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CONCEPTUAL DESIGN OF HiSOR, THE SYNCHROTRON RADIATION FACILITY AT HIROSHIMA.

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INTRODUCTION

Since the first experiment of utilization of the synchrotron radiation (SR) as a light source for research works the demand for SR light has ever increased in such a speed that the existing synchrotron radiation facility is always full of users. The demand for both more number of beam channels and for more intense photons led us to plan new facilities.

The users' group at Hiroshima and near-by, having hard times in accessing the existing facilities because of both lack of available beam time and the geographical distance between Hiroshima and the location of the major synchrotron facility, has submitted a proposal to construct a SR facility in a new campus site of Hiroshima University. This project is now known as HiSOR project and is await for approval by the government.

In this paper we describe the outline of the conceptual design of the storage ring and the booster synchrotron for HiSOR.

OVERVIEW

The guiding principles for designing the accelerator are as follows:

1). HiSOR should be a compact facility which can be operated by a small number of staff members; the total area needed should not exceed 100X50 m^2.

2) HiSOR must produce X-rays with the intensity comparable to those available at the 2.5GeV ring of the Photon Factory at KEK,(KEK-PF).

These requirements are apparently self-contradictory; the former dictates a small and low energy machine, while the latter requires a high energy machine. In order to compromize them we have come to the idea of low energy machine with enough number of superconducting horizontal wigglers to generate X-rays. The energy we chose is 1.5 GeV. The accelerator complex for HiSOR will look like Fig.1.

The storage ring has six long straight sections of which 4 are dedicated to horizontal wigglers and one is used for an undulator.

Experiences at the synchrotron radiation facilities over the world seem to indicate that the full energy injection scheme is far better than the storage-acceleration scheme. We have, therefore, decided to have a 1.5GeV electron synchrotron as an injector. A 45MeV linac will be used to supply electrons to the synchrotron.

STORAGE RING

In order to have long straight sections for insertion devices the lattice should be achromatic. Among various candidates we have chosen the Chassman-Green DFA lattice for HiSOR storage ring. This lattice is superior to others when , as in our case, the maximum number of long dispersion-free straight sections are to be realized in a limited circumference. In the present design, the length of a straight section is 4.7m. The circumference is 99.96m.

The Twiss parameters and the expected beam size are shown in Fig.2 and Fig.3, respectively. Calculated horizontal beam emittance is $7\times10^{-8}\pi$.m.rad for 10% x-y coupling. The natural chromaticities for horizontal and vertical motions are -9.5 and -7.4, respectively. They are corrected by two families of sextupole magnets.

It is known that the sextupoles may produce bad side effects: narrowing of the dynamic apertures which gives rise to difficulties in the injection process and the shortening of the life time. In the case of HiSOR, however, the results of the particle-tracking program, as shown in Fig.4, has proved that the dynamic aperture is wide enough.

The RF frequency is tentatively decided to be 120MHz and the harmonic number is 40. This choice is made to ease the single bunch operation. The maximum RF

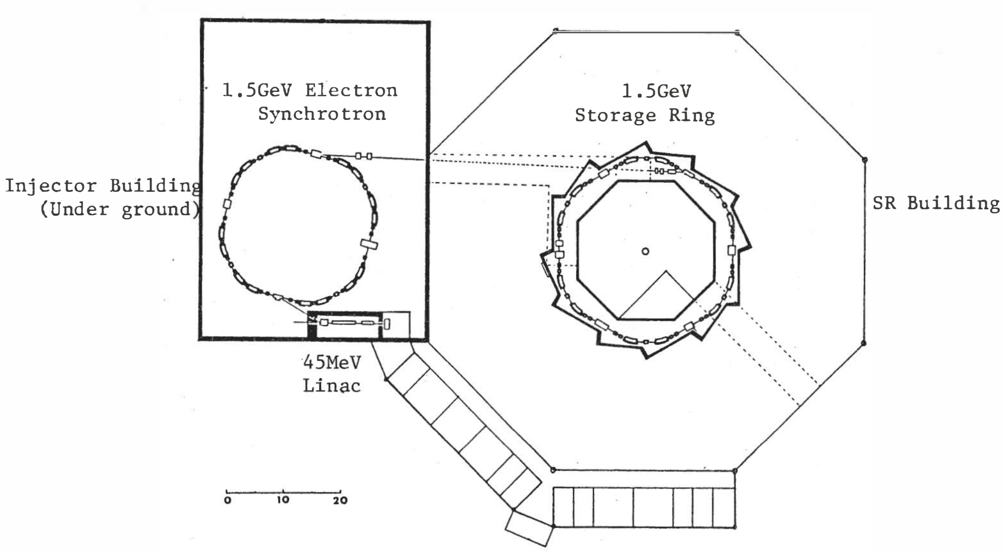

Fig. 1 Plan view of the HiSOR accelerators.

