Present status of HiSOR

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Abstract

The HiSOR is a compact synchrotron radiation source at Hiroshima University composed of a 700 MeV storage ring and a 150 MeV injector microtron. It has been operating stably since 1997. An electron beam of 200 mA is stored with a lifetime of 12 hours. Performance improvement program is in progress.

1. Introduction

The HiSOR is a compact synchrotron radiation (SR) source consisting of a 700 MeV storage ring with a 150 MeV microtron as a injector[1-3]. It was completed in 1997 and, after the commissioning operation for one year, was opened to users in 1998.

The HiSOR storage ring is composed of two 180° bending magnets and two long straight sections where a linear and a linear/helical switchable undulators are installed. Four quadrupole doublets are equipped at the ends of the undulators. The magnetic field of the bending magnet is as strong as 2.7 Tesla, and the critical wave length of the SR from the bending section is 1.42 nm.

At HiSOR facility, a small ring called REFER (Relativistic Electron Facility for Education and Research) is operating in addition to the SR source. The 150 MeV microtron provides this ring with electrons.

Since the machine group consists of only two persons, the machine studies have been carried out with collaborators from KEK, Nagoya University, IMS and the industry.

2. Operation status

The weekly operation schedule is such that Monday is devoted to the machine study and maintenance, and Tuesday through Friday is for stationary use of the SR for experiments. The daily operation mode for user's days is such that the beam injection to the storage ring is made around 9 o'clock and the beam is dumped around 18 o'clock.

From the formal start of operation in 1998 until March 2000, the maximum authorized stored-current for the HiSOR storage ring was 100 mA. The reason of suppressing the maximum stored current was that rather short lifetime of the stored beam might cause non-negligible radiation around the ring. Owing to the upgrade of the vacuum system and the bake-out by SR in fairly long term, the vacuum degree was greatly improved and hence the beam lifetime became much longer. We then made preparations for the operation with stored currents over 100 mA, and got an approval from the radiation control authority for the operation with a stored current of 200 mA at maximum.

We successfully started the operation with stored currents close to 200 mA at the beginning of fiscal 2000. Typical changes of the stored current and the instantaneous lifetime during a cycle of operation are shown in Figure 1.

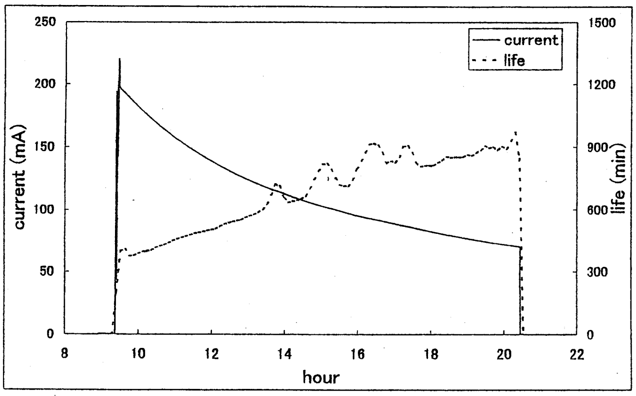

Fig.1. Typical changes of the stored current and the instantaneous lifetime during a cycle of operation.

The beam lifetime is about 6 hours at the initial current of 200 mA, whereas it is about 13 hours when the current decreases down to 100 mA. The improvement of the beam lifetime is now at a saturation level.

Scheduled shutdowns of the light source and the microtron is made for five weeks in summer, three weeks around New Year's day and one week each in the sessions of Japanese Physical Society of Japan in spring and autumn. The annual overall maintenance of the SR source system is made during summer shutdown period.

3. Construction of a beam diagnostics beamline

For the machine studies as well as for the stable operation of the SR source, it is indispensable to monitor the SR, through which the behavior of the circulating electron beam can be diagnosed. So far simple beam-diagnoses have been made at very narrow space. In order to facilitate more sophisticated diagnosis, a new beamline dedicated to the beam diagnosis is under construction[4]. Outline of this beamline is as follows.

