Measurement of Beam Parameters on the Synchrotron Light Source HiSOR

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Abstract

A tune measurement system based on the RF knock-out method has been introduced to the synchrotron light source at Hiroshima University, HiSOR. This paper describes measurements of the tune for various operating conditions and the tune-related beam parameters of the HiSOR storage ring.

1 Introduction

The 700 MeV synchrotron light source at Hiroshima University, HiSOR has been operating since April 1997 [1,2]. The HiSOR storage ring is of a racetrack type consisting of two 180° bending magnets with edge focusing and four quadrupole doublets [3,4]. At each straight section, a linear and a helical undulator are installed. Major orbit elements of the ring are shown in Fig.1. Main parameters of the ring are shown in Table 1. The maximum stored current at present is 100 mA, limited by the radiation level around the ring.

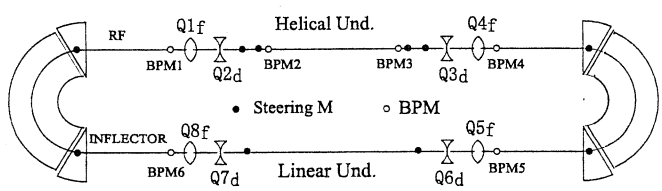

Fig.1 Main orbit elements of HiSOR storage ring.

Table 1
Main parameters of HiSOR storage ring

Energy	700 MeV
Circumference	21.946 m
Bending Radius	0.87 m
Betatron Tune, Horizontal	1.672
, Vertical	1.724
RF Frequency	191.244 MHz
Harmonic Number	14
RF Voltage	220 kV
Stored Current (Max.)	100 mA
Beam Lifetime	8 Hours

In 1998 a tune measurement system based on the RF knock- out (RFKO) method was introduced to HiSOR [5]. In addition to the tune survey, we have measured tune-related beam-parameters such as betatron function, chromaticity and an effect of an ion clearer on the tune. We have also measured another basic parameter, the dispersion function of the ring. The results of measurement are described in the following sections.

2 Tune Measurement System

The betatron oscillation is detected through an electrode of the beam position monitor of button type and analyzed by a spectrum analyzer. The spectrum line of the betatron oscillation is expected to appear as the side band of integer multiples of the revolution frequency ω_0 as $n\omega_0 \pm q\omega_0$, where q is a decimal part of the betatron tune. The frequency range of the spectrum analyzer is set around $2\times\omega_{rf}$, where ω_{rf} is the RF frequency, since the electrode of button type has sensitivity above 300 MHz. For exciting betatron oscillation, an RF power with the frequency sweeping up to ω_0 is applied to the kicker electrode.

3 Result of Measurement

3.1 Tune Survey

The first measurement of the tune on HiSOR showed that both horizontal and vertical tunes were different from design values, as shown in Fig.2. Possible reason of the disagreement between the measurement and the beam optics calculation is the incorrect relation of the exciting current of the quadrupole magnet with the field strength (k-value) of it.

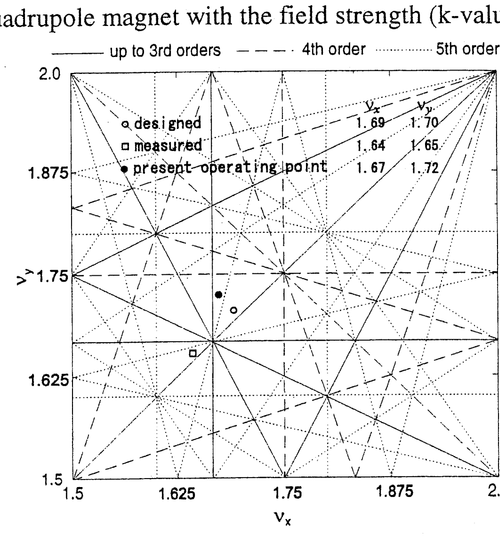

Fig.2 Tune diagram of HiSOR storage ring.

Then we made a systematic measurement on the relation between the tunes and the exciting currents for the focusing and defocusing magnets. Using the graph summarizing the results, we could move the operating point close to the designed value, as shown in the figure.

3.2 Beam-Current Dependence of Tune

Fig.3 shows the dependence of the tune on the stored beam current up to 100 mA. It is seen that the vertical tune changes from 1.509 to 1.514 while the change of the horizontal tune is small. It seems that the ion trapping affects the vertical tune for the stored currents above 40 mA.

