Studies on the Beam Orbit Change in ATF Damping Ring

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Abstract

We observed a beam orbit change in the KEK/ATF damping ring which was correlated with the temperature and season. Also, the beam orbit oscillation (100Hz) was observed. The centered beam orbit in the arc-sections of the ring should be maintained because stable multi-bunch beam with extremely low emittance is required as the essential technology for JLC (Japan Linear Collider). We present the measurement results and three plans to reduce the orbit change.

1 Introduction

The ATF damping ring is a prototype for LC R&D (Research and Development). The main purpose is to generate a very small and flat multi-bunch beam with a horizontal emittance near 1nm and vertical emittance of 0.01nm at an energy of 1.5GeV[1]. The KEK/ATF consists of S-band high gradient linac, a beam transport line(BT), the damping ring and an extraction line. Presently, we are refining the beam tuning techniques and are upgrading the linac buncher system. The typical recent operation condition of the damping ring is listed in the Table 1.

Table 1. Typical operation condition and design values

	Typical condition	Design
Beam Energy	1.29GeV	1.54GeV
Circulating time	640msec	200msec
Wiggler magnets	Off	On
Bunch Population	1.2×10^{10} e/bunch	2×10^{10} e/bunch

In the following sections we report the status of the beam orbit drift and oscillation in the damping ring. Plans to reudce the orbit change are expained. Finally, discussion and summary are given.

2 Beam Orbit Drift

Fig. 1 shows difference between measured circumference and design one of the damping ring[2]. We have changed rf frequency in the range of –20kHz to 20kHz because of keeping the centered beam orbit in the arc-sections. This corresponds the circumference change of the ring in the range of –3mm to 3mm. The circumference expands until Aug. by 6mm and shrinks to measured values on Jan. when we started operation of the ring 1997. Rate of concrete expansion is about 10^{-5} /degree. Thermal expansion is main source of this problem because calculated values is consistent with measurements.

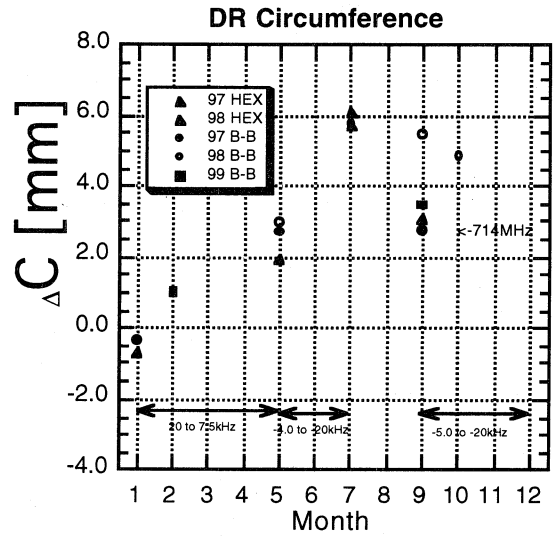

Fig.1 Change of Damping Ring Circumference, Horizontal axis indicates month on which the circumference was measured. Vertical axis is the difference between measured values and design one.

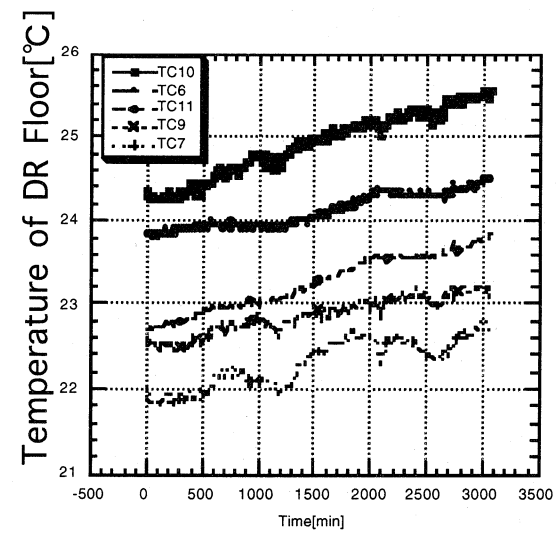

Fig.2 Temperature Drift of the Ring Floor, Average slop is 2.4×10^{-4} degrees/min..