The vertical positions of the SR are measured by two wire-monitors which are located 3.15m and twice the distance downstream from the source point. By measuring the beam position at two points, we can know the emission angle of the SR. A consecutive data logging will reveal possible drift of the beam position and emission angle.

The wire monitor has two sense wires at both sides of the light beam and automatically moves in vertical direction to equate both photoemission signals from two wires. The instantaneous beam position is given by a linear encoder. This self-tracking mechanism, suggested by T.Miyahara et al.[5], ensures that two wires are always irradiated by the same amount of light, and makes the position measurement free from the error caused by unbalanced degradation of the sense wires due to unbalanced irradiation of the SR. Switching from the self-tracking mode to the scan mode, we can also get the vertical profile of the beam.

The SR is, behind the second wire monitor, reflected downward by a mirror and, after passing through a window, further reflected by another mirror in air toward an optical system on a precision table. A half-mirror on the table divides the light beam into two ways; one is to measure the time structure of the beam by a streak camera, and another is to observe the transverse position and profile of the beam by a CCD camera. Other devices for beam monitoring can be introduced on the table.

4. Bunch length measurement

Measurement of the bunch lengthening gives the information on the interaction of the electron beam with the surroundings along the beam. We originally aimed at measuring the impedance of the HiSOR storage ring by observing the bunch lengthening of a single bunch under the influence of short-range wake fields. The measurement, however, suggested that the bunch lengthening at the 150 MeV operation was dominated by a coupled-bunch instability even in a single bunch operation.

Figure 1 shows the bunch length in operations at 150 MeV and 700 MeV as a function of the beam current per bunch.

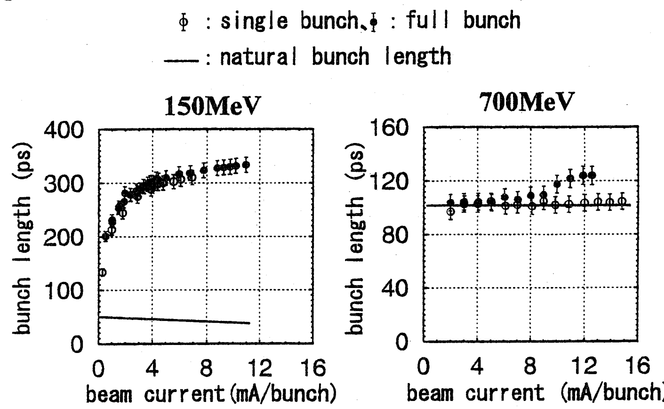

Fig.2. Bunch lengths as a function of the beam current at 150 MeV and 700 MeV operation.

The measurement of the bunch length was made by observing the SR with a streak camera. The bunch configuration in the ring was controlled using the rf knockout method to be a single bunch, two bunches at symmetric positions and full 14 bunches. In the figure, the bunch lengths for single bunch and full bunch operations are shown, the bunch lengths for two bunch operation being similar to those for the single bunch operation. Curves in the figure are calculations of the natural bunch length.

It is seen from the figure that the bunch lengths at the 150 MeV operation are much lengthened from the natural bunch length for both single and full bunch operations. At the 700 MeV operation, the bunch lengths are equal to the natural ones below the beam current of 7 mA, at which the bunch length for the full bunch operation begins to deviate from the natural one.

In order to investigate the origin of the bunch lengthening, we have made a frequency analysis of the beam in relation to the frequency component of the electromagnetic field in the rf cavity using a spectrum analyzer. When the bunches are lengthened than natural ones, at both 150 and 700 MeV operations, we have observed clear peaks in the frequency spectrum of the beam at the frequencies $nf_{rf}\pm 12f_{rev}+f_s$, where n, f_{rf}, f_{rev}, and f_s are the positive integer, the rf acceleration frequency, the revolution frequency and the synchrotron oscillation frequency, respectively. In this case, the frequency spectrum of the rf shows a distinct peak at 1.311 GHz, which corresponds to $6f_{rf}+12f_{rev}$. The threshold current at which the bunch lengthening occurs in 700 MeV full bunch operation coincides exactly with the one at which the rf spectrum begins to show the 1.311 GHz peak.

