RECENT RESULTS ON KEK/ATF DAMPING RING

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Abstract

One of the more stringent requirements on a future linear collider(LC) is the generation and preservation of beams with very small transverse and longitudinal emittances. These emittances are essential for achieving the LC design luminosity. The Accelerator Test Facility(ATF) has been designed to investigate the feasibility of the LC operation scheme and to develop beam-control techniques for the LC. The purpose of the ATF is to develop accelerator technology that can stably supply to the main linear accelerator an extremely flat "multi-bunch beam" which can be squeezed down to a few nanometers at the collision point. This paper reports the results of damping ring commissioning and accelerator studies, which started in January, 1997. In particular, we report the transverse emittance ratio obtained.

1 INTRODUCTION

The ATF damping ring is a prototype for LC R&D (Research and Development). The design work for the damping ring proceeded through several LC workshops and many discussions with SLAC collaborators. The construction was started in Nov. 1993.

The main purpose of the ATF 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. Beam commissioning and machine studies are performed since Jan. '97 by an international collaboration consisting of 9 foreign Lab. and by a domestic collaboration with 9 Univ.[1,2].

The KEK/ATF consists of an S-band high gradient linac, a beam transport line(BT), the damping ring and an extraction line. The pre-injector was completed in Aug. '93, when development of multi-bunch beam diagnostics started. In Nov. '95, we completed the high gradient linac for experiments on multi-bunch acceleration and on multi-bunch beam loading compensation. After installation of the main hardware components, in Jan. '97 we started the beam commissioning in the damping ring. Last year November, we completed the extraction line for precise beam diagnostics. Presently, we are refining the beam tuning techniques and are upgrading the linac buncher system.

Since the many beam instrumentation devices in the ring turned out not to be sufficient for precise beam tuning, we are also upgrading each of the systems and are developing new diagnostics. For example, a laser wire is under basic study. The typical recent operation condition of the damping ring is listed in 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	6~8x10^9 e/bunch	2 x10^{10} e/bunch

In the following sections we describe the status of the beam tuning, report the emittance measurements, and discuss some problems. Upgrades for the next machine study period are explained. Finally, a discussion and summary are given.

2 BEAM TUNING

A COD (Closed Orbit Distortion) correction algorithm and local orbit bumps are used to correct the stored-beam orbit, many (~10^6) turns after injection. After this correction, the typical peak to peak COD is less than 2mm in horizontal and 1mm in vertical plane. We measured the R_{12} single-pass response matrix of each BPM to excitations of the different dipole correctors, with sextupole magnets turned off. From these data we calculated typical quadrupole field strength errors of about 1% and upgraded the optics model to account for these errors, which arise from an interference effect between adjacent magnets. The dispersion functions at BPMs in the ring and in the extraction line are measured from the orbit shift induced by a change in RF frequency. The vertical dispersion in the arc section was reduced from

40mm to 5mm by an additional correction using vertical steering coils after the COD correction. The transverse and longitudinal oscillations are measured and the tunes in the typical operation condition agreed well with the model values. We thus established correction techniques for COD and dispersion, and a beam-based technique for measuring quadrupole field errors[3].

3 EMITTANCE MEASUREMENTS

SR Interferogram Pattern

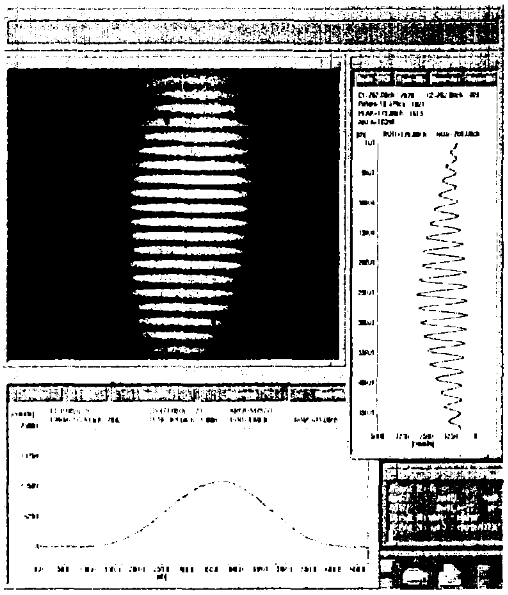
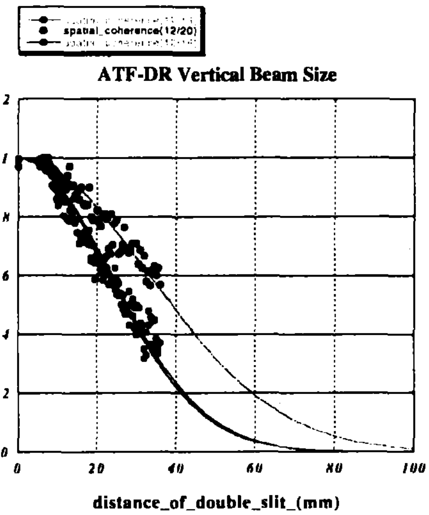


