THE ACCELERATOR SYSTEM FOR HiSOR

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Abstract

We have studied detailed features of the main components of the 1.5 GeV storage ring and the injector machine for HiSOR. Here we briefly report on some selected items; vacuum system, single bunch operation and superconducting wigglers. The conceptual design of the buildings is also described.

Introduction

Conceptual design of the accelerator system for HiSOR, a synchrotron radiation facility proposed by Hiroshima University, has been published in several articles.[1] Since then, we have been studying practical problems which might affect the cost and performance of the accelerator system. In this paper we first review the basic features of the HiSOR accelerator system and then describe some specific parts on which recent works have been concentrated.

Basic features

The storage ring for HiSOR is designed to have small circumference, 100 m, to be manageable by small number of operating crew. The lattice structure is a six-fold symmetric Chasman-Green DFA type to be operated at 1.5 GeV. The beam emittance is comfortably small, $7\times10^{-8}\pi$ m rad, which is a compromise of a high brilliance and a stable operation. Since the electron energy is relatively low, the SR from the bending magnet does not contain hard x-rays. This feature is most appreciated by the scientists working with VUV and soft x-rays. Hard x-rays, whose intensities are comparable to the one available at KEK-PF, are produced by the high-field wigglers placed in the dispersion-free straight sections. Main parameters for the storage ring is summarized in Table 1.

The injector is a combination of a 45 MeV linac and a 1.5 GeV synchrotron. Multiturn injection to the storage ring at 1.5 GeV is envisaged. Since the synchrotron and the linac are free except at the injection time , twice a day, some plans are going on to utilize them for nuclear physics and other applications. Table 2 shows parameters of the synchrotron.

Table 1. Parameters of the storage ring.

Electron energy	E	=	1.5 GeV
Circumference	2πR	=	100.71 m
Mean radius	R	=	16.03 m
Revolution time	T	=	335.9 ns
Superperiodicity			6
Synchrotron radiation			
Energy loss per turn	U_0	=	127.2 kV
Critical energy for normal bending section	ϵ_c	=	1.809 keV
Long straight section			6 × 4.875m
Betatron tunes	ν_x	=	5.25
	ν_y	=	2.25
Synchrotron frequency	f_s	=	26.48 kHz
Beam current	I	=	300 mA
Momentum compaction factor	α	=	0.0117
Natural Chromaticities	ξ_x	=	-10.86
	ξ_y	=	-6.90
Damping times	τ_x	=	8.24 ms
	τ_y	=	7.93 ms
	τ_e	=	3.98 ms
Energy spread	σ_e/E	=	0.00071
Emittance (zero coupling)	ϵ_x	=	$7.20\times10^{-8}\pi$ m rad

Table 2. Parameters of the booooster synchrotron.

Maximun Energy	1.5 GeV
Injection Energy	45 MeV
Repetition rate	0.5 Hz
Maximum circulating current	50 mA
Lattice	
Type	DO_1FDO_2F
Symmetry	6
Circumference	83.925 m
RF	
Harmonic number	35
Frequency	125.025 MHz
Peak voltage	150 kV
Operation mode	
Betatron tune	
ν_x	4.25
ν_y	2.25
Average β function	
$\overline{\beta_x}$	3.64 m
$\overline{\beta_y}$	2.25 m
Dispersion	
Maximum η_x	1.78 m
minimum η_x	0.23 m
Emittance at maximum energy ϵ_x	$1.2\times10^{-7}\pi$ m rad

