DEVELOPMENT OF DEDICATED LINAC AND BOOSTER FOR KEK PF

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Abstract

KEK Photon Factory (PF) is a major light source facility in Japan. The injector of PF is KEK LINAC and it is shared with other three rings; PF-AR, SuperKEKB HER (High Energy Ring) and LER (Low Energy Ring). Due to the large electricity consumption, all accelerators in KEK are shut down during every summer for about 3 months. In 2017, because of the LINAC upgrade for SuperKEKB Phase 2 operation, the summer shutdown will be extended to about 5 months. On the other hand, the PF users always strongly wish the shorter shutdown and longer operation. Especially the structural biology users require the ability for the measurement within about 2 weeks after the irregular sample manufacture throughout the year. In order to satisfy these requests, the independent injector system is required for the realization of such longer operation. The examined system consists of an about 100 MeV small linac and a booster ring in the present PF ring tunnel. We show the results of the feasibility study for the independent injector system for the PF ring.

INTRODUCTION

PF ring is a 2.5 GeV synchrotron light source. The scheduled yearly operation time is about 5000 hours in 2000s. However it has been reduced to about 3000 hours in recent years because of the financial difficulties. In contrast to that, the users' requirement for the longer operation becomes larger and larger recently. Furthermore, the summer shutdown schedule is extended to about 5 months in 2017 because of LINAC upgrade for the SuperKEKB Phase II operation. Thus, the feasibility of the independent injector system for the PF ring is studied.

The present injector LINAC is about 600 m long. It supply beams for four storage rings of PF, PF-AR, SuperKEKB HER and LER. Even if the PF ring is only operated and other three rings are shut down, almost all parts of the LINAC is required to operate now. Because the cost of electricity is very high in summer, the long summer shutdown is unavoidable. Even for the spring and autumn seasons when the electricity usage is relatively cheap, the smaller operational cost with the smaller electricity consumption is always desirable. The rough estimation of the electricity consumption is about 3 MW for PF ring and 3 MW for LINAC including the utilities. If the required electricity is reduced from 6 MW to 4 MW, the operation time can be extended from 3000 hours to 4500 hours with the same cost [1].

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[1] The calculation of the real cost is much more complex and this estimation is not the real case.

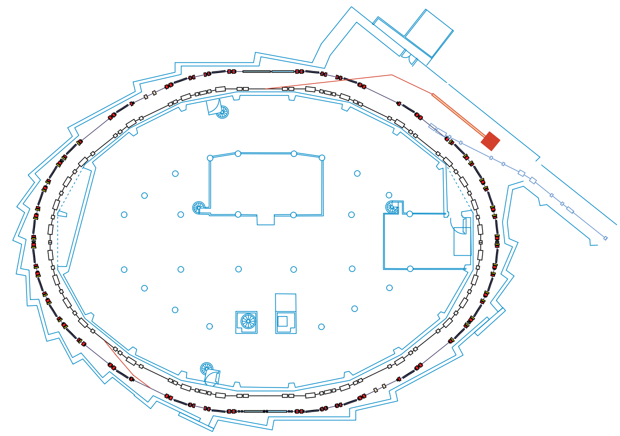

Figure 1: Configuration of the new injector system. The small linac consists of an electron gun (red square) and one accelerating structure (bold orange line). The orange line shows the schematics of the beam transport line.

NEW INJECTOR SYSTEM

From the perspective of the operation stability and the electricity consumption, the combination of the low energy small linac and the booster ring seems to be the best choice. A new building is unrealistic and whole system should be placed in the existing building. The booster may be fixed on the inner wall of the main ring tunnel as is very common for the recent third generation light source. The small linac system can be constructed in the assembly space around the injection point in the PF accelerator shielding. The configuration of this first intuitive design is shown in Figure 1.

Electron Gun and Small Linac

The typical thermionic electron gun used in the present KEK LINAC requires the space of about 2 m × 2 m including the buncher system. The one module of accelerating structure of the present LINAC has four acceleration tubes with one klystron. The total length is about 10 m and It can generate the electron beam of about 160 MeV with SLED (SLAC Energy Doubler). For the thermionic gun dedicated for PF, the old gun at the sector 3 in LINAC was just removed due to the construction of a new beam transport for the SuperKEKB damping ring. If we can use it, the one accelerating module is only required and costs about 200 million US$ without an installation work.

Booster Ring

The lattice of the PF ring has the shape like the distorted oval (Figure 1). The accelerator shielding was constructed to fit this shape and the booster should be kept this shape. The PF ring was constructed in 1981. Comparing with the

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present lattice of the PF ring after several large upgrade, the original lattice at the construction has much relaxed parameters with almost half numbers of the magnets. This old original lattice has a large dynamic aperture and seems to be the good starting point of designing the booster ring. Considering with the past costs for the straight section reconstruction of the PF ring (new lattice for about half ring) and the construction of the recirculation path of the cERL (whole new accelerator), the cost of the booster ring may be about 1000 million US$ with an intuitive rough estimation.

