Commissioning of ATF Damping Ring

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Abstract

Accelerator Test Facility (ATF) is constructed in the TRISTAN Assembly Hall consists of 1.54GeV S-band Linac, beam transport line, damping ring and extraction line for linear collider R&D. The commissioning of the linac was held in November 1995, and the commissioning of the damping ring was held in January 1997. During 6 months of damping ring initial operation, much hardware tuning and control software tuning have been made. While the hardware installation is continuously underway, we summarize the beam commissioning and the status of the initial 6 months run of the damping ring at this moment.

1 Introduction

ATF[1] is a test-stand of key components to realize a linear collider such as multi-bunch beam generation, high gradient acceleration, low emittance beam generation and its instrumentation development. The ATF consists of a 1.54GeV S-band Linac[2] and a damping ring[3] built in the TRISTAN Assembly Hall which is 120m x 50m. The main purpose of the damping ring is to develop an extremely low emittance beam($1x10^{-11}$ m for vertical). The first operation of the linac was held in November 1995. Beams of single bunch and multi-bunch were successfully accelerated up to 1.3GeV energy. The beam experiment of energy compensation of a multi-bunch beam was also succeeded. After 5 months of linac operation, the damping ring components have been installed into the housing tunnel and completed in January 1997. The commissioning of the damping ring started near the end of January 1997. The ring was operated at first with 0.96GeV energy and achieved maximum $6x10^9$ intensity of single bunch storage in the run of the first three months. In the run of another three months, the beam energy was raised to 1.3GeV with almost the same intensity of single bunch. During this commissioning period, many hardware and software commissioning were held with cooperation of many foreign collaborators. This paper summarizes the hardware commissioning and the beam result which has been tuned during these 6 months operation[4].

2 Operation summary

The typical operation condition in July 1997(at the end of first 6 months run) is listed below:

Beam energy : 1.3 GeV
Intensity : max. $5x10^9$, single bunch
Injection repetition : 0.78 Hz or 1.56 Hz
RF voltage : ~ 200kV
Tune : $\nu x \sim 14.2$, $\nu y \sim 8.4$, $\nu z \sim 0.005$
COD (peak to peak) : x ~ 6 mm, y ~ 6 mm

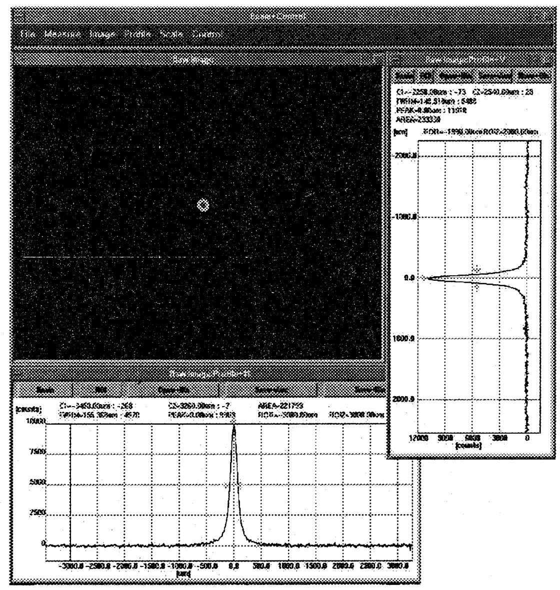

Fig. 1 example of beam profile by SR monitor

An example of achieved beam profile measured by a SR monitor is shown in Fig.1. The processed image shows 155μmFWHM in x and 145μmFWHM in y as a beam size which seems to be around the diffraction limit. In Fig.2, another list of the beam result and target value are shown together with the damping ring configuration. The detail is discussed in the following.

Beam Size and Emittance

The beam size in the damping ring was measured by an SR monitor[5] located near the downstream end of the West Arc. Since the expected resolution limit of this monitor is around 50μm for the light wavelength of 500 nm, this is not an adequate monitor for the emittance confirmation such as 6μm vertical beam size. However this monitor provides an good emittance measurement down to 50μm beam size. The measured rms. beam size with the SR-monitor was typically 90μm in horizontal, 85μm in vertical. Attempts have been made to alter the beam size by changing the x-y coupling. This is done by making the x and y tunes close to each other, or by using skew magnetic field and creating vertical orbit bumps. In all cases we could not see any changes in the beam size. These observations suggest a hypothesis that the real beam size is actually smaller than the resolution limit of the SR monitor, which, for some reason, may be larger than the design resolution limit of around 50μm. However, before settling on such a conclusion, we should argue about: characteristics or physics of the synchrotron

