BEAM DIAGNOSTICS OF CENTRAL JAPAN SYNCHROTRON RADIATION RESEARCH FACULTY ACCELERATOR COMPLEX

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Abstract

A new synchrotron radiation facility, Central Japan synchrotron radiation research facility (tentative name) has been built in Aichi area, Japan. Principal diagnostics system for the accelerator complex has been installed and data have been obtained on beam profile, beam position, current and betatron tunes. Using the diagnostics system, the accelerator complex has been successfully commissioned.

INTRODUCTION

Central Japan synchrotron radiation research facility (tentative name) is constructed in collaboration between Nagoya University, Aichi prefectural government, Aichi Science & Technology Foundation (ASTF), industries and other universities in Aichi area. The main aim of the facility is to provide synchrotron radiation for researches and industries.

Basic design of the accelerators including beam diagnostics system was done by Nagoya University and mechanical design of the accelerator components was done by Toshiba Corporation and Nagoya University. Construction and installation of the accelerator components was done by Toshiba Corporation.

Construction of the facility started in 2010 and finished in Apr. 2012. Commissioning of the accelerator complex started in Mar. 2012. At each stage of the commissioning, the beam diagnostics system played an essential role. In this paper, the beam diagnostics system and the data taken with the system during the commissioning is described.

OVERVIEW OF ACCELERTOR COMPLEX

The Central Japan Synchrotron Radiation Research Facility's accelerator complex consists of a 50 MeV linac, a 1.2 GeV booster synchrotron and a 1.2 GeV storage ring. As shown in Fig. 1, main accelerator components are installed in a shielding wall.

Table 1: Parameters of Accelerator Complex

Storage ring	
Electron energy	1.2 GeV
Circumference	72 m
RF frequency	499.654 MHz
Beam current	> 300 mA
Natural emittnace	53 nm-rad
Betatron tune	(4.72, 3.23)
Normal bend	1.4 T, 39 deg.
Superbned	5 T, 12 deg.
Booster synchrotron	
Electron energy	50 MeV - 1.2 GeV
Circumference	48 m
RF frequency	499.654 MHz
Natural emittnace	220 nm-rad
Repetition rate	1 Hz
Injection linac	
Electron energy	50 MeV
RF frequency	2,856 MHz
Repetition rate	1 Hz
Gun Pulse length	0.56, 0.70, 1.05 nsec

A short bunch (< 1 nsec) electron beam generated by a thermionic electron gun is accelerated by the linac to 50 MeV. Injection of the electron beam bunch to the booster synchrotron is made on axially using a kicker magnet. The booster synchrotron is designed to be compact and therefore the mechanical aperture is small. For example, the gap height of the bending duct is only 16 mm.

The accelerated electron beam to 1.2 GeV is extracted by a kicker magnet and injected into the storage ring using 4 kicker magnets. The storage ring has a special feature that hard X-ray SR can be produced from 4 superconductive bending magnets (super-bend). The injector works at 1 Hz. The circumference of the storage ring is 72 m and frequency of the acceleration cavity is 499.654 MHz. The control system of the accelerators is based on EPICS. Parameters of the accelerator complex are shown in Table 1. A detailed description of the accelerators can be found in [1].

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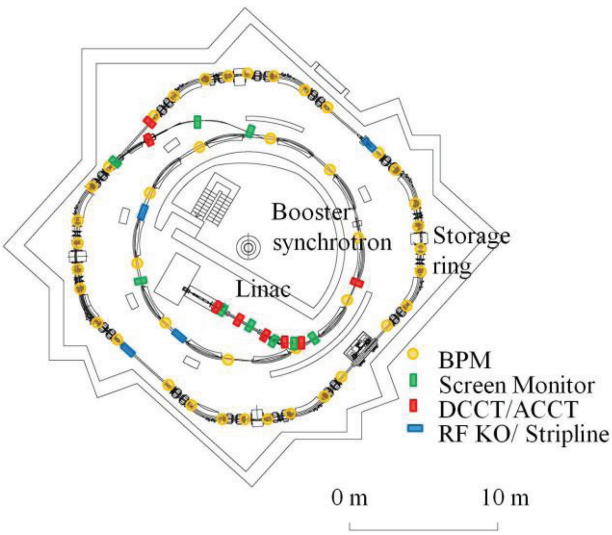

Figure 1: Schematic drawing of accelerators and monitors.