Temperatures of the concrete floor were measured as shown in Fig.2. After magnet power supplies were turned on, temperature of the floor increased by rate of 2.4×10^{-4} degrees /min.. At same time we measured beam orbit drift in the arc-sections. Dispersion function at BPM was measured by rf ramp technique and energy drift was calculated by following equation as shown in Fig.3.

$\triangle E/E=\triangle x/\eta$ and $\triangle E/E=\Sigma\eta_i\triangle x_i/\Sigma\eta_i^2$

0.01% energy drift corresponds 30μm circumference expansion when we assume momentum compaction factor of 0.0022 (design value) according to following equation.

$dE/E=-\alpha\Delta C/C$, where dE is energy drift, C circumference.

Correlation of the energy drift in the arc-sections was measured as shown in Fig.4. We obtained clear results. What is main source of energy drift also indicates to be the change of the floor temperature.

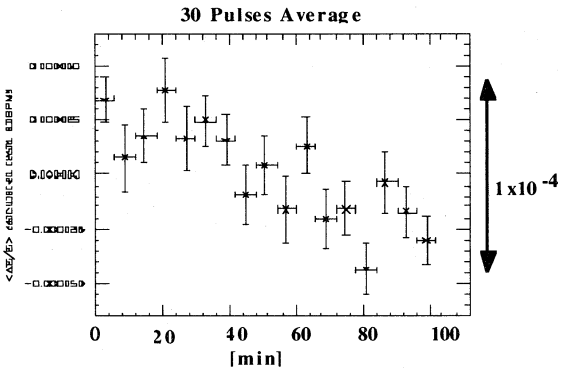

Fig.3 Energy Drift, Horizontal axis is time. Vertical axis is beam energy drift.

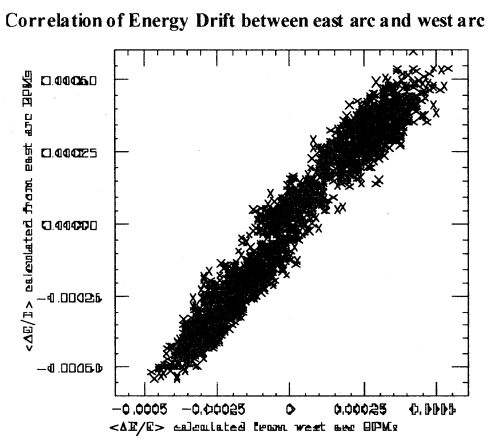

Fig.4 Correlation of Energy Drift between west and east arc

Fig.5 shows the stored current and the energy drift for 400 min.. When beam injection orbit and beam orbit in the ring were precisely tuned, almost 100% beam capture efficiency was achieved. This stability was only kept for a few hours.

A COD (Closed Orbit Distortion) correction algorithm and local orbit bumps are used to correct the stored-beam orbit after many (~10^6) turns from injection. After correction, the typical peak to peak COD is less than 2mm in horizontal and 1mm in vertical plane[3].

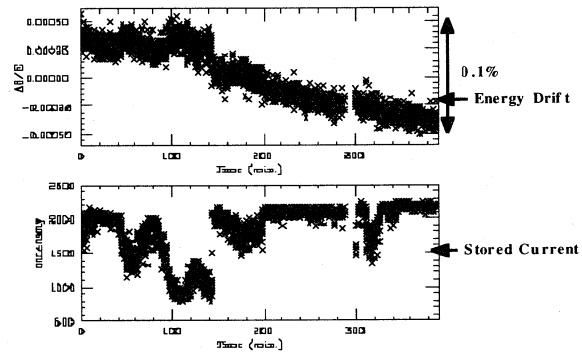

Fig. 5 The status of Energy Drift and Stored Current for 400min., Typical stored electrons/bunch is 1×10^{10}.

