OPERATION STATUS OF THE SPRING-8 STORAGE RING

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Abstract

Operation status of the SPring-8 storage ring is presented. In 1999, a total operation time of the storage ring is 4864 hours, and 3364 hours (69.2%) has been delivered to the users. The down time due to failures is 61 hours, 1.3% of the total operation time of the storage ring. The beam lifetime during user service mode is about 140 hours at 100mA in the multi bunch operation. After the summer shutdown of 1999, optics of the ring was changed from the Hybrid type to new optics that has 48-hold symmetry. The 6 nm.rad of the emittance measured for the horizontal plane is close to the theoretical value. The vertical emittance is extremely small, a few pm.rad order and the coupling is less than 0.1%. Bunch impurity in less than 10^{-6} range is routinely achieved in the single and several bunch operation of user service mode. Beam stability is one of the major accelerator improvement programs at the SPring-8 storage ring. In order to stabilize the orbit of the storage ring, a periodic and global orbit correction is now routinely used in user time operation. Further improvement of this procedure has been done. The operation of the storage ring is going well with the achievement of performance far beyond the most of target specifications. The beam performance of the SPring-8 storage ring is presented.

1 OPERATIONS

1.1 Operation Statistics

The SPring-8 storage ring is usually operated in three-weeks mode for 1 cycle, with 38×8 hour shifts for user service mode, another 6×8 hour shifts for machine studies, and about 48 hours for tuning.

Up to now the storage ring completed three years operation for user time. Over this period the storage ring operated for more than 13,000 hours of which more than 9,000 hours were dedicated to user time. Figure 1 shows the operation statistics for the last four years. During the year 1999 a total operation time of the storage ring was 4,864 hours, and 3,364 hours (69.2%) has been delivered to the users. The down time was 61 hours, 1.3% of the operation time for the users. The remaining 1,439 hours (29.6%) were used for the machine tuning, for the beamline tuning and for the commissioning of new photon beamlines.

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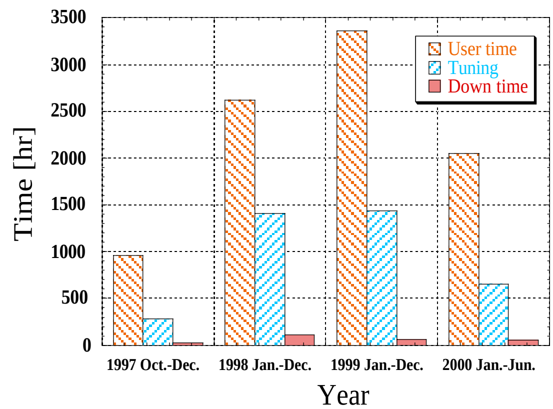

Figure 1: Operation statistics for the last four years.

1.2 Filling Modes

In 1999, 47.5% of the total user time was delivered in the multi-bunch mode operation. In the first half of 1999, a 2/3-filling mode was used for the user time operation. After the summer shutdown of 1999, a 24/29-filling mode began to be used for the user time operation, where 24/29 of the 2,436 available RF buckets were filled continuously with electrons. In the SPring-8 storage ring, the beam lifetime depends strongly on these filling modes. The beam lifetime became longer in the filling more than 24/29. It seems that the electron beam size grows as a result of an instability due to an ion-trapping effect.

Recently the operations of the several bunch and hybrid filling modes with isolated bunches were increasing. In 1999, the several bunch modes were 1,148 hours (34.1% of user time) and the hybrid filling modes were 617 hours (18.3%). For example of a several bunch mode and hybrid filling mode, the 21-bunch train mode (21 equally spaced 3- or 7-bunches trains) and 1/12-partially filled multi-bunch +10-isolated bunches were used. Since we can select an arbitrary RF bucket among 2,436 ones at each injection, the filling pattern in the storage ring can be controlled easily. In case of isolated bunches, 1 or 1.5 mA/bunch were stored, and purities in the low 10^{-6} range were routinely achieved in the user time operation. The maximum current per bunch is about 16mA in machine study.

The stored beam was usually refilled or accumulated at a repetition of once or twice a day.

2 PERFORMANCE OF THE STORAGE RING

The over-all performances are listed in Table 1.

Table 1. Performance of the SPring-8 Storage Ring.