BEAM DIAGONSIC SYSTEM AND INITAL RESULTS

We adopted mature standard devices such as Bergoz ICT for the beam diagnostics. Therefore no novel beam monitoring system was used except for a single pass beam monitoring system and a betatron tune measurement system.

Linac and Beam Transport Line

The 50 MeV linac system is made of a thermionic gun, a pre-buncher, a buncher-accelerator, two regular accelerators and a beam transport line with a 30 deg. bending magnet. Standard Bergoz FCTs are installed just after the gun, between the buncher-accelerator and the regular accelerators and after the bending magnet. A Bergoz ICT is installed just after the bending magnet to measure correct accelerated beam charge. Screen monitors are installed between buncher-accelerator and the regular accelerators, between the two regular accelerators and just after a Q-doublet. The screen is made of a standard alumina sheet. Beam image on the screen is taken by a fast gated CCD camera. Using the screen monitor after the Q-doublet, Q-scan experiment was carried out. Transverse beam emittance and betatron functions are estimated with the Q-scan method and an example is shown in Fig. 2. Using the estimated betatron functions, the beam optics of the transport line was calculated to match into the booster synchrotron.

Booster Synchrotron

In the booster synchrotron, screen monitors are installed just after the injection kicker and at the 7th straight section. Looking at the monitors, initial beam transport parameters were determined. A turn by turn

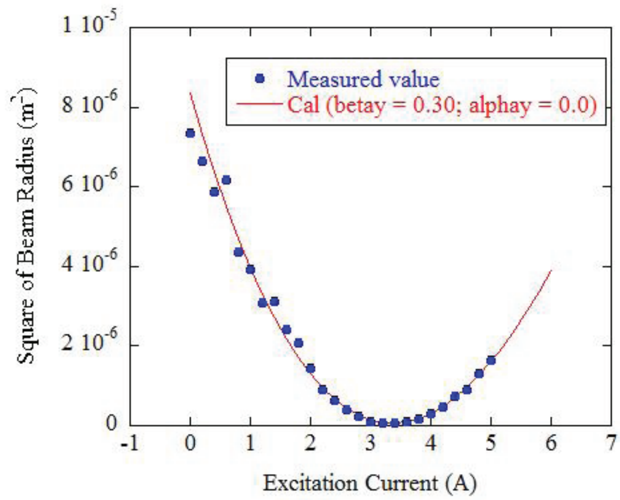

Figure 2: Example of data measured by Q-scan method. Deduced normalized vertical emittance is 42 mmmrad.

BPM system which has been developed at UVSOR [2] was used to adjust the injection parameters so that the electron beam can circulate for many turns in the booster synchrotron. In the turn by turn BPM system, 4 electrode signals are basically fed to a digital oscilloscope (LeCroy 620Zi) and they can be switched over from one BPM to another BPM quickly. The orbit of the stored beam was measured with Bergoz MX-BPM modules. To detect the beam orbit during the ramp up, a fast read out system of Bergoz analogue output signal has been developed. It allows detection of the orbit at 1 msec step during the ramp process.

The betaron tune of the booster synchrotron during ramp up was measured using a tune measurement system. The block diagram is shown in Fig. 3. RF signal, frequency-modulated with noise is generated from an arbitrary wave generator (Tektronix AFG3252). Normally the frequency is chosen near the expected

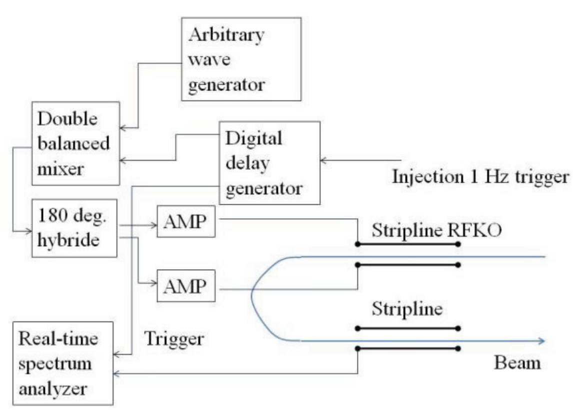

Figure 3: Block diagram of tune measurement system.

