BETA-MATCHING AND DAMPING OBSERVATION BY SR MONITOR AT ATF DR

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Abstract

Some of the measurements were done by using SR monitor at Accelerator Test Facility Damping Ring(ATF DR) in KEK. A fast gate camera can observe the turn by turn transverse beam profile. A beta-mismatch causes the oscillation of the envelope which has the twice of betatron frequency and relates the amount of the amplitude. The optimization of the injection condition can be done by using the monitor. A two dimensional streak camera can observe the trend of the change of the bunch length over long time range. The observation of the damping phenomena from the injection to the extraction at ATF DR is reported.

1 INTRODUCTION

ATF DR has been constructed to produce a extremely low emittance beam as a future linear collider development. The design parameters are beam energy = 1.5GeV, beam current = 600mA, bunch population $1x10^{10}$ electrons/bunch, bunch number=20, bunch train = 5 and repetition rate=25Hz. The target beam emittance is ε_{nx}=5.1μm, ε_{ny}=30nm, ε_{nz} =12mm. The present operation parameters are beam energy = 1.3GeV, bunch population 3~$8x10^9$ electrons with single bunch and repetition rate=0.78Hz.

In order to diagnose the beam characteristics, SR monitor which uses visible light(~500nm) was prepared[1]. The SR monitor consists of a fast gate camera with focused lens system for transverse beam measurement and a two dimensional streak camera for longitudinal beam measurement. The source point of SR is located at 27cm inside of the bending magnet(R=5.73m) at end of the west arc section. The focused lens system uses a first lens(f=1000mm) and a second lens(f=40mm) for the fast gate camera. The SR is divided by half mirror after the first lens and fed to streak camera through a second lens(f=80mm). The diffraction limit of the focused lens system is severe to measure the damped transverse beam size. Recently, SR interferometer has been installed to measure the damped transverse beam size[2]. The fast gate camera(Hamamatsu 2925) has a 3ns minimum gate width which can measure a turn-by-turn and bunch-by-bunch beam profile when apply a appropriate gate timing and width. The two dimensional streak camera(Hamamatsu C5680) can measure the bunch length with 2ps time resolution. The video analyzer using workstation is commonly used for both the fast gate camera and the streak camera but different software which can be controlled from the VAXs accelerator control computer. By using the fast gate camera, following measurements were executed, 1)turn-by-turn beam size oscillation at just after the injection which comes from the beta-mismatch, 2)position displacement by changing the rf frequency which comes from the dispersion, 3)horizontal and vertical damping time. By using the streak camera, longitudinal damping time was measured. The impedance of the DR was estimated from the relation between the circulated beam intensity and the bunch length by using the streak camera[3].

2 MEASUREMENTS

These following measurements were automated from the accelerator control computer. The video images are processed in the video analyzer and the profiles of the images are transferred to the control computer. The settings of the accelerator components and acquisition timings are given by the program.

2.1 Beta Matching

The beta-mismatch from the beam transport to the ring causes the oscillation of the beam envelope. The amount of the effect can be measured as the spectrum of the oscillation of the square of beam size[4]. The beam envelope at a fixed point oscillates twice of the betatron frequency by the effect.

The measurement was executed that the beam profile at each single turn was acquired by changing the observed gate timing of the fast gate camera from the first turn to 200th turn. The data acquisition was executed by using the different beam pulse because the acquisition speed was limited by the hardware. The beam size was estimated by gaussian fitting of the profile. The peak of the Fourier transform indicates betatron frequency and the twice of the frequency which indicates the beta-mismatch. Fig. 1 and Fig. 2 show the measured square of the beam size and the Fourier transform for horizontal and vertical, respectively, at each current setting of the last quadrupole magnet(QF53T) located at near end of the beam transport line. The design fractional tune was ν_x=0.1422 and ν_y=0.7198. The ν_x and $2\nu_x$ peaks close to the designed value are clearly observed and the $2\nu_x$ peaks vary with the current settings of QF53T in Fig. 1. The current setting at minimum amplitude of the $2\nu_x$ was 45.7A. The ν_y was not so clear but $2\nu_y(1-2\nu_y)$ peaks close to the designed value are clearly observed in Fig. 2. The current at minimum amplitude of the $2\nu_y$ was 44.2A.

