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INVESTIGATION ON THE SUPPRESSION OFINTRABEAM SCATTERING IN THE HIGHINTENSITY HEAVY ION BEAM WITH THE HELP OF LONGITUDINAL DOUBLE-BUNCH OF ELECTRON*

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Abstract

Intrabeam scattering is the main reason of degradation of the beam brightness and shortening of brightness lifetime in the collider, light source and storage ring. The intrabeam scattering presents dissimilar influence in the different facilities. Electron cooling was chosen to suppress the effect of intrabeam scattering and another unexpected effect happened during the cooling. The distribution of ion beam quickly deviates from the initial Gaussian type, then form a denser core and long tail. The ions standing in the tail of beam will loss soon owing to large amplitude. This solution will focus on the investigation on the suppression of intrabeam scattering in the high intensity heavy ion beam in the storage ring with the help of longitudinally modulated electron beam. The stronger cooling was expected in the tail of ion beam and the weaker cooling was performed in the tail of ion beam. The particle outside will experience stronger cooling and will be driven back into the centre of ion beam during which the ion loss will decrease and the lifetime will increase. The intensity of ion beam in the storage ring will be kept and maintain for a long time.

INTRODUCTION

This solution will focus on the investigation on the suppression of intrabeam scattering in the high intensity heavy ion beam in the storage ring with the help of longitudinally modulated electron beam. The traditional DC electron beam in the electron cooler was modulated into electron bunch with different longitudinal distribution. The stronger cooling was expected in the tail of ion beam and the weaker cooling was performed in the tail of ion beam. The particle outside will experience stronger cooling and will be driven back into the centre of ion beam. The ion loss will lessen and the lifetime will be increased. The intensity of ion beam in the storage ring will be kept and maintain for a long time. Two functions will be combined into one electron cooler. The more short pulse, the more high intensity and more low emittance heavy ion beam was expected in the cooler storage ring. In the future, these results of this project will be constructive to the upgrade and improvement for existing machine and also be helpful to the design and operation for future storage and high energy electron cooler.

SOME CONSIDERATIONS

The final equilibrium transverse emittance and longitudinal momentum spread were determined by the cooling effect and intra-beam scattering heating effect together in the case of fixed ion energy and particle number. If we want to get more particle number, in other words, more intensive ion beam, a new parameters configuration will be necessary in the new equilibrium state. In the absence of electron cooling, the transverse ion beam will be blown-up due to not suppression intra-beam scattering effect. The transverse dimension and longitudinal length of ion beam will increase with time, as a result, some ion will loss and the lifetime of ion beam will become short.

LIFETIME AND INTENSITY OF ION BEAM

The ion beam of $^{238}U^{92+}$with population $1*10^{11}$ particle was required in the high energy high intensity accelerator facility [1]. In this situation, the final emittance and momentum spread were the key parameters which the physics experiments concerned, more important parameters of ion beam were lifetime and the ion number in the detectors.

MOTIVATION

Two essential questions should be certainly answered and clearly described in advance.

The first question concerned by physics experiment is that whether enough particle [2] be provided to the experiments terminals.

The second one concerned the lifetime [3] of the ion beam with so high intensity whether enough to satisfy the requirements of physics experiments, because it determines the efficiency of experiments.

NEW SOLUTION PROPOSED

There are three points in this solution. The first point, the intensity of electron bunch presents certain distribution according to the ion bunch distribution in the longitudinal direction. The second point, the electron bunch distribution will change actively according to the ion beam distribution in the cooling process. As a result, the electron beam will provide different strength cooling in the different periods. The third point, the transverse intensity distribution can change also, the electron beam can present different transverse distribution according to the transverse distribution of ion beam in the cooling process. The purpose of this solution will aim to suppress the effect of IBS, increase the lifetime of ion beam and reduce the ion loss during cooling [4].

