Synchrotron and Storage Ring

1. Synchrotron

Although the original computer-control programs were able to achieve beam commissioning and constant beam operation of the booster synchrotron, a new control program was implemented to integrate the computer-control systems of the SPring-8 accelerators. This new control program was developed from a program coded specifically for the SPring-8 storage ring. It was designed for improved usage of the synchrotron and was tested without interrupting the beam operation of the storage ring. Since January 1999, the synchrotron has been operated with this new control system for the SPring-8 accelerators [1].

Since the autumn of 1998, we have been able to use short-bunched electron beams of 1 ns bunch-length in the SPring-8 linac. In the short-bunched beam structure, the bunches neighboring the target one have low beam current, with intensities of about 10^{-3} times that of the target bunched beam. In the synchrotron, a non-target beam is shaped to form a single bunch beam by the RF-KO system. The current intensity of a single-bunched beam is generally 0.4 mA with DCCT in the synchrotron in the beam-injection mode of the storage ring. Beam currents in the synchrotron-operation mode are shown in Fig. 1, and the current intensity of the single-bunch mode operation in the synchrotron is increased with the 1 ns linac-beam. We replaced the main amplifier and power-transferred line of the RF-KO system with a new RF-KO system (Amplifier Research Co.) to improve the purity of the single-bunch beam in the storage ring. Its RF output power is five times higher than that of the old one in pulse operation. The lowest impurity level of the single bunch beam in the storage ring was less than 2×10^{-8}, and that in user time was 2×10^{-6} [2].

We are using two klystrons in the Synchrotron as the RF source of the accelerating RF-cavities. Only one of them has been changed, due to vacuum problems at the RF window. The operation time was 6,000 hours.

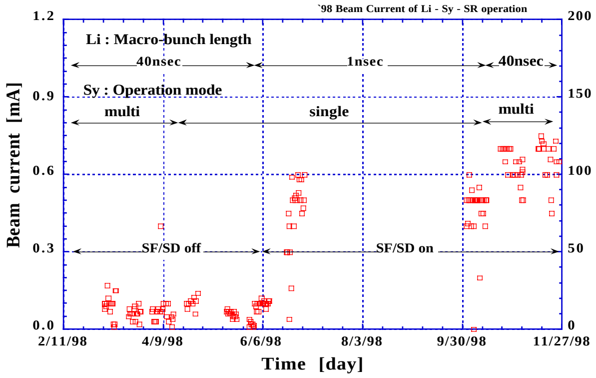

Fig. 1. Beam currents in the synchrotron-operation mode.

In 1998, synchrotron operation was disturbed by some troubles. These problems are classified in Fig. 2 classified by instrumental groups: RF, magnet, vacuum and computer-control systems. RF problems accounted for almost all troubles in the synchrotron; these happened at the beginning of the phase-pattern control of the RF due to the accelerating power of the klystrons. Because the phase-pattern control starts one hour before the operation and recovers the RF system, these RF troubles do not require interruption of the beam operation. Other problems due to the control system seemed to increase in November 1998, and these forced us to interrupt the synchrotron operation in order to carry out checks of the new computer-control system, which were carried out in non-operation time.

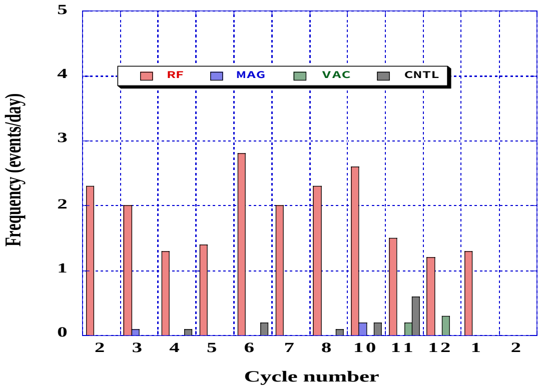

Fig. 2. Histgram of troubles in the synchrotron.

2. Storage Ring

2.1 Magnets

Water temperature fluctuation in the water-cooling system, which is expected to maintain the temperature of the magnets, vacuum chamber and the front ends of the beamlines at a constant value, was measured to be 5˚C in maximum fluctuation. With the Equipment Control Division, we replaced the control logic of the cooling system with a new logic, in which the response curve of the feedback loop suppressing temperature fluctuation was changed from a step curve to a continuous one. As a result, temperature fluctuation has been suppressed to 0.3 ˚C since October 1998 [3].