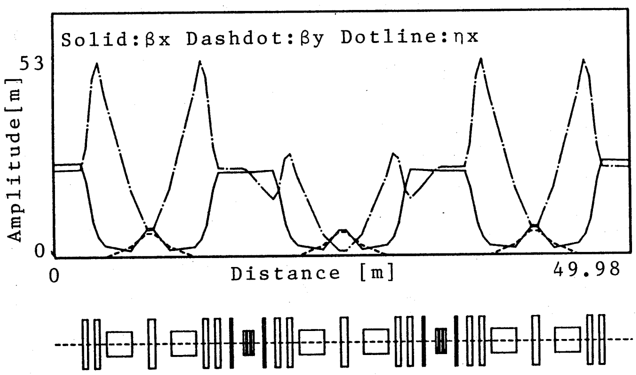

Fig. 2 Twiss parameters βx and βy and the horizontal dispersion ηx with wigglers are shown. The horizontal and vertical tunes are $\nu x = 5.25$ and $\nu y = 1.25$, respectively.

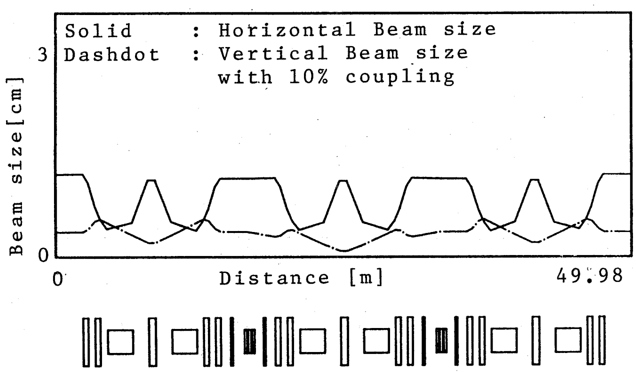

Fig. 3 Beam sizes (10σ) in the storage ring. The operation point is the same as in Fig. 2.

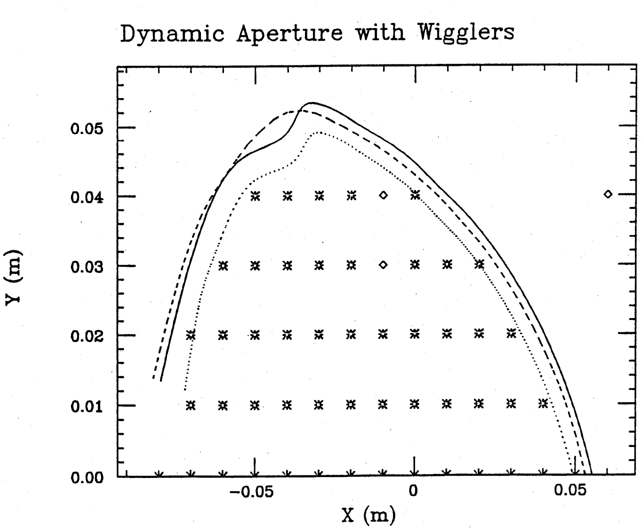

Fig. 4 Dynamic Aperture of the storage ring at the center of long straight section. The solid, dashed and dotted curves correspond to momentum deviation Δp/p of 0, 1 and -1%, respectively.

voltage is determined to be 220kV by the requirement for assuring the Touschek life of 20hr at 1.5GeV.

The vacuum system for the HiSOR storage ring needs some special care because the walls of vacuum chambers at the bending sections are directly hit by SR due to large bending angle,30°, in a single magnet. Lack of enough space for mounting vacuum pumps is another problem. According to the simulation which takes into account the gas desorption by SR[1], pressure of 10^{-9} torr (CO equivalent) can be achieved with the help of powerful distributed ion pumps whose pumpimg speed is 400ℓ/s.m.

In Fig.5, shown is the expected brilliance of the photon beams from the undulator, the wigglers and the bending magnets of the HiSOR storage ring. The field strength of the bending magnet is 1.2 T. The wiggler has superconducting magnets with maximum field of 4.4T. The parameters for the undulator, we assumed, are identical to those for the one at KEK-PF and has 60 periods with the K parameter ranging from 0.1 to 1.78.