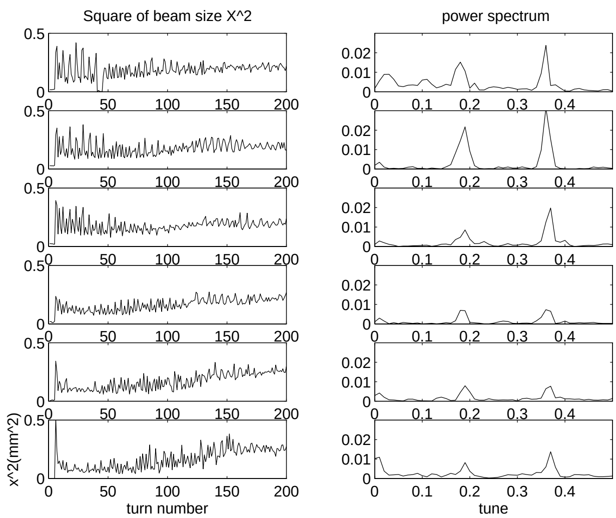

Fig. 1. Square of the horizontal beam size(left) and the Fourier transform(right) at different focus settings. The QF53T current settings are 43.7A, 44.2A, 44.7A, 45.2A, 45.7A and 46.2A from top to bottom.

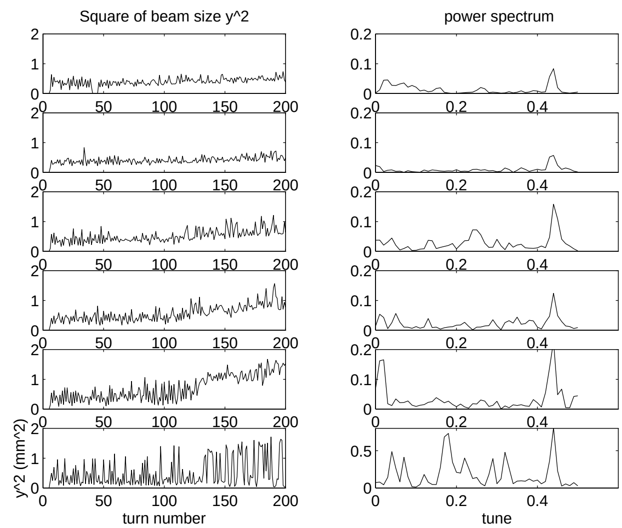

Fig. 2. Square of the vertical beam size(left) and the Fourier transform(right) at different focus settings. The QF53T current settings are 43.7A, 44.2A, 44.7A, 45.2A, 45.7A and 46.2A from top to bottom.

The optimization of the beta matching was not yet complete at this time.

2.2 Dispersion

The dispersion at the SR source point is significant for estimation of the horizontal equiblium emittance, because the horizontal beam size is comparable with ηdp/p. The dispersion at SR source point was measured as position displacement of the beam profile by changing the rf frequency of the ring. The result is shown in Fig. 3. The beam profile of the fast gate camera was acquired at the damped gate timing. The center position was estimated by gaussian fitting of the profile. The dispersion is expressed by following equation,

$$\eta = \frac{x}{\Delta p / p} = \frac{x}{\Delta f / \alpha},$$

where Δf is the difference of the rf frequency and α=0.002143 is used as a momentum compaction factor. The position resolution of this monitor is 10μm. The estimated dispersions are η_x=56.5+/-3mm and η_y=4+/-4mm. This value is consistent with the fitted value of the result of the dispersion measurement using BPMs.

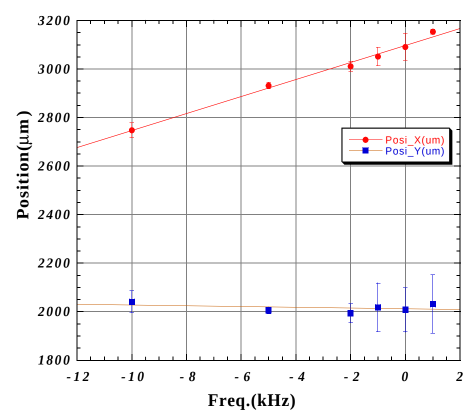

Fig. 3. Dispersion measurement : The center position of the acquired beam image was plotted as the function of the rf frequency. The reference rf frequency was 713.996MHz.

2.3 Damping time

The beam size and the bunch length as function of time are expressed by following equation

$$\sigma^2(t) \propto \varepsilon(t) = \varepsilon_i e^{-2t/\tau} + \varepsilon_e (1 - e^{-2t/\tau}),$$

where ε_i is the initial emittance, ε_e is the equilibrium emittance, and τ is the damping time.