We also started new designs for projects such as construction of a 30 m long straight section, re-construction of septum magnets #5, #6 and #7 of the beam-injection system to realize top-up operation, new skew Q-magnets to select the coupling strength and several other improvement efforts.

Instrumental troubles with the magnet system also occurred and the causes were identified as 1) three power supplies of the correction magnets and one power supply of the sextupole magnets, 2) irregular data-transfer through the I/O bus between the central-EWS and I/F of the bump 1 power-supply, and 3) interlocking of the water flow of the sextupole magnets. Corresponding solutions were 1) replacing some parts of the control units with new ones, 2) under investigation, and 3) decreasing the limit level of the water-flow monitor. The latter countermeasure was taken because the old level was estimated based on the water-flow ability of the hollow conductor, which makes up the coils of the magnets; however, the new limit-level is determined by increasing the coil temperature with the magnet current in stationary operation.

2.2 RF System

We planned to utilize higher RF accelerating voltage for the cavities in the storage ring and have begun improvement of the RF system at the A-station. In order to increase the output power of the RF system, we increased the ability of the water-cooling system in the first stage of this improvement.

The causes of instrumental problems in the RF accelerating system were identified as 1) decreased quality of the CCG heads, 2) decreased flow in the water cooling system, and 3) arch discharge in the circulators. These problems were solved by 1) replacing the old CCG heads with new ones and adding extra other new heads (we decide on one CCG head to measure the vacuum pressure during the baking period and other ones for the usual ultra-high vacuum), 2) instructing the Equipment Control Section to suppress the fluctuation in the water flow, and 3) preparing arch detectors to observe the arch discharge, which we doubt occurred in the circulators, and inquiring to ANT about irregular operation of the arch detectors that were equipped with the circulators. The klystron of the RF D-station was replaced with a new one for the first time. Before replacement, this klystron had an operation time was 8,000 hours.

2.3 Vacuum

A straight section chamber (SS3C), a bending magnet chamber (BM2C), a crotch section chamber (CR2) and a bellows chamber (BE2C) at the No. 33 cell had been replaced by new ones for the laser-electron-photon beamline BL33LEP. New photon absorbers were also installed in the new vacuum chambers, SS3C and CR2. The main pumping system of the storage ring consists of distributed non-evaporable getter (NEG) strips, a concentrated pumping system using a lumped NEG pump (LNP), and a sputter ion pump (SIP) during normal operation of the vacuum system. However, four sets of turbomolecular pumps were used for the evacuation of outgases by the synchrotron radiation (SR) irradiated from the new photon absorbers when the operation of the storage ring was restarted after the summer shutdown period.

In the summer shutdown period of 1998 for the second year running, all of the NEG strips and the LNP were re-activated at a temperature of 450 °C for approximately 60 minutes without chamber baking. As a result, the averaged pressure readings of the storage ring are 1×10^{-8} Pa without stored beam, 1×10^{-7} Pa at the SSC and 9×10^{-7} Pa at the crotch and absorber location with a beam current of 70 mA.

The nylon tubes used for the compressed air that drives the remote-controlled vacuum valves and the absorber shutter burst in succession due to the radiation damage in the storage ring tunnel. All the nylon tubes were replaced by stainless steel.

In order to prepare a new dummy chamber suitable for the rest of the space in the straight section of No. 4 cell, the dummy chamber was replaced by two gate valves and four vacuum chambers during the winter shutdown period. Between the gate valves, we inserted a dummy pipe with a pumping port and three bellows chambers for quick change without baking. When we make a new device with a length of up to 530 mm, we can easily insert the device in the straight section of the No. 4 cell without remaking other chambers. The pumping system, which consists of a SIP, a titanium sublimation pump and an all-metal angle valve, was connected to the pumping port. During the bakeout, the turbomolecular pump is attached to the pumping port. The pressure in the straight section was recovered to the order of 10^{-8} Pa after 24 hours baking.