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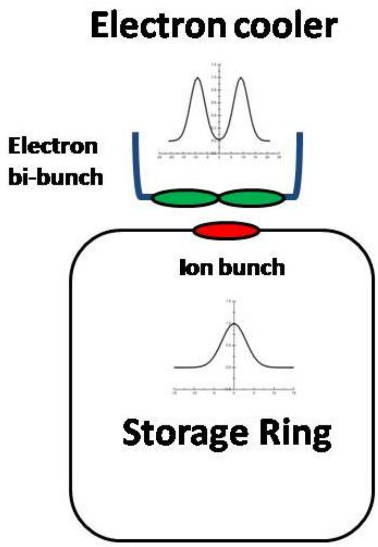

Figure 1: The longitudinal relation between the ion bunch in the storage ring and electron double-bunch in the electron cooler.

In the interest of cooling the un-Gaussian distribution ion beam and suppressing the IBS in the ion beam, we plan to modulate the electron beam in longitudinal direction [5]. In the first step, two proximate electron bunches were delivered by the electron gun, and triggered isochronously. An ion bunch will be cooled by this two electron bunches, it was shown in the Fig. 1. We hope this solution can provide stronger cooling in the tail of ion pulse, and relatively weaker cooling in the core of ion bunch. Further, The hollow electron beam will be united with the longitudinal electron bunches. We hope decrease the ion loss caused by recombination. The hollow electron beam in which the radial distribution of electron can be changed will be combined with the longitudinal modulated electron bunch chain in which the longitudinal distribution presents proper distribution as demonstrated in the Fig.2.

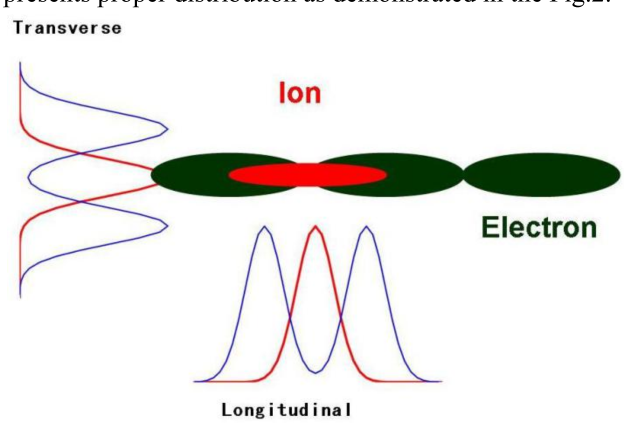

Figure 2: Diagram of ion bunch and electron double-bunch distributions in the transverse and longitudinal directions respectively.

If we use the pulsed electron beam, as one possible result, we can use higher average electron density than the DC electron beam, the ion in the beam can experience higher cooling than DC electron beam, and these ion were expected to be cooled down quickly, and to avoid escaping from the RF bucket.

Betacool Simulation

Betacool program [6] has the ability to simulate the cooling and intrabeam scattering processes together in the various conditions, such as electron bunches and it can give the information about the lifetime of ion beam and final equilibrium emittance and bunch length, etc. Another function was developed for calculating the cooling and scattering intrabeam in the case of bunched electron beam.

According to the information from the IBS measurement results, the electron beam will be provided different distribution in the different periods, such as in the beginning of cooling and intrabeam scattering, before achieve the equilibrium and final equilibrium situation. In the beginning, the ion beam needs to cool down fast with the lowest ion loss, while before the equilibriumit needs modest cooling, and in the period of equilibrium, it just needs maintaining the proper cooling to counteract IBS effect.

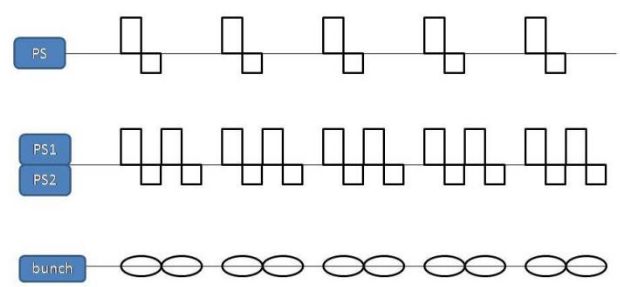

Figure 3: Sketch of two electron bunches generated by two independent HV power supplies with the help of delay trigger.