Infrastructure and Beam Transport

The infrastructure should also be reinforced for the new injector system. The basement of the PF ring is hollow where the water pipes, cables for the magnets and utilities are fixed. In order to support the booster weight, the new walls or pillars are required in the under space of the accelerator shielding. The capacity of the water and electricity also needs to be enlarged.

The beam transport from the new dedicated linac to the booster is designed for about 150 MeV. However the new extraction system of the booster, BT and the existing injection system is for 2.5 GeV. The height of the booster should be the same as the main ring. In order to maintain the present injection point of the PF ring, the extraction point from the booster should be almost in the middle of the arc section. In Figure 1, the injection point is assumed to be BL14 straight section because the superconducting wiggler is only one old insertion device before straight section upgrade and will be replaced. If the replacement is by the in-vacuum multipole wiggler, this configuration seems not to be completely unrealistic.

DESIGN OF THE BOOSTER RING

PF has experienced several upgrades along with the improvement of the ring emittance [1]. In order to design the new booster, the lattice developed as the first upgrade of PF in 1986 was considered. The horizontal emittance is 128 nmrad, and the booster ring is the dyad-symmetrical. Figure 2 shows the optical functions. The half part of the booster ring is indicated in Figure 3 and the parameters of the ring are listed in Table 1. The dynamic aperture is wide enough as is the original PF ring, and the other conditions and parameters concerning the injection, extraction and RF are supposed to be considered hereafter.

SUMMARY

PF is the major light source facility in Japan. However, in order to limit the electric utility expense, the use-run is halted in every summer. This time we propose the new independent injector system composed of the new linac and booster to respond the requests from users, especially in biology. In order to suppress the construction cost, the new linac and booster will be contained in the existing tunnels of the PF ring and the BT. The design of the booster is based on the original PF ring after the first upgrade in 1986 in order to fit its shape to the oval PF tunnel. The optical function and other parameters are satisfied for the stable operation, and other conditions and parameters regarding the injection, extraction and RF are now considered.

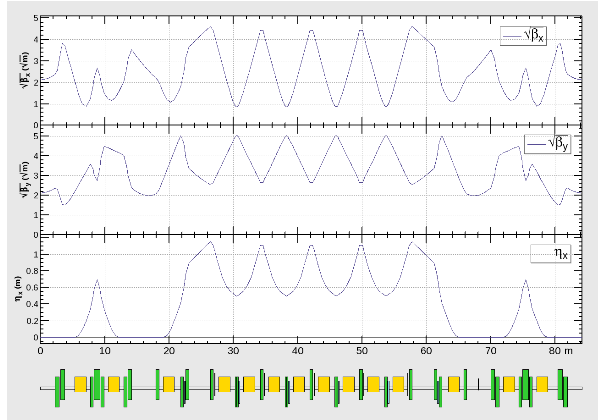

Figure 2: Optical functions of the booster ring. The booster ring is the dyad-symmetrical.

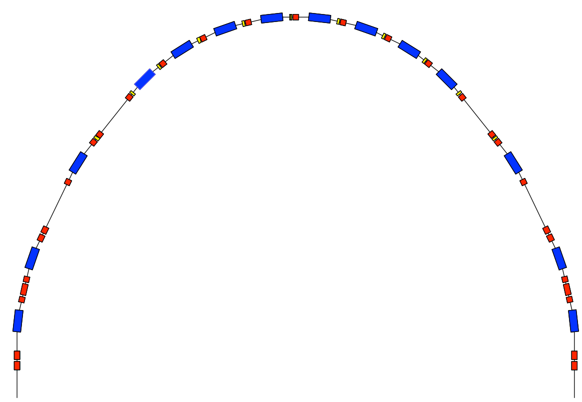

Figure 3: Lattice of the half of the booster ring. Blue boxes show the bending magnets, red the quadrupole magnets and yellow the sextupole magnets.

Table 1: Parameters of the Booster Ring

Injection Energy [MeV]	150
Extraction Energy [GeV]	2.5
Circumference [m]	168.37
RF freq. [MHz]	500.1
Energy loss [MeV/rev]	0.22
Momentum compaction	0.0156
Damping time (x, y, z) [ms]	6.31, 6.34, 3.17
Betatron tune (x, y)	8.45, 3.30
Horizontal emittance [nmrad]	128
Energy spread	7.68×10^{-4}
Bunch length [mm]	10.07
Repetition rate [Hz]	1-2

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