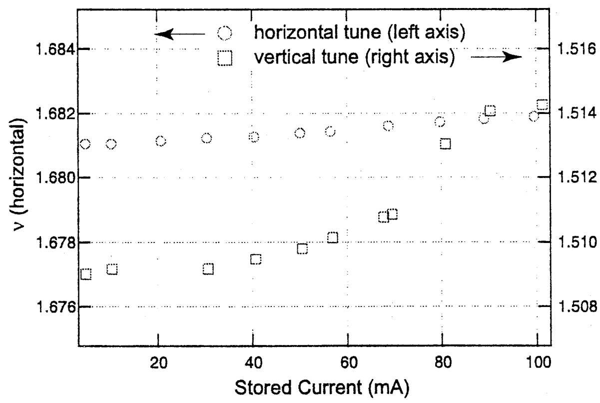

Fig.3 Beam-current dependence of the tune

3.3 Ion-Clearer Voltage Dependence of Tune

To avoid ion trapping, ion clearer electrodes are installed at four places in each straight section and in the bending magnets of the ring. We have measured the tune, varying the voltage of these electrodes at beam current of 60-100mA. The potential was applied only to upper electrodes, the lower electrodes being grounded. The result is shown in Fig.4, as "high current". It is seen that the tunes change drastically when some tens volts is applied, and vary slowly for higher voltages. The drastic change can be regarded as due to a rejection of trapped ion because the beam profile observed by synchrotron light shows also sudden change. The slow change at higher voltages may be the effect of the electric field of the ion clearer electrodes on the electron beam itself. Thus we have made similar measurement at low beam current 10 mA, at which the effect of ion trapping is expected to be negligible as seen in Fig.3. The results are shown in Fig.4 as "low current". This measurement was made at different operating point, then only the slope can be compared with "high current" measurement. It seems that the variation of the horizontal tune at high ion-clearer voltages is caused by the potential of the electrode, not by ion rejection. The change of the vertical tune, on the other hand, shows inclinations with opposite polarities for "high current" and for "low current". We are trying to find the cause of this phonomenon.

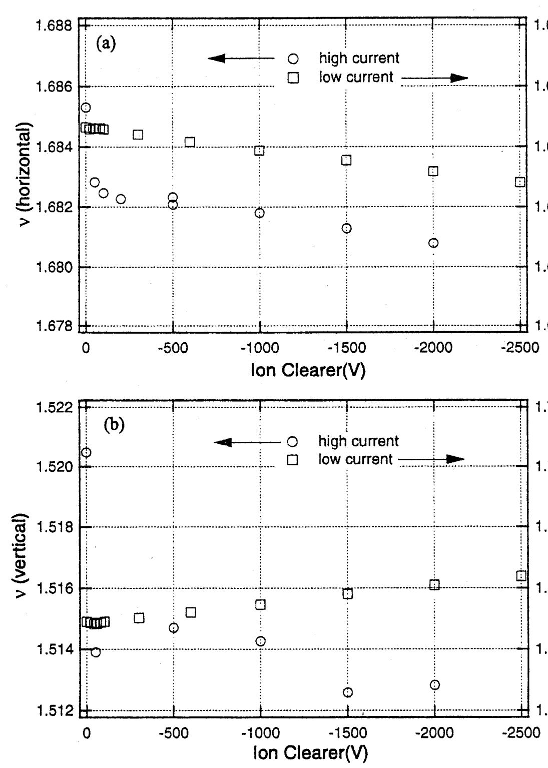

Fig.4 Tunes when ion clearer voltage is changed.

3.4 Betatron Function

The betatron function at the place where focusing element is located can be measured by using the relation

$$\Delta \nu = \beta \frac{\Delta k}{4\pi}$$

where $\Delta\nu$ is the change of the tune when the focusing power of the relevant element is changed by Δk. By connecting a current bypass circuit to the power line for the quadrupole magnet, we have measured the values of the betatron function at Q1,Q2,Q7 and Q8 (see Fig.1). The results are shown in Fig.5 together with calculated curves.

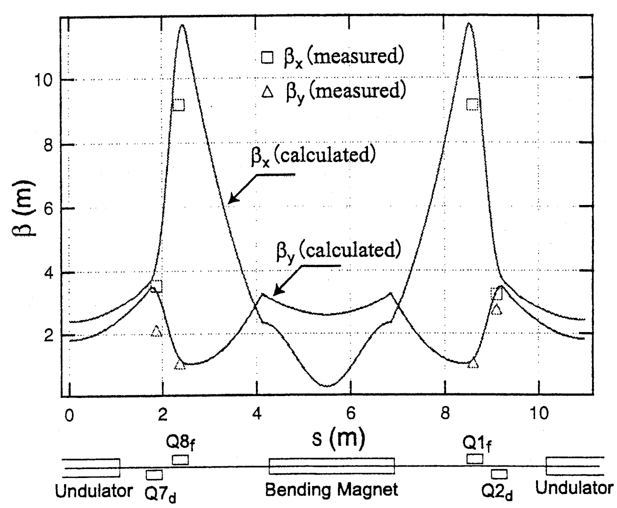

Fig.5 The betatron function of HiSOR storage ring, measured and calculated.