For the transverse, the single turn profile of the fast gate camera at each timing from the injection were collected and calculated the damping time. The beam size was estimated by gaussian fitting of the profile. The measurement was repeated at various operation condition. The example is shown in Fig. 4. The measured horizontal damping time was agreed with the calculation. The measured vertical damping time was often larger than the calculation. The beam blow up for vertical direction was observed at the early time from the injection(~20ms) when that time. After beta-matching at injection, beam blow up was disappear and the damping time was agreed with the calculation. The example is shown in Fig. 5. The comparison of the damping time is summarized at Table 1.

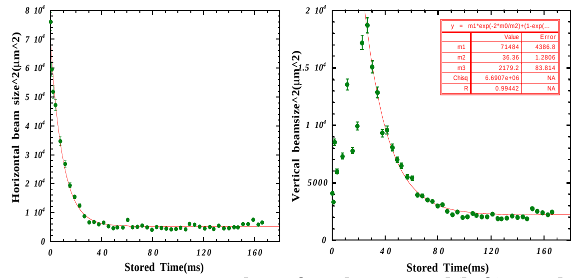

Fig. 4. Damping plot for horizontal(left) and vertical(right): before beta-matching.

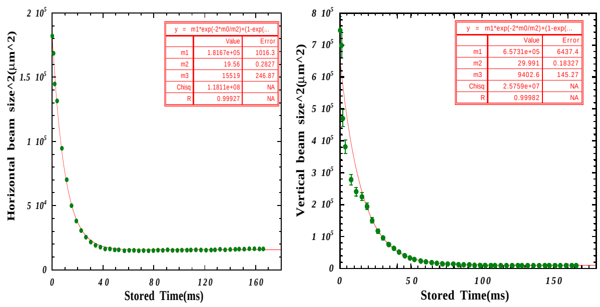

Fig. 5. Damping plot for horizontal(left) and vertical(right): after beta-matching.

Table 1: Transverse damping time

Before beta-matching	after beta-matching	Calculation
τ_x=19.2+/-0.8ms	τ_x=19.5+/-0.3ms	17ms
τ_y=36.3+/-15.3ms	τ_y=29.9+/-1.7ms	27.3ms

For the longitudinal, the damping phenomena of the single pulse was measured by the two dimensional streak camera . Before April 1998, the measured damping time was often larger than the calculation. The bunch length at just after injection spreads beyond 180 degree of the rf bucket. The bunch shape is shown in fig. 6. The distribution of the beam consists of two inside peaks and two outside peaks. The oscillation of the beam timing was observed even if after the enough damping. Same phenomena come from non-linear synchrotron motion was observed by modulating the rf frequency at ALS[5]. The signal noise of the rf low level system was reduced at April 1998. After the treatment, the inside and outside peaks are disappeared and the measured damping time was agreed with the calculation. The damping plot is shown in fig. 7. The damping time is summarized at Table 2.

3 SUMMARY

Three measurements, the beam size oscillation, the dispersion and the damping time, were done by using SR monitor. Some of the interest behavior was observed. For example, the vertical damping time was affected by the injection condition but not for horizontal damping time.

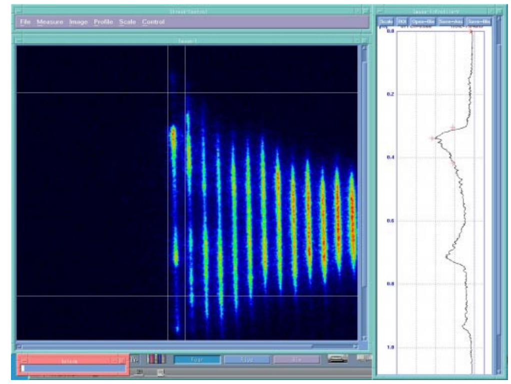
Fig. 6 Bunch shape before cure the low level noise. There are two inside peaks and two outside peaks which come from nonlinear synchrotron motion.

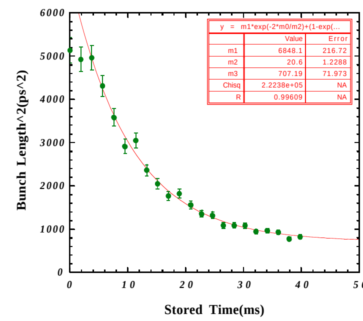

Fig. 7: Damping plot for longitudinal

Table 2: Longitudinal damping time

Before noise reduction	after noise reduction	Calc.
τ_z=25.1+/-3.2ms	τ_z=20.6+/-1.2ms	19.5ms

In order to investigate the relation of the non-linear synchrotron motion to damping time, Furthermore systematic study is needed.

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