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Figure 4: Electron beam profile measured using SR monitor. The stored beam current is 7 mA single bunch. Deduced horizontal beam size is less than 1 mm.

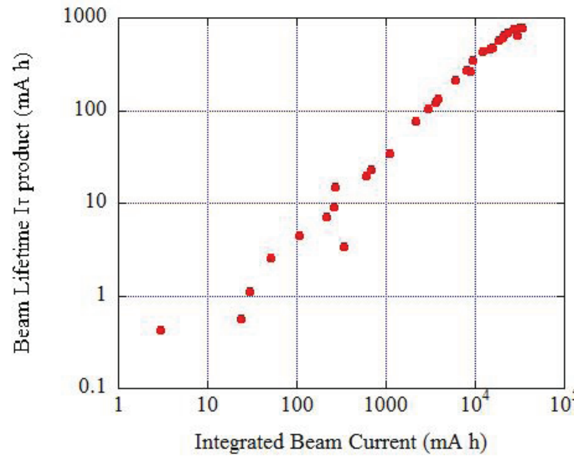

Figure 5: Beam lifetime versus integrated beam current from the start of the beam storage.

betatron frequency. This signal is then multiplied in a double balanced mixer with a gate signal generated in a digital delay generator (SRS DG645). After being split by a 180 deg. hybrid and amplified by 60 W amplifiers, the signal is applied to a stripline-type RFKO. The beam oscillation is detected with another stripline pickup and the frequency is analyzed with a real-time spectrum analyzer (Tektronix RSA3303) triggered by the same gate signal from the digital delay generator. At the initial stage of the booster synchrotron commissioning, we observed the betatron tune varying during the ramp up process. With the tune measurement system, we tuned the betaron tune by changing excitation current to Q magnets step by step.

The circulating beam current in the booster synchrotron is measured using a DCCT Bergoz NPCT which can operate at 10 KHz.

Storage Ring

The accelerated beam to 1.2 GeV in the booster synchrotron is transported to the storage ring. The beam trajectory was tuned looking at 3 screen monitors in the transport line.

As already mentioned, 4 super-bends are installed in the storage ring. Therefore the electron beam circulates through 4 super-bends and 8 normal (1.4 T) bending magnets. In the initial stage of the commissioning, we could not circulate the electron beam for many turns because of unbalance of magnetic field between the super-bends and normal bending magnets. Using the turn by turn BPM system, we tuned the excitation current of the super-bends and could store the electron beam. After successful storage of the electron beam, we measured the beam orbit using Bergoz MX-BPM modules with a Cosylab microIOC analogue to digital module. The system works but we sometime observed that the operation becomes unstable. We are searching for the cause now.

A synchrotron radiation monitor has been installed at a normal bending magnet beamline (BL9N). Visible SR is reflected by a water cooled mirror by 90 deg. upward. The mirror is made of cupper coated by gold. The SR is transported outside the shield wall by aluminium mirrors. The observed beam profile is shown in Fig. 4. With the SR monitor we could observe beam instabilities due to ion trapping and some other sources.

PRESENT SITUATION OF COMMISSIONING

Figure 5 shows measured beam lifetime ($I\tau$) as a function of the integrated beam current of the storage ring starting from the successful beam storage on July 2012. At the beginning, the lifetime was 0.4 mA*h. After beam scrubbing, the stored beam current exceeds 300 mA and the lifetime becomes around 800 mA*h (Sep. 26 2012). Although there are some problems which should be solved, we think we are close to completion of commissioning.

Commissioning of beamlines has already started, ready for the first user FY2012. We are now providing SR for the beamline commissioning.

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