Scheme and Scenario

In order to get the double-bunch with the certain frequency corresponding the ion beam revolution frequency, two independent HV power supplies were arranged in parallel connection. Delay trigger was used in this solution, as illustrated in the Fig. 3. Every electron bunch was driven by the independent HV power supply, and the strength, width and space will be adjusted independently. In additional, the time relation between the double electron bunch can be triggered slightly advance precede and trail before and after the ion pulse in the electron cooler, and ion pulse will be timely, earlier or later.

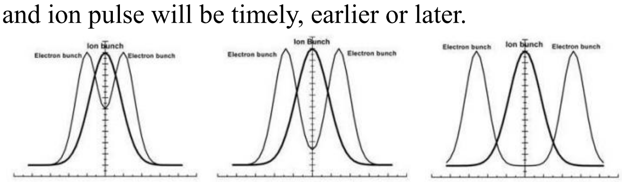

Figure 4: The longitudinal distributions of ion bunch and electron double-bunch with different interval.

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Implement

In order to optimize and improve the effect of this double-bunch chain, we plan to vary the strength, interval of individual bunch and delay time with respect to the ion bunch to investigate the efficiency of cooling and suppression of IBS as presented in Fig. 4.

A double-bunch chains were expected to deliver form the electron gun of cooler in order to implement the different cooling in the different position of ion beam, the ion in the centre of ion beam will be cooled mildly and the ion located in the tail of ion beam will be cooler intensively and fleetly. As a result, the ions outside of the beam was drug into the central part of ion beam, the ion loss caused by larger oscillation amplitude will be reduced, and the ion beam intensity was retained.

Experimental Investigation

Intrabeam scattering not only depends on the lattice optical parameters of storage ring, but also depends on the parameters of ion beam, such as population, energy and charge state of ion. Furthermore, IBS depends on the condition and mode of cooling system.

The intrabeam scattering in the cases of different ion beam energy and population will be studies as well as the electron cooling process. The transverse emittance and longitudinal bunch length will be measured after the electron beam was switched off, the transverse growth rate and longitudinal growth rate, ion loss, and ion beam lifetime will be derived from these experiments.

The transverse emittance and longitudinal bunch length will be measured with the help of beam profile monitor and Schottky probe, and their developing with time will be recorded in the case of different energy and population in the ion beam with different initial ion beam parameters.

The normal uniform DC electron beam was chosen as the reference, the cooling time, equilibrium emittance and momentum spread will be measured in this condition, and the information of beam lifetime and beam loss during the cooling was derived from the data of beam current transformer.

The second step, the perform of a double-bunch chain with a certain space but uniform distribution in transverse direction was studied.

The third step, the behavior of transverse hollow electron beam with uniform longitudinal distribution will be investigated in CSRm.

The forth step, the perform of a double-bunch chain with a certain space, and hollow distribution in transverse direction was studied.

The fifth step, the parameters of electron bunch amplitude, interval, width and delay time were varied to optimize and improve the cooling process.

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SUMMARY

The high energy and high intensity accelerator facility was required to provide high density and high charge state ion beam with long lifetime in the storage ring to satisfy the requirements of physics experiments. To maintain the ion beam density for longer time and reduce the ion loss, lifetime is the critical subject. Due to intrabeam scattering, the quality and the lifetime of ion beam will degrade during accelerating and storing. The electron cooling was chosen as a way to suppress the IBS and improve the quality of ion beam. There is a shortage point in the case of conventional DC electron cooling. The solution proposed in this paper was expected to overcome the deficiency of DC electron beam. The longitudinal modulated electron beam was adapted to suppress the IBS effects. The electron beam was constructed into certain strength distribution longitudinally. The stronger cooling was expected in the tail of ion beam, and the weaker cooling was applied in the core of ion beam. As a consequence, the ion loss was reduced and the lifetime of ion beam was lengthened. Meanwhile, the ion beam density was maintained for longer time in the storage ring, and ensued the certain luminosity in the physics experiment terminals. The detailed investigation will carry out in the future.

This exploration was expected to provide some helpful information for the design of electron cooler and operation parameters and mode in the case of high density high charge state ion beam.

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