A NEW BEAM INJECTION SCHEME FOR A COMPACT LOW-ENERGY STORAGE RING

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Abstract

A very compact storage ring at low energy has an unique application such as Compton X-ray source. Scheme for efficient injection is an issue for such a compact storage ring. Utilizing a phase-shift during acceleration in the non-relativistic energy region, a new idea for accumulating the incoming bunch on an already circulating bunch without any kicker or orbit bump has been presented.

INTRODUCTION

A very compact storage ring may have unique applications. Here, we assume a table-top size system that beam energy to be less than a few MeV.

One of the issues of such a small ring is the injection scheme [1]. In the case of a conventional system with a pulsed injection kicker, the pulse width must be well smaller than the ring revolution and there needs to be empty buckets due to its leading and falling time. The beam intensity is also limited by the bunch intensity of the source in the case of a single pulse injection. A steady state and multi-turn injection may have an advantage if we try to fill as much bucket as possible with a low current source.

PRINCIPLE OF THE INJECTION SCHEME

Fig.1 shows a conceptual schematic of the system. It consists of an electron source, a DC magnet merger, an accelerator, and an ring path. A low energy beam directly provided from a gun is injected. The injection can be done on axis utilizing the energy difference of the circulating beam and the injection beam. Injected beam is assumed to be a non-relativistic energy. It is accelerated with a low gradient and a relatively long accelerator. Since the injected beam is $\beta < 1$, its phase slips during the acceleration. At the exit of the accelerator, the beam ends up near 90 degree off phase. Since the ring circumference is designed to be harmonics of the RF bucket spacing, the beam comes to the accelerator at the 90 degree off which has no acceleration after a ring revolution. The beam of many injections can be accumulated in the same bucket.

Beam energy and phase in the accelerator is explained in Fig.2. The high energy circulating beam pathes at the off phase, which is an usual situation of the storage ring. The injected low energy beam starts with the accelerating phase, but its phase slips because of its lower velocity. Although the efficiency of acceleration is quite bad, it falls on the close phase of the circulating beam. Since this scheme

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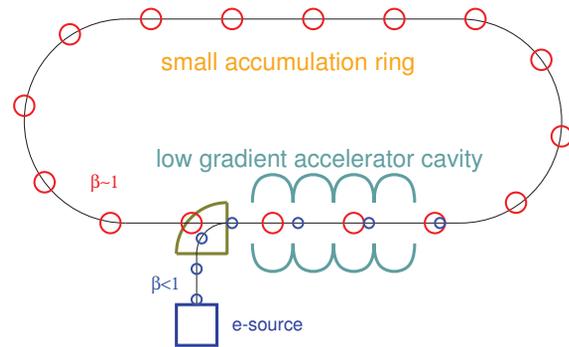
Figure 1: Scheme of the system.

utilizes the non-relativistic nature, it only applicable in the very low energy system.
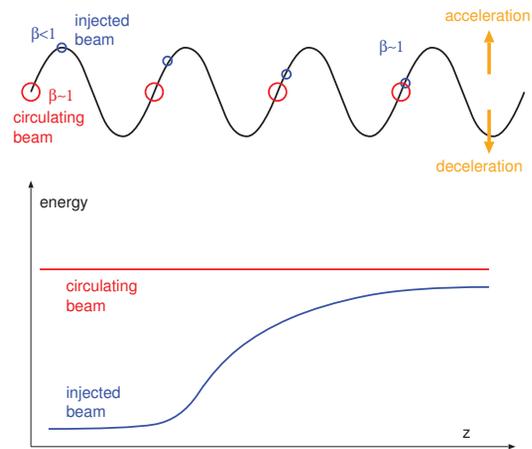
Figure 2: Energy and phase variation in the accelerator.

PHASE SPACE

Because of the phase space conservation, it is apparent that the injected beam can not merge perfectly. Fig.3 shows the longitudinal phase space of energy and timing. Injected beam may be designed to be near the stable area, but never be inside of it. It goes far away after staying around the edge of the stable area in several turns. In order to fall into the stable area, a damping mechanism is necessary, but an radiation cooling does not work at this energy.