Fig. 1

We installed and commissioned a SR (Synchrotron Radiation) monitor to measure the transverse beam size and bunch length, and to estimate the damping time. Due to diffraction, the damped transverse beam size can not be measured by this SR monitor (500nm visible light). So, a SR interferometer was added to the SR monitor system. Using this interferometer we can determine the vertical beam size from a measurement of the spatial coherence. The procedure is illustrated in Figs. 1 and 2. Fig. 1 shows an interference fringe formed on a CCD camera behind a double slit, and Fig.2 a typical result of such an emittance measurement. For a high emittance optics in early 1998, we measured a vertical emittance of 8.1×10^{-11}m[4]. The technique can also be applied to the horizontal beam size when the double slit is rotated by 90°. Measurement of the horizontal spatial coherence for the design optics (135°) were consistent with the design value of the horizontal emittance (~1.4nm). We subtracted the contribution to the beam size arising from energy spread and dispersion at the source point, where the dispersion at the SR monitor was determined from the shift of the beam profile center induced by a change in RF frequency[5].

The value of the horizontal emittance was confirmed independently by emittance measurements in the extraction line. The extraction line is equipped with 4 wire scanners, an air Cerenkov γ detector, BPMs with single-pass signal processing and a current transformer (CT). Fig 3 shows a typical waist scan on one of these wires, and the fitted parabola from which the horizontal emittance is determined[6]. The quality of the fit is good.

ATF DR Emittance measurement by SR-interferometer with high emittance Optics (90 degrees) **3/12/'98**



From measurements of spatial coherence, following results were obtained by orbit tuning. Once, we measured the vertical emittance of 7.5 x 10^{-11}m at the extraction line by MW1X waist scan with 50μm wire (1/15/'98).

12/18/'97	$\sigma_y \leq 24.4\,\mu$m	$\varepsilon_y \leq 2.2 \times 10^{-10}$m
12/19/'97	$\sigma_y \leq 23.9\,\mu$m	$\varepsilon_y \leq 2.1 \times 10^{-10}$m
12/20/'97	$\sigma_y \leq 16.1\,\mu$m	$\varepsilon_y \leq 10.0 \times 10^{-11}$m
3/12/'98	$\sigma_y \leq 14.8\,\mu$m	$\varepsilon_y \leq 8.1 \times 10^{-11}$m

Fig. 2

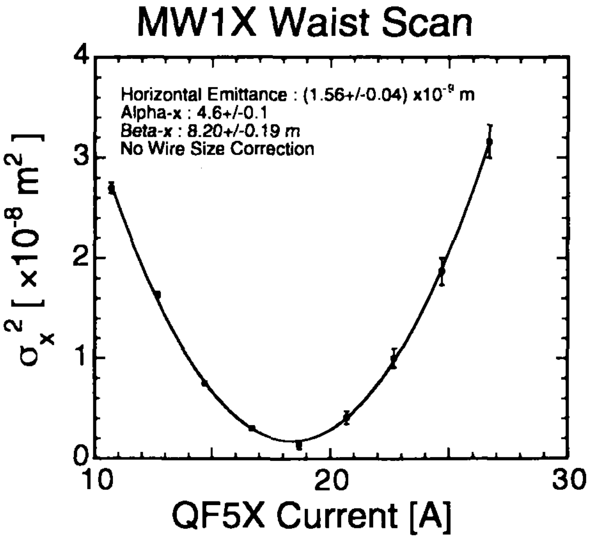


Fig. 3

For the logitudinal emittance measurement, a thin screen monitor (130μm thickness) was used to measure the energy spread at a high dispersion point (1.7m). The beam size caused by the beam energy spread is about 1mm, much larger than the 90μm spread expected from multi scattering on the screen. Fig. 4 shows results of an energy spread measurement.