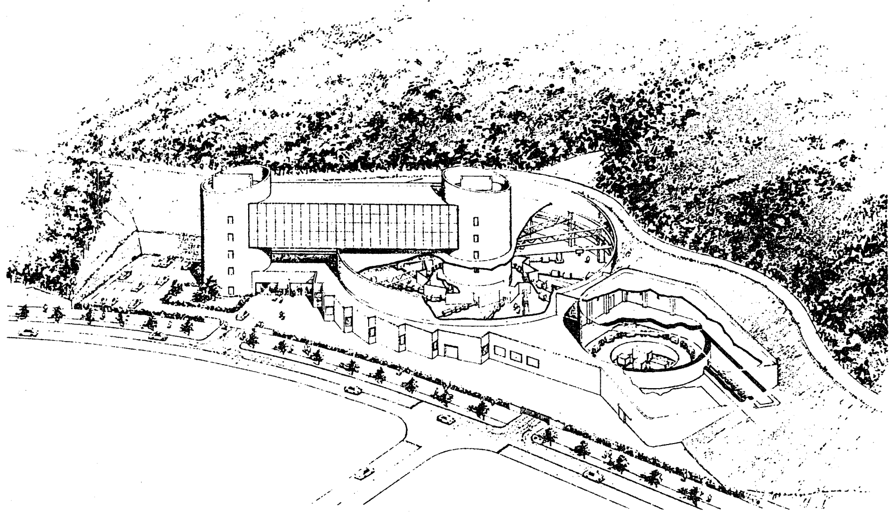


Fig.1 An arist's view of the HiSOR buildings.

Site and building

The site for HiSOR is supposed to be at the foot of a hill in the new campus of Hiroshima University in Higashi-Hiroshima city. According to the survey there is a stable granite layer under the shallow soil. We found that the amplitude of the earth vibration is very small; ideal place for constructing a storage ring. One shortcoming is that the site is not wide enough for future extension.

An artist's view of the HiSOR building is shown in Fig. 1. The main entrance for HiSOR is at the leftmost cylindrical building where an auditorium and meeting rooms are situated. Above the main experimental hall,the central cylinder of 80m in diameter, there is a corridor connecting the third and fourth floors of the left cylindrical building to the central tower where the machine control room is situated. Along the corridor we have offices for the crew and the visiting scientists. To the right, there is a building for the synchrotron and the linear accelerator. The upper level of the synchrotron is a utility room for power sources etc.

The radiation shielding problem for these buildings has been worked out, the result of which is reported elsewhere.[2]

Vacuum system

The shape of the vacuum chamber for the bending section of the storage ring needs a special design because of the following reasons:

1) The bending angle in a single magnet is large, 30 degree, so that considerable part of SR will directly hit the vacuum chamber.
2) We provide two SR ports for each bending section.
3) Single bunch operation is foreseen which requires a low coupling impedance.

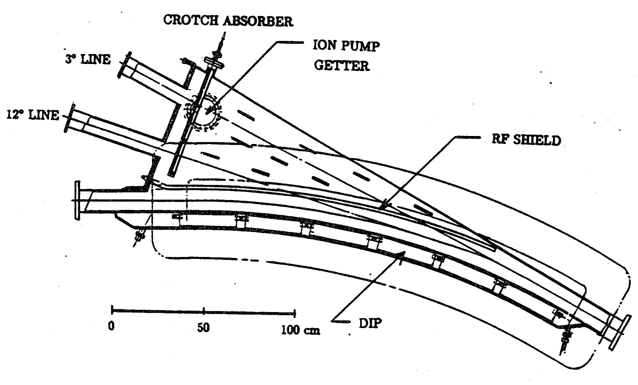
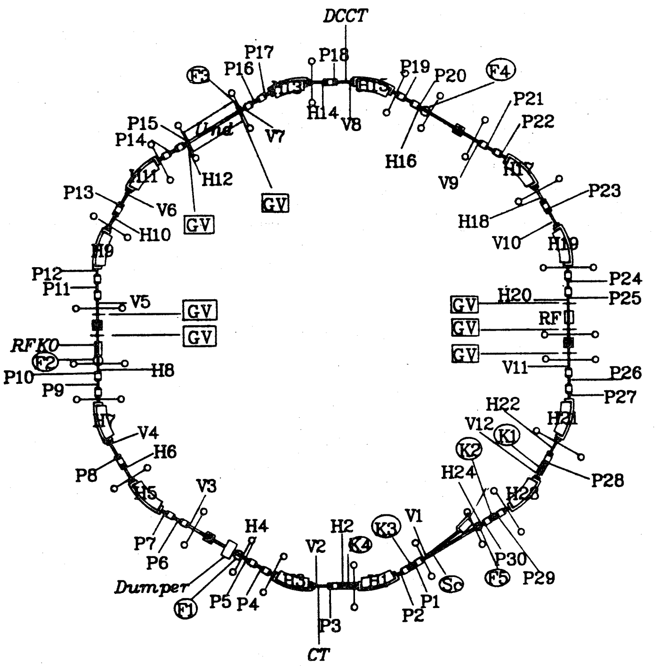