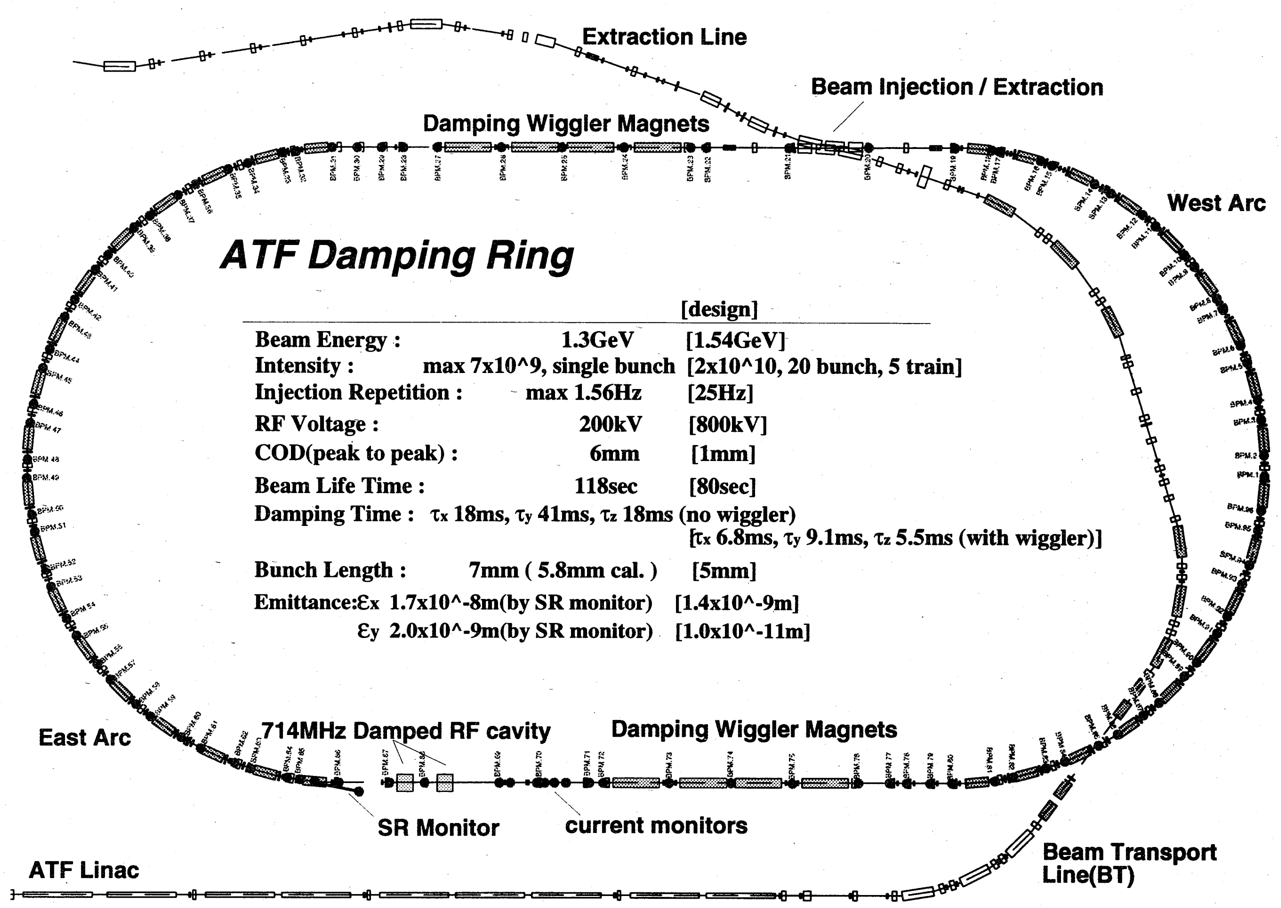

Fig.2 Beam status of damping ring and its configuration

radiation near the light source point that is relevant to the SR monitor, and an error or misunderstanding of the optical system of the monitor.

Using the calculated beta function at the source point, the beam emittance as measured by the SR-monitor is quoted as :ε_x ~1.7×10^{-8} m, ε_y ~2.0×10^{-9} m. However, it should be noted that the accuracy of these numbers are much subject to the performance of the SR monitor and our understanding on it.

In an attempt to understand the large vertical emittance, the dispersion in the ring was measured by introducing an RF phase jump. The measured vertical dispersion was comparable to the horizontal one (about 0.1 m). This suggests that the vertical emittance can be comparable to the horizontal emittance. It is noted that our measurement was done in a condition with large COD in both x and y(peak to peak ~6mm).

Damping times of the beam size are not far away from the expectation (e.g. measured : τ_x~18msec τ_y~41msec where expected values are : τ_x~17.5msec τ_y~27.6msec). For more precise measurements, we will need to understand more about the SR-monitor.