These facts strongly suggest that the bunch lengthening is caused by a coupled-bunch instability of mode 12 due to some higher order mode of the rf cavity. The bunch lengthening of the single bunch at 150 MeV can be interpreted as that even a single bunch, when the energy is not high, can suffer from a coupled-bunch instability in such a small ring as HiSOR.

Higher order modes of the rf cavity have been explored with the model cavity and the real cavity using a network analyzer. Among many peaks in the frequency spectrum, there exists one peak which is close to 1.311 GHz. On the other hand, we have calculated the electromagnetic field in the cavity using the three-dimensional computer code MAFIA. The calculated result shows that the relevant peak corresponds to a TM022-like mode, which generates a longitudinal electric field on the axis. These facts support that the bunch lengthening is caused by the coupled-bunch instability.

A simple image of the bunch lengthening mechanism is that the fundamental electric-field in the cavity is deformed by the wake field of 1.311 GHz TM022 mode, which acts for the bunches to lengthen along the longitudinal direction. We have made a simulation of the bunch lengthening under the superposed electric field of the form

$$V_0\{\sin\phi_s + k\sin(n\phi_s+\phi_h)\},$$

where V_0 is a peak electric field of the fundamental mode, ϕ_s is the synchronous phase, n is equal to $(6f_{rf}+12f_{rev})/f_{rf}$, ϕ_h is the phase difference between the fundamental and the higher order mode, and k represents the relative strength of the higher order mode. The derivative of above expression gives a electric field gradient at the bunch and determines the bunch length. By appropriate choices for the values k and ϕ_h, the experimental results can be reproduced.

5. Expected improvements

Further improvements expected for the HiSOR storage ring are, as for general SR sources, to improve the beam stability and to increase the beam current.

Generally the accelerator suffers the drift of beam parameters from the temperature change after the start-up of the operation until the temperature equilibrium is attained. Since the operation of the HiSOR storage ring is started and stopped every day, the beam drift continues throughout a day. The beam position monitor (BPM) installed in the ring sometimes shows a beam movement of one hundred μm in the vertical direction and two hundreds μm in the horizontal direction in one day. The closed orbit correction relying upon BPM indication does not restore the light beam position. Since the BPM indication may include the drift of the monitor itself, we installed micrometer on a firm base to measure the relative movement of the BPM housing. It proved that the drift of the BPM itself was about ten μm showing that most part of the BPM indication is attributed in practice to the movement of the electron beam position. Although the present amount of the drift is not very serious for experiments by using the light, we are now searching for the accelerator components that influence the electron and light beam positions through the temperature change. Precision tilt meters are installed on the bending magnet by courtesy of KEK.

The design value for the stored current of HiSOR storage ring is 300 mA, while presently attained value is 200 mA. It has been proven that the beam instability due to some higher-order-mode of the RF cavity limits the maximum stored current in the injection at 150 MeV. We are discussing to introduce a higher order mode damper to the RF cavity.

References

[1] K.Yoshida et al., J. Synchrotron Rad.(1998).**5**,345

[2] K.Yoshida et al., Proc. First Asian Particle Acc. Conf. KEK, Tsukuba(1998) 653

[3] K.Yoshida et al., Proc. Proc. 12th Symp. Acc. Sci. and Tech., RIKEN, Wako(1999)54

[4] K.Umemori, et al., in these proceedings.

[5] T.Miyahara and T.Mitsuhashi, Rev. Sci. Instrum. 63(1), 538(1992).

[6] T.Fujita, et al., in these proceedings.