Fig.2 The vacuum chamber for the bending section.

An example of the designed vacuum chamber is shown in Fig. 2. The RF shield with small holes are provided to reduce the RF impedance. A large part of the SR is absorbed at the crotch absorber. The out gas due to photodesorption is meant to be pumped out from the port at the crotch. According to a computer simulation, good vacuum, 10^{-9} torr CO equivalent, is achieved under the circulation current of 350mA with use of high power distributed ion pumps (DIP), 400 ℓ/s/m, titan getter pumps (TGP) and sputter ion pumps (SIP).

There has also been much progress in the design of the vacuum system around the straight section. We are happy to find space, though not luxurious, for beam monitors, kickers, steerers etc., as schematically shown in Fig. 3. A simulation has shown that the closed orbit distortions can be corrected to 0.1 mm with this arrangement.



P1-P30 : Position monitors
DCCT : DC current transformer
CT : Current transformer
RFKO : RF knock out electrodes
F1-F5 : Florescent plates
V1-V12 : Vertical steerers
H1-H24 : Horizontal steerers
K1-K4 : Pulsed magnets for injection
GV : Gate valves

Fig.3 The arrangement of various components along the circumference of the storage ring.

Single bunch operation and RF

There is a strong demand for single bunch operation at HiSOR because the existing SR facilities are not quite adequate for the time-resolving measurement of various type.

In order to enjoy flexibility in number of bunches, a single, double and triple bunch modes as well as the ordinary 168-bunch mode, we are developing an electron gun which has a capability of RF modulation and fast gating.

It has been known that a part of the electrons escapes from their own RF bucket and is captured by another one due to the Tousheck effect.[3] This is most serious in the acceleration stage of the electron synchrotron. In order to ensure a good single pulse purity, we have to selectively knock out the electrons in the unwanted RF bucket by applying the fast RF pulse on the RFKO electrodes. This requires that the neighboring buckets are separated widely enough for the tail of the RFKO pulse to damp.

Thus we are tempted to use 125 MHz RF frequency for the synchrotron while maintaining the 500 MHz for the storage ring. The latter is dictated by the high power requirement. According to a standard calculation, the longitudinal beam spread at 1.5 GeV for 125 MHz RF is sufficiently small; the portion of electrons to be lost at the injection to the storage ring is less than 10^{-4}.

Superconducting wigglers

Possible effect of the strong field wiggler on the beam dynamics in the HiSOR storage ring has been well studied ; the tune-shift caused by the quadrupole component of the wiggler magnet can be compensated by readjusting the three Q magnets, two of them being situated upstream and one downstream the wiggler while the sextupole field should be kept as small as 10 /m^2 [1]. We are designing a superconducting wiggler of which the multipole field components are extremely small. Another important features implemented are a semi-automatic operation and virtually maintenance-free nature. A 4.4 T wiggler with required quality seems to be feasible.[4]

Concluding remarks

We have devoted ourselves on some selected items which, we deemed, should be studied to some depth before finalizing the detailed design of the HiSOR accelerator system. The results are mostly satisfactory; we are confident that the conceptual design proposed earlier, i.e. a small X-ray ring, is feasible.

In the next step, we are going to study some optional features to be realized in the second phase of HiSOR project; such as an operation mode with a smaller emittance, ex. $3 \times 10^{-8}\pi$m rad and very high field, say 6 T, superconducting wigglers.

References

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