hydrogen $H^-$ ions from energy of 0.08 MeV to energy of 5 MeV. The channel parameters were chosen in such a way that they provide practically full current transmission for the beam with 50 mA current and normalized emittance of 0.1 $\pi\cdot$cm$\cdot$mrad as well as full trapping of particles in the acceleration. The voltage between vanes is constant and equal to 79.8 KV, mean channel radius is 2.92 cm, vanes modulation increases up to 1.9, equilibrium phase varies from –90° to –30°. The code automatically defines the transverse characteristics of the input beam matching to the focusing channel.

Channel parameters and calculated cells lengths are automatically passed to the code devoted to beam dynamics investigation with the macropaticles method. Among the other data for this code the number of ion sorts, charges and masses of ions and currents for each sort are given.

## 2. RESULTS OF THE MODELLING

In the calculated variant of the channel the dynamics of two-component beam consisted of protons and negative hydrogen ions was investigated. Absolute values of the components currents in all investigations were equal to each other and varied from variant to variant from 0 to 50 mA. The normalized emittance of each component in all variants was 0.1 $\pi\cdot$cm$\cdot$mrad. As it was mentioned above, the calculations showed that current transmission and trapping of particles in the acceleration for one-component proton beam with current 50 mA and emittance 0.1 $\pi\cdot$cm$\cdot$mrad were practically full (current transmission — 0.0998, trapping — 0.0997).

The calculations have shown, that current transmission of two-component beam slightly diminishes if current of each component increases from 0 to 50 mA (0.992 at current 25 mA and 0.976 at current 50 mA), while the longitudinal trapping diminishes significantly larger (0.91 at current of 50 mA). The analysis of the process of the simultaneous bunching shows that with current growth the bunching beams trap a small part of oppositely charged particles inside the bunch in the beginning of the channel. During further acceleration these oppositely charged particles leave the potential well, but they remain outside the separatrix of their own component and so out from the acceleration process. This effect as well as neighbor bunches dephasing effect (see introduction) lead to significant decreasing of trapping of the charged particles in the acceleration.

On figures 2-3 the characteristics of two-component beam with current of each component of 50 mA at the channel output are presented. Shown on figure 2 are phase and phase distributions of the beam, longitudinal phase portrait of output beam and parameters of the ellipsis describing the phase portrait of the two-component beam. On figure 3 the transverse phase portraits of the two-component beam are shown.

## 3. CONCLUSIONS

The comparison of the bunching process of high current beam consisting of one sort of ions and two similar sorts of ions with opposite ion charges have shown that for two-component beam significantly (up to 10%) diminishes the trapping of charged particles in the acceleration, while the general current transmission decreases only slightly. The main reason of the accelerated particles current diminishing is the trapping of particles during the bunching in the potential wells formed by the particles with the opposite charge. In the beginning of the acceleration these particles are placed at the center of the oppositely charged bunch and in further acceleration they occur outside the separatrix of their own component.

## 4. REFERENCES

1. Bondarev B.I., Durkin A.P., Ivanov Yu.D., Shumakov I.V., Vinogradov S.V. "Code Package for RFQ Designing", Report on this Conference.