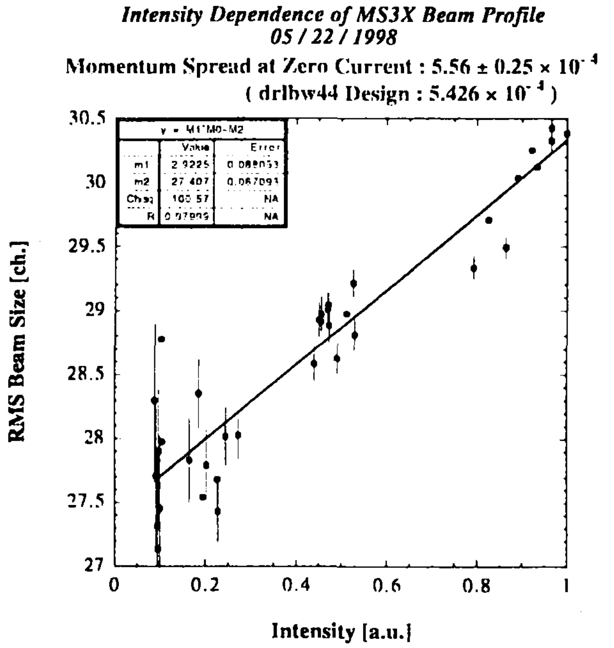


Fig. 4

4 PROBLEMS

During commissioning a number of problems were encountered. We measured physical aperture by detecting beam loss over the first few turns for different injection orbits, and we estimated the dynamic acceptance from the beam lifetime measurement. The physical aperture is consistent with the design. It corresponds to an acceptance of about 2 x 10^{-6} m. However, the measured dynamic acceptance for the stored beam is only 1 x 10^{-7} m which is 20 times smaller than the physical aperture. This problem will be addressed in the next beam commissioning period[7]. Another problem concerns the SR mirror inside the vacuum. The surface of this mirror was deformed by carbon contamination within a few days of operation. A copper mirror coated by aluminiu was used because of its good reflection efficiency. We will replace this mirror by a beryllium mirror as used in many light sources. A third problem is the stability of the ring circumference. We observed a change in the ring circumference by up to 6mm, correlated with the outside temperature and humidity. Over one year, rf frequency changes of about 20kHz were required in order to maintain a centered beam orbit under these conditions.

5 UPGRADES FOR NEXT OPERATION

The linac buncher section is being modified to reduce the energy tail. BPM signal processing for the linac was replaced by a single pass system for faster beam tuning. In the ring, three steering magnets were installed near the SR monitor. The installation of these magnets was postponed because of tight space constraints in this location. We now think that the beam orbit correction near SR monitor is necessary. Improving the orbit in the south straight section should increase the acceptance. The ring BPM circuit was modified and a multi-turn read out using either CAMAC block transfer mode or list processing mode will be available soon. The BPM resolution will become a few micron. The SR interferometer for both horizontal and vertical emittance measurements will be ready for routine operation after replacement of the SR mirror. Many beam parameters will be measured quickly and simultaneously after an upgrade to the control system. The optics model will be refined using beam based technique, for example, R_{12} measurement. Also we will continue to improve the orbit and dispersion correction.

6 DISCUSSION AND SUMMARY

Comparison of measured machine parameters and the model prediction shows that the first order optics agrees with the design. Of great interest is the emittance ratio ($\varepsilon_x/\varepsilon_y$) obtained in 90° optics and 135° optics. The change of ring circumference, and the associated variations of the beam orbit and tune made it difficult to establish stable operating conditions and disturbed the precision measurements in the extraction line. However, we can roughly estimate the emittance ratio in the ring from the results of the SR interferometer and the effect of intra-beam scattering. ~3% emittance ratio for 90 ° optics was obtained from fig. 2 but not clearly confirmed. 3~4% emittance ratio would be obtained for the design optics[3,8]. The measured dependence of the energy spread on the beam intensity in fig. 4 indicates an emittance ratio of about 4% assuming the intra-beam scattering effect as the source of the beam-size variation[8]. To accurately measure the vertical emittance, it will be necessary to better stabilize the beam in the ring. A tune feedback system should overcome some of the problems associated with the circumference change. The study of the sensitivity to changes in the ring circumference is very important for LC in order to determine the optimum momentum compaction factor of future rings 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 1998. After that, we will proceed with multi-bunch beam study.

7 ACKNOWLEDGEMENT

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