New vacuum chambers will be installed at No. 43 cell for the infrared beamline BL43IR in the summer of 1999. These new ones consist of a crotch chamber equipped with a copper mirror and a bending magnet chamber that has a different cross section than a conventional bending magnet chamber for extracting the infrared component of SR.

The design work on new vacuum chambers for a 30 m long straight section has been started. Those chambers will be installed on the storage ring in the summer of 2,000 with re-arranged magnets and a long insertion device.

2.4 Beam Diagnostics

2.4.1 Beam Position Monitors (BPM)

The BPM signal processing electronics circuits for COD measurements was improved. Current dependence and filling dependence of COD measurements, which were undesirable phenomena, were reduced to a level within the repeatability of COD measurements. The solution was to put a narrow band-pass filter and isolators in front of the RF block of the electronics. After that, the measured position data agrees within a repeatability range of a few microns, regardless of the filling pattern and stored beam current up to 1 mA or more. The detailed report is presented in Ref. [4].

2.4.2 Beam Diagnostics using Visible SR

The photon counting system used for the single-bunch impurity measurement [5] was installed at the end of the photon extraction line of the No. 38 cell in the storage ring. At this line, the visible component of SR has been led into a darkroom prefabricated in the experimental hall. Optical components of the photon counting system were set up in the darkroom. A micro-channel plate type photo-multiplier tube (MCP-PMT) was used as a detector. The output pulses of the MCP-PMT are discriminated after amplification. We use two discriminators (LLD and ULD) to improve the S/N ratio of the time spectra. The time interval between the output of the LLD and the timing signal synchronized to the bunch revolution is converted to the pulse height by a time-to-amplitude converter (TAC). The pulse height distribution of TAC is analyzed with a multi-channel analyzer (MCA). Not only the single bunch mode, but also many kinds of several-bunch operation modes are available with the storage ring, for instance a 21-bunch mode of equal spacing. According to the filling pattern, we change the dividing factor n of a circuit that divides the RF signal to output the timing signal and then measure the averaged time spectrum of plural bunches circulating in the storage ring. We cannot find any unwanted satellite bunches around the main bunch. The sensitivity of the impurity measurement is 7×10^{-7} (measurement time: 1,000 seconds), which is limited by the S/N of the MCP-PMT.

A beam profile monitor using visible SR was also installed in the line of No. 38 cell. This monitor images the electron beam in a bending magnet by using the visible part of the SR spectrum. The visible light was imaged on a CCD camera by two achromatic doublet lenses. The imaged light was monochronized by a bandpass filter attached to the CCD camera, of which the center wavelength and the FWHM are 546 nm and 10 nm, respectively. A linear polarizer was placed in front of the CCD camera to select the component parallel to the electron orbit plane in a bending magnet. This monitor was applied to the horizontal beam size measurement and the test experiment to develop an SR interferometer by using a double slit. In the test experiment, the correlation curve was measured between the visibility and the vertical beam size, controlling by the nominal coupling ratio in the storage ring. These measurement conditions are deteriorated by stray light from reflections inside the vacuum chambers and multiple peaks due to the mirror fabrication error. It is necessary to improve the vacuum chambers with large apertures and the mirror with tight tolerances.

2.4.3 Construction of Beam Diagnostics Beamline BL38B2

Construction of dipole-magnet beamline BL38B2 has started. This beamline is designed for accelerator beam diagnostics and R&D of accelerator components. Planned research subjects include: 1) accelerator beam diagnostics, such as measurement of the transverse beam size, bunch length, single bunch impurity and so on, and 2) R&D of accelerator components, such as measurement of photon stimulated desorption of gas molecules from vacuum component materials, development of high heat load components such as photon beam absorbers, development of photon beam position monitors and various other endeavors.

A distinctive feature of the beamline is high throughput. The horizontal angular opening of SR is 4 mrad, which is twice that of conventional B2 beamlines. The beamline transports to experimental devices wide spectral regions of SR including visible and UV light as well as soft and hard X-rays. The beamline has a large vertical aperture of 6 mrad so that low energy SR components such as visible and UV light can be efficiently extracted. The design and manufacture of UHV components at the front end have been completed, and they will be installed in the storage ring tunnel during the summer shutdown period in 1999. An optics hutch of 18 m length will also be constructed in the experimental hall in the summer of 1999.

References

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