What we can consider without a damping mechanism is to use as much area of the phase space as possible to accept many injections. For example, putting a high bandwidth longitudinal kicker in the ring can be considered. By setting a time varying energy change. it can accumulate limited number of turns in the stable area.
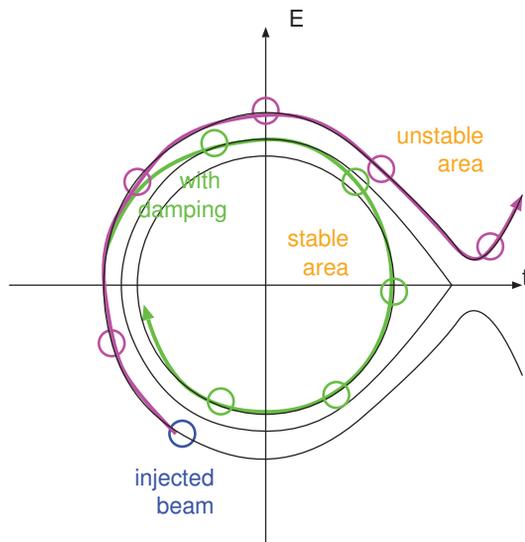
Figure 3: Longitudinal phase space.

Figure 4: Stochastic cooling with a longitudinal kicker.

Another idea is to convert the longitudinal spread to transverse phase space. If the longitudinal kicker is located at a dispersive point and the applied energy change has a position dependence, it can correct the energy difference. Such a position dependent kicker can be designed by using a dipole mode RF kicker operating at the node, for example. But this case, it excites the transverse motion. Again, by putting a high bandwidth transverse kicker, it can accumulate limited number of turns in the transverse phase space.

DAMPING CONSIDERATION

In order to actually store infinite number of injection, some kind of damping mechanism is necessary. With the high bandwidth kicker discussed above, one promising scheme is a stochastic cooling. Since number of bunches in a bucket is finite, it should work strongly as far as its statistical fluctuation is large enough. Fig.4 illustrates feedback schemes for stochastic cooling. (a) shows a longitudinal feedback case. A position monitor is located at a dispersive section. It monitors an average in the energy-timing phase space. Corrections in energy are applied by a longitudinal kicker before it circulates the ring. (b) shows a transverse feedback case. A dipole mode accelerator cavity is installed at the dispersive section as the node to be coincide with the nominal orbit. A bunch that has energy difference gains energy shift because of its orbit shift. It can correct the longitudinal motion, but an transverse oscillation gets excited. The average transverse orbit is detected by a position monitor and is corrected by a transverse kicker before one revolution.

Although the effect of conventional synchrotron radiation is negligible at this energy, any other kind of energy loss such as residual gas ionization or interaction with a material [2] can work for a radiation damping. If we consider an application of laser Compton source, the beam in-

teracts with a high intensity and a high average power laser. The energy loss to scatter the photon works as a damping force [3]. If we try to produce an applicable useful flux of Compton signal, the laser cooling should be strong.
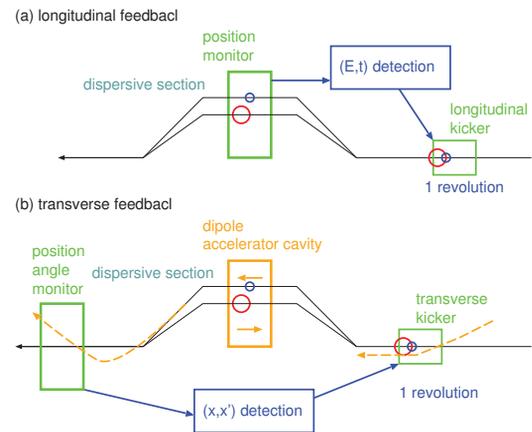
FUTURE WORK

We have started to consider a new beam injection scheme. Even if it can inject a bunch near the stable area of longitudinal phase space, a strong damping scheme is the key to store in the bucket. A detail design needs to be done to discuss the feasibility.

First, we need to define the energy range that this scheme is applicable. Then, to start with, design an example to set the injected beam as close as possible to the longitudinal bucket phase space. An estimation of required damping speed should be done. Then, to start with, feasibility of a stochastic cooling will be estimated.

Since it assumes a low energy beam, space charge effects get strong and it sets an upper limit of current. The limitation should be checked.

Although we assumed application of an electron beam so far, the key of this scheme, a phase slip in non-relativistic region of energy, appears in much wider range in the case of heavy ions. It is worth considering also.

ACKNOWLEDGMENT

REFERENCES

[1] H.Yamada, Nucl. Instr. Meth. B79 (1993) 762-766.

[2] H.Yamada, J. Micro/Nanolithography, MEMS and MOEMS(JM3); 7(2008) 043004-1:65

[3] E.Bulyak, et al. "Beam Dynamics in Compton Storage Rings with Laser Cooling", TUPD093, proceedings of IPAC'10.