3 Beam Orbit Oscillation

We observed slow beam oscillation (100Hz) by

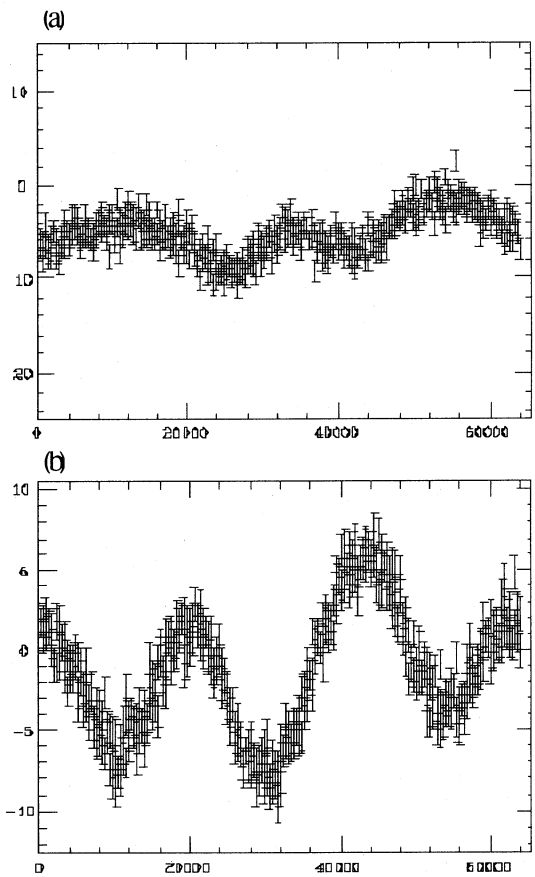

Fig.6 Vertical Beam Oscillation, Vertical axis shows y beam position in μm unit. Horizontal axis is number of turns. (a) Temporal filter to reduce the current ripple was added to main bending power supply. (b) No filter

measuring turn-by-turn beam orbit until 64,000 turns. Revolution period of the ring is 462nsec. Fig.6 shows 100Hz beam oscillation. We tried installation of temporal filter into the ring bending power supply to reduce the current ripple until $3x10^{-3}$. We could reduce the oscillation amplitude from 10μm to 5μm in vertical direction. Performance measurement on the temporal filter indicated the reduction of factor 3 but beam orbit measurement gave the result of factor 2. The ring consists of 36 bending magnets, many quads, sextupole magnets and steering magnets. The bending magnet is combined function type with defocusing component. The vertical beta-function in normal cell is maximum at the center of bending magnet. We should consider eddy current effect and COD effect into beam slow oscillation. We also found the horizontal 100Hz beam oscillation of 30μm which was complicated comparing vertical one.

4 Plans to Reduce the Orbit Change

Strategies to maintain the centered beam orbit are as follows;

1. Circulation system for heated air from power supplies
2. Installation of two chicanes to control the orbit length
3. Automatic control of RF frequency

Above strategies are plans to reduce the beam orbit change in the arc-sections. The circumference change generates tune drift by about 0.01. So, beam becomes unstable. Strategy-1 is under construction. Since the thermal conductivity of concrete is about 40 times more than one of air, direct ventilation of hot air from power supplies is very effective to stabilize the temperature of the concrete.

After we will measure the range of the circumference change, automatic control of RF frequency will be tested. There are two 2m straight sections to install two chicanes. If we will succeed the reduction of the circumference change from 3mm to 1mm, construction of the chicane system will be started since compact chicane system was already designed[4].

5 Discussion and Summary

Concerning the beam oscillation, we are retuning the power supply regulation until $5x10^{-4}$. Level of the current ripple of power supplies should be less than 10^{-3}. Addition of the filter for the bending magnet power supply will be done to satisfy the above condition. Considering the effect of the eddy current, a few μm beam oscillations will be remained as the result.

The change of ring circumference, and associated variations of the beam orbit and tune made it difficult to establish stable operating conditions and disturbed the precise measurements in the extraction line. To accurately measure the vertical emittance, it will be necessary to better stabilize the beam in the ring. A tune feedback system should overcome problems associated with the circumference change. The study of the beam sensitivity to changes in the ring circumference is very important for LC in order to determine the optimum momentum compaction factor of the ring and to develop countermeasures. We will try to achieve a vertical emittance of 0.01 nm at 10^{10} electrons/bunch by the end of 1999. After that, we will proceed with multi-bunch beam study.

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