Beam Dynamics

1. Introduction

The main objectives of this year are divided into three parts. The first is the estimation of machine parameters, which shows the present completion level of an accelerator. This is also necessary for setting the next target of performance improvement and was carried out especially for the storage ring. The second is stabilization of essential beam parameters such as beam energy, beam orbit and so on. The third is a study on upgrading beam quality and new possibilities.

2. Study on Stabilizing Eectron Beams in Linac

To precisely control a filling pattern and beam impurity in the storage ring, we investigated the mechanism of beam energy fluctuation in the linac. By conducting various experiments, we found that the energy fluctuation is mainly caused by a phase shift of power feeding electromagnetic waves due to temperature fluctuation of the atmosphere and cooling water [1]. As a result of suppressing the temperature fluctuation and other causes [2], a beam energy stability of ~0.1 % (1σ) could be achieved.

3. Study on Stabilizing Electron Beams in Synchrotron

To improve the stability of electron beams in the synchrotron, we investigated the fluctuation of betatron tunes and chromaticities from bottom - to - top energy regions [3]. The obtained results were also useful to improve the scheme for generation of a pure single bunch in the synchrotron.

We measured betatron tunes with a real-time spectrum analyzer covering the entire energy regime. Tune fluctuation observed during energy ramping was improved by adjusting the current pattern of the quadrupole magnets.

We also measured chromaticities with the same analyzer by changing the beam energy. Up to now, only the vertical chromaticity was successfully measured. A change in the vertical chromaticity during energy ramping is well explained by a simple model where extra sextupole fields are generated by the eddy current.

4. Estimation of Machine Parameters in Storage Ring

4.1 Betatron Coupling

A speckle pattern of the Be window installed at the front end was observed with the undulator radiation. This shows that the storage ring has very small vertical emittance without any skew quadrupole corrector. However, since the vertical emittance is too small to measure, at present we have not measured it directly. To demonstrate the achieved small vertical emittance indirectly, we have studied the betatron coupling of the storage ring.

By measured bandwidth of the nearest linear coupling resonance, the betatron coupling was expected to be less than 0.1 %. We tried to prove the validity of our estimation by measuring the dependencies of various ring parameters on the betatron coupling, *i.e.*, betatron tunes, transverse coherent oscillations, horizontal beam size and Touschek Lifetime. The obtained results are in a good agreement with the theoretical calculations [4].

4.2 Measurement of Synchrotron Frequency

We made a system to measure synchrotron frequency through a phase deviation between the signal induced by the beam and the reference signal of the RF accelerating cavities [5]. Since this doesn't interrupt the beam operation, we can monitor the synchrotron frequency anytime. By using this system, we are investigating the dependence of the synchrotron frequency on RF and beam parameters [6].

4.3 Measurement of Optics Parameters

We developed a method to estimate betatron functions and phases in a consistent way. The concept of our approach (Model Calibration Method: MCM [7]) is to introduce effective focusing errors by considering the betatron phase advance and then build a suitable model of the ring. By using measured response matrix data and applying the MCM, the model response matrix was improved. As a result, the distribution of effective focusing errors and the calibration factors of both BPMs and steering magnets could be estimated. By using the above data, the betatron function and phases could be calculated.

These results were confirmed experimentally by (i) making a local bump orbit and observing its leakage with and without taking into account the gain factors, and (ii) measuring betatron functions at some quadrupole magnets by changing their strength. Details are given in Ref. 8.

4.4 Measurement of BPM Offsets

In the storage ring, the main magnets are aligned on common girders so that focusing errors coming from each magnet on the same girder nearly cancel each other out. Furthermore, each girder is aligned so that magnetic centers are connected as smoothly as possible. Therefore, a part of the BPM offsets can be estimated by summing Fourier components of closed orbit distortion (COD) whose harmonic number is much higher than betatron tunes. In Ref. 9 it was reported that this method had been applied successfully to the storage ring. To check the reliability of the resulting offsets, we also measured the offsets at some BPMs by using a beam-based method. We then compared the results to those obtained in Ref. 9 and found good agreement [10].

4.5 Measurement of Bunch Length

The bunch length of an electron beam was measured with a streak camera (Hamamatsu C6860) by changing the RF voltage and stored beam current. The time resolution of the streak camera is 2 ~ 3 psec at a synchro-scan mode.

Measured dependence of the bunch length on both the stored current and the synchronous phase is in good agreement with the calculation results obtained by the original simulation code [11]. This shows that our impedance estimation [12] is mostly valid.

5. Optimization of Chromaticities in Storage Ring

It is well known that a head-tail instability can be suppressed by using positive chromaticities. A large chromaticity is also effective for suppressing a coherent beam motion. We studied the effect of positive chromaticities on the beam stability by changing the chromaticity value and peak current. By increasing the positive chromaticity value, we succeeded in storing a single bunch of 10 mA without any coherent motion. From this result, we usually set horizontal and vertical chromaticities to about +3 and +4 values, respectively, in routine user operation.

6. Stabilization of Electron Orbit in Storage Ring

To correct slow movement of an electron orbit in the storage ring, we developed a periodic COD correction system. This system controls the electron orbit globally by using three harmonics of the COD, *i.e.*, the tune harmonic and its satellite harmonics. The correction period is usually set to 1 minute. Twenty-four and sixteen steering magnets are used in the horizontal and vertical planes, respectively. This system is working routinely in user operation, and a stability of about 10 μm per day has been constantly obtained [13].

7. Development of Simulation Code for Slow Positron Production

By using synchrotron radiation with high energies, we can generate a high intensity slow-positron beam. To estimate slow positron beam properties, we developed a Monte Carlo code, named LEPRE (Low Energy Positron RE-emission) [14]. This code traces positron behavior according to a stopping profile formula based on the Makhovian distribution [15]. As necessary material properties, the values used in EGS4 [16] and used in Ref. 14 are adopted. We ran a preliminary test of LEPRE with the tungsten moderator foils system [17], and reasonable re-emission rates were obtained.

We are now working to develop a new Monte Carlo code that will have both the EGS4 and LEPRE functions in order to trace the positrons from pair production to thermal diffusion and re-emission.

8. Study on Lattice with Magnet-free Long Straight Sections

Aiming toward the installation of four magnet-free long straight sections (LSSs), we fixed the basic lattice parameters in autumn 1998 by optics mapping [18]. Here, we considered (i) the possibility of lowering natural emittance to 5 nmrad, (ii) an optics flexibility at both LSS and normal ID sections, (iii) reuse of existing quadrupoles that would be removed, (iv) minimum modification of the ring, and (v) maximum length of a magnet-free straight section.

Each LSS has a drift space of about 27 m, which is sufficient for the installation of an insertion device. A matching section at each side of the LSS is about 10 m long and composed of a quadrupole sextet.

References

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