It is seen that measured values almost agree with the calculation, and the symmetry of the cell is satisfactory.

3.5 Chromaticity

The chromaticity can be estimated by measuring the change of the tune when the RF frequency is varied, using the relation

$$\Delta\nu = -\xi \frac{1}{\alpha}\frac{\Delta f_{rf}}{f_{rf}}$$

where α is the momentum compaction factor. We have calculated the value for α to be 0.1435, assuming k-values that reproduce the actual tune value (see section 3.1). The resulting value for the chromaticity is shown in the column [a] in Table 2. In the column [b], the natural chromaticity by usual calculation is shown. It has been pointed out that the conventional formula for the natural chromaticity is not accurate for small rings [6]. The value in column [c] is the calculation based on the second order map, which is given in the reference 6. Both calculations, however, do not reproduce the experimental value.

Table 2
Chromaticity as measured [a] and calculated [b],[c]

	[a]	[b]	[c]
ξ_x	-0.966±0.088	-2.15	-2.07
ξ_y	-2.97±0.58	-3.49	-3.51

3.6 Dispersion Function

We can obtain the value of the dispersion function, η, at the points where beam position monitors (BPM) are installed, by measuring the displacement of the beam position Δx when the RF frequency is varied by Δf_{rf}, using the relation

$$\Delta x = -\eta \frac{1}{\alpha}\frac{\Delta f_{rf}}{f_{rf}}$$

The value of η by this equation depends on the momentum compaction factor, as in the case of obtaining the chromaticity. Using the same value of α as for the chromaticity, obtained value of η at BPM2, BPM3, BPM4 and BPM6 (see Fig.1) are shown in Fig.6 together with the calculation.

The agreement between the measurements and the calculation seems not perfect. It should be noted that both of them depend on the k-values of the quadrupole, and the values employed here are hypothetical ones as mentioned in sections 3.1 and 3.5. A few percent changing of the k-value would result in agreement of the measurement with the calculation.

4 Conclusion

By introducing the tune measurement system, we are able to operate the HiSOR storage ring at any desired operating point, and to know the effect of various operating conditions on the tune. It has been clarified that the usual calculation of the beam optics using measured k-values of quadrupole magnets does not accurately predict the tune value in the case of HiSOR storage ring. Nevertheless calculations of the betatron function and dispersion function almost agree with the measurement. Now the HiSOR storage ring is under stable operation storing 100 mA with a lifetime of 10 hours. In the near future we will get approval from the radiation protection authority for the operation with 200 mA. Measurement of beam parameters will be still more important to examine possible beam instabilities for the operation with higher beam currents.

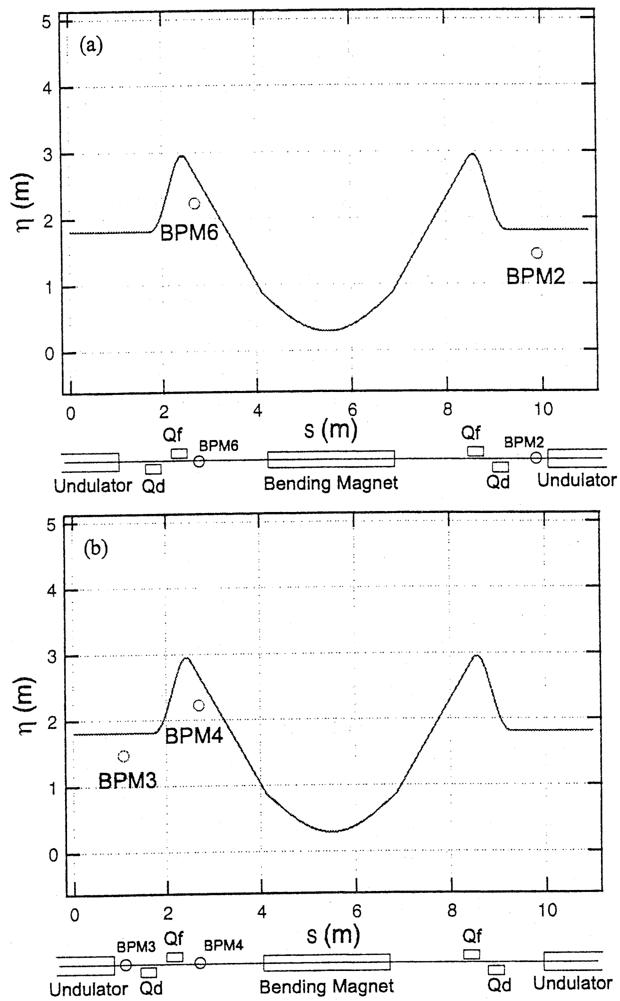

Fig.6 The eta function of HiSOR storage ring, measured and calculated.

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