Shown also in Fig.5. is the brilliance of the SR from the bending magnet of KEK-PF[2]. The beam currents are normalized to 150 mA for comparison. We see that HiSOR well competes with the higher energy machine, KEK-PF, even in the X-ray region.

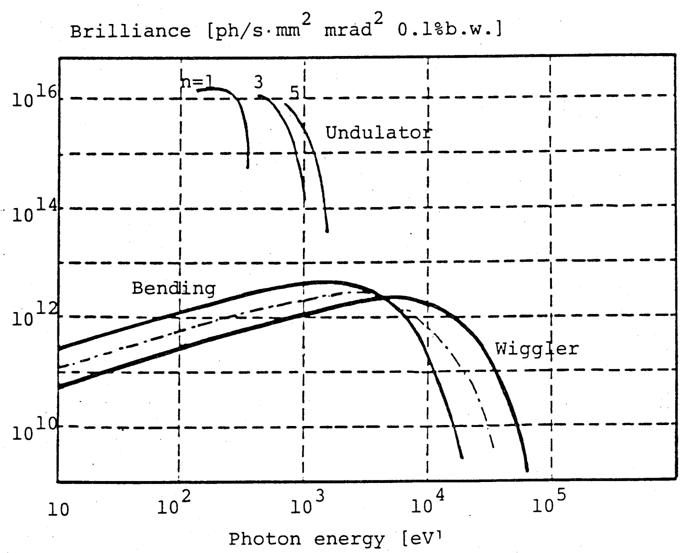

Fig. 5 Brilliance of synchrotron radiation. The dash-dotted line represents the brilliance for the bending magnet of KEK-PF[2]. The electron beam currents have been normalized to 150mA.

SYNCHROTRON

The synchrotron is of a separated-function type. A trapezoidal excitation with the repetetion rate of 0.5Hz is assumed. There are two candidates for the lattice of the synchrotron magnets: a simple DFO lattice (Type1) and an achromatic one (Type2). Their circumferences are 84.966m to match the RF frequency of 120MHz with the harmonic number of 34. The Twiss parameters are shown in Figs.6 and 7.

The electrons are injected from the 45MeV electron linac. The multi-turn injection scheme is employed. According to a simulation, electrons within the linac pulse-width corresponding to about 7 turns of synchrotron ring are successfully injected. The electrons accelerated to the maximum energy are ejected with two fast kickers. The emittance of the ejected electron beam is 1×10^{-7} and 6×10^{-7} π.m.rad for the Type1 and the Type2 lattice, respectively.

From the viewpoint of cost for magnets and power supplies, the Type1 lattice looks better than the Type2; while the former has only two families of quadrupoles, the latter has five families. The disadvantage of the Type1 is that it does not have any dispersion-free straight sections; the dispersion at the RF cavity is known to excite a coupled synchrotron-betatron resonance. Moreover, the injection and ejection scheme is easier at the straight section without the dispersion. The Type2, on the other hand, has four dispersion-free long straight sections which are to be used for an RF cavity, an inflector for injection from the linac and an ejection septum. The remaining one straight section may be reserved for slow extraction which , in the future extension, is useful for nuclear physics and other applications using 1.5 GeV electrons. Final decision for the lattice of the synchrotron is yet to be made by compromizing the cost, stability and possible operation modes for applications other than a mere injector to the storage ring.

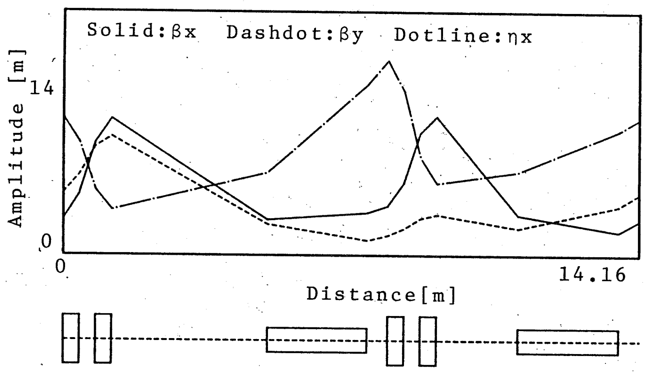

Fig. 6 Twiss parameters βx and βy and the horizontal dispersion ηx of the Type1 synchrotron.