Bunch length

The bunch length of the beam in the DR was, again, measured by using the SR monitor, which is operated in the streak-camera mode[5]. The measured bunch lengths are generally longer than calculations (e.g. measured rms. 7.0 mm, while the expected value is 5.8 mm). Possible reasons are: (1)Errors or misunderstanding of the SR-monitor optical system, (2)Space charge effects and saturation in the streak camera, (3)Bunch lengthening due to wakefields, potential well or instabilities in the DR, (4)Instabilities from other sources. We have some data that indicates an intensity dependence of the bunch length. Calculation of the impedance of vacuum components in the DR have been redone. It suggests that we may be in the regime where potential well distortion or instabilities are to be seen. However, this has not been confirmed yet. The combined effects of true bunch lengthening and saturation in the streak camera need to be carefully resolved[6].

In contrast with the bunch length, the longitudinal damping time agrees with expectation (measured 18 msec, while the expected value 19.4 msec).

Beam lifetime

Beam life time was measured by DCCT current monitor in the storage mode operation. Decays of the stored beam current have been analyzed by a fitting calculation that takes into account both the Touschek effects and the exponential-like vacuum-limited beam lifetime. The observed life times were typically 118 sec (exponential) and 100 sec (Touschek-like), as evaluated at a beam intensity of $2x10^9$.

The expected exponential decay time is 2400 sec, assuming that it is dominated by the beam gas scattering under a vacuum pressure of around $6x10^{-6}$ Pa. The measured average vacuum level is about $5x10^{-6}$ Pa at the monitor ports. The expected Touschek life time is about 500 sec assuming a 10% x-y coupling of the beam and 1% energy acceptance in the ring. If we simply take the face value of the measured Touschek life, it suggests an x-y coupling of 1%. This is in contradiction with a suspected large coupling which is implied by the measured large dispersion. Possible reasons for the short measured Touschek life include: (1)The DR aperture is small, (2)Effects of scattering with gas whose density has a beam-current dependence.

Optics diagnostics

The lattice diagnostics have been performed by analyzing the dependence of the first-turn orbit on perturbations given by steering magnets. Sextupole magnets are turned off during this data collection. From this analysis correction factors were calculated for main power supplies to reconcile the model calculations with the observed orbit distortion patterns. The calculated correction factors were implemented for a number of main magnet power supplies which excite many magnets in series. The factors are 0.7% for the main quads (QF2R), 0.6% for the combined bends (quadrupole component) and a few % for other quads, 9 of them have 1.1~4.6% error, which is rather big compared to the specifications of the power supply. The exact origins, in terms of the hardware setup, of these correction factors are not understood. We will check the power-supply currents in this summer shutdown time. After applying these corrections, the measured and calculated vertical tunes have come to agree well. However, the horizontal tune continues to have a discrepancy of 0.2 (measured tune is bigger). Effects of sextupoles are suspected but not confirmed.

The lattice diagnostics based on a π-bump method, which is complimentary to the first method, has been also performed in the regular arc sections. With this technique errors of each main quad (QF2R) and each combined bend are investigated. Corrections has not been set in usual operation yet.

Alignment

We found that the circumference of the ring increased during this run by the need to decrease the RF frequency for beam storage. It is confirmed by conducting a survey of the ring magnets that the ring expanded almost uniformly by about 6.4 mm in circumference. The required RF frequency change was -28 kHz, corresponding to an increase of the orbit length by 5.1 mm. It may be explained by expansion of the floor due to a large temperature increase from the winter towards the summer seasons, but we do not fully understand the nature of the expansion mechanism. To achieve and maintain a low emittance beam, some special cures may be necessary.

The typical COD in the 1.3 GeV operation (peak to peak 6mm in x and y) was larger than that of 0.95 GeV operation (peak to peak 4mm in x and 2mm in y). It may be an effect of the floor expansion. Some survey data show an up-down pattern of maximum 1.4mm (peak to peak) vertical misalignment from the east arc towards the west arc. It may be one of the reasons of this large COD. We are going to refine the vertical alignment of the ring magnets to achieve an accuracy of 30μm (rms.).

Other measurements and observations

The tune has been measured by analyzing the bunch oscillation that is induced by an injection error. Sometimes it has been difficult to obtain clear signals. The beta functions were also measured by changing the strength of quads, and by observing the dependence of the tune on such perturbations. The results have relatively large measurement errors (fractional error 25~68%) dominated by the lack of the accuracy in tune measurements. We are preparing a transverse kicker for tune measurements.

Effects of wigglers have been studied somewhat. However, mostly we operated the DR with wigglers off. We found that the field integral of each wiggler magnet (a wiggler section consists of 4 wiggler magnets) is not canceling, resulting in a total horizontal kick of about 2 mrad. We changed the cable connection of the magnets to form a chicane with 4 wigglers. It decreased the extraneous kick from the wiggler sections but not completely. We are preparing 4 large steering magnets to compensate the kicks in the summer down time.

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