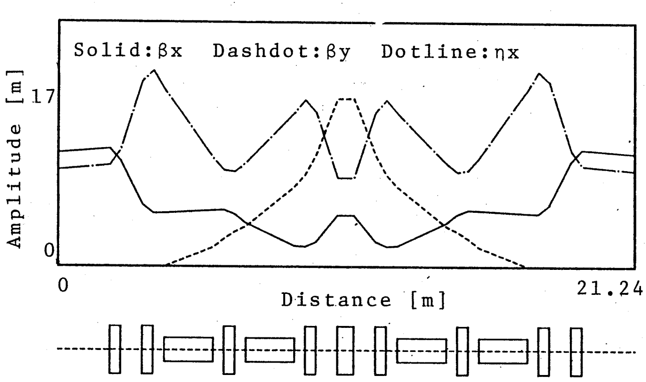

Fig. 7 Twiss parameters βx and βy and the horizontal dispersion ηx of the Type2 synchrotron.

OPERATION MODES

Under the standard condition, the storage ring is operated at 1.5GeV with the highest possible circulating current, say, 300mA. A single bunch storage mode is also possible. It can be achieved by applying a suitable gating pulse to the electron gun of the linac. Other possible operation modes are a 1.8GeV storage and a 1.0GeV storage mode. While the feasibility of 1.8GeV operation is yet to be worked out, the low energy operation down to 1.0GeV seems to have no problem; the Touschek life is expected to be more than 8 hours with 300mA circulating current.

Since the HiSOR is a compact machine, it will be relatively easy to schedule these non-standard operation modes as compared with the case of a larger machine where the most of users are reluctant to agree with any non-conventional operation mode.

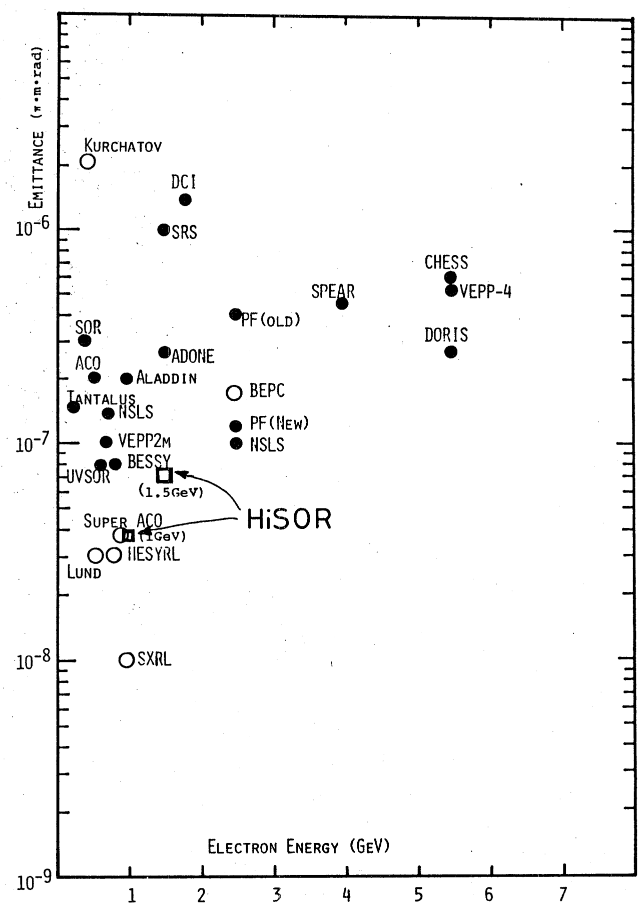

Fig. 8 The emittance and the energy of SR ring being operated (closed circles) and under construction (opend circles)[3].

CONCLUSION

We have designed a 1.5GeV storage ring for HiSOR. It has an achromatic structure with six dispersion-free straight sections. Four wigglers and an undulator will be used. In spite of its small size, 100m in circumference, it can generate excellent SR light in a wide wavelength region, from VUV to X-rays. By compromizing the beam emittance and the dynamic aperture we found a good operation point; the beam emittance of 7×10^{-8} π.m.rad, which is smaller than any other 1.5GeV machine working now over the world,see Fig.8[3], is achieved with the dynamic aperture more than ±5cm.

We believe that the present conceptual design is a good starting point for the detailed design works for the HiSOR storage ring. As for the structure of the 1.5GeV electron synchrotron, we have presented two candidates. More works are necessary to decide it.

The authours express their sincere thanks to the accelerator experts at KEK, Institute for Nuclear Study, UVSOR and INS-SOR. The calculation is performed by using the MAGIC code. Special thanks are due to professor Kamiya and Professor Kobayashi of KEK-PF for helping the calculation. Professor Komura and all other members of the HiSOR study group are deeply acknowledged for their encouragement and useful discussions.

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