	Designed value Hybrid / HHLV	Achieved value Hybrid	HHLV
Energy	8GeV	8GeV	8GeV
Circumference	1436m	-	-
Number of bucket	2436	-	-
Revolution time	4.79µs	-	-
Symmetry	24 / 48	24	48
(β_x / β_y) at ID section		(24/10),(1/8)	(25/4)
Current			
single bunch	5mA	16mA	
multi bunch	100mA	100mA	100mA
Bunch length (FWHM)	36ps	36ps[\$1]	32ps[\$2]
Emittance	6.99 / 6.0nm.rad	6.8±0.5nmrad	6nmrad
Tunes (ν_x / ν_y)		51.16 / 16.36	43.16/21.36
Chromaticities(ξ_x / ξ_y)			
natural	(-115.9/-40.0) / (-105.9/-51.2)		
operation		(3.2/3.9)	(7.0 / 4.0)
Momentum acceptance	~2%[\$1]	1.3%[\$1]	1.9%[\$1]
			2.8%[\$2]
Energy spread (ΔE/E)	0.0011	0.0012	0.001
Coupling	less than 10%	≤0.06%	≤0.04%
Lifetime			
100mA (multi bunch)	24hr	~70hr[\$3]	~140hr[\$4]
1mA (single bunch)	-	~5hr[\$1]	~11hr[\$1]
			~25hr[\$2]
COD			
horizontal (rms)	-	<0.1mm	<0.1mm
vertical (rms)	-	<0.1mm	<0.1mm
Beam size at ID section			
horizontal(rms)	-	400µm / 86µm	390µm
vertical(rms)	-	6.7µm / 6µm	3µm
Residual dispersion at non-dispersive section			
horizontal (rms)	0	9.8mm	7.0mm
vertical (rms)	0	2.7mm	4.5mm (1.1mm[\$5])

[\$1] Vrf=12MV
[\$2] Vrf=16MV
[\$3] 2/3-filling, Vrf=12MV
[\$4] 24/29-filling, Vrf=16MV
[\$5] with correction by 24 skew Q's

2.1 Optics

At the normal operation of the storage ring for user time operation, 'Hybrid optics' had been used until the summer shutdown of 1999. In the 'Hybrid optics', the horizontal betatron function β_x takes a large value (24m) and a small value (1m) alternately in the straight sections. After the summer shutdown of 1999, the new optics in which β_x and β_y take the same value (β_x : 25m, and β_y: 4m) in all the straight sections have been used in user time operation. The "new" optics has a high symmetry and optimization for insertion device in all the straight section, compared with the 'Hybrid optics'. The new optics is called a 'HHLV optics' which means 'High Horizontal and Low Vertical betatron funcfion'. Betatron tunes are ν_x=43.16 and ν_y=21.36. Two kinds of optics are shown in Fig. 2.

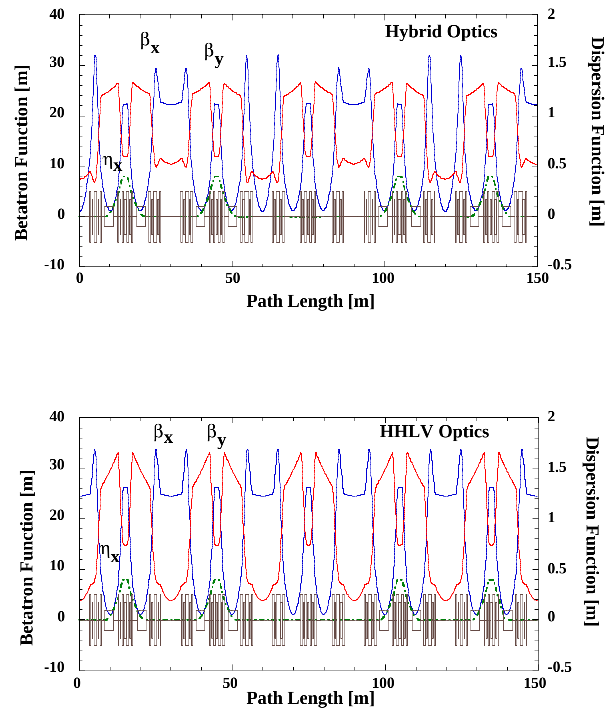

Figure 2: Hybrid and HHLV optics.

2.2 Beam Stability

In the third generation synchrotron radiation source, stability of the electron beam orbit is one of the most important performance requirements for achieving a highly brilliant photon beam. In the construction design of the SPring-8 storage ring, the effect of perturbation sources inducing orbit movement was minimized. Consequently, an orbit stability of less than 70µm was achieved in the horizontal and vertical planes without any feedback control. In order to stabilize the orbit of the storage ring, a periodic and global orbit correction is now routinely used in user time operation. The reference orbit should be set before starting the periodic correction. The orbit is calculated by taking an average of nine sampling of COD measurements using 96 BPMs out of 288 BPMs. Periodically, the correction program subtracts the reference orbit from the latest one and calculates harmonic components of the difference between the two orbit. 24 horizontal and 16 vertical steering dipoles are usually used for harmonic correction. This procedure corrects only the COD components corresponding to the betatron tune harmonics and its satellite in the horizontal and vertical directions at intervals of 1 min. The results are shown in Fig. 3. The obtained beam stability is 0.7µm (in rms) for the 43rd betatron tune harmonic in the horizontal COD and 0.35μm (in rms) for the 21st harmonic in the vertical COD. Also, the circumference change corresponding to the 0th harmonic in the horizontal COD was corrected within 0.3μm (in rms) by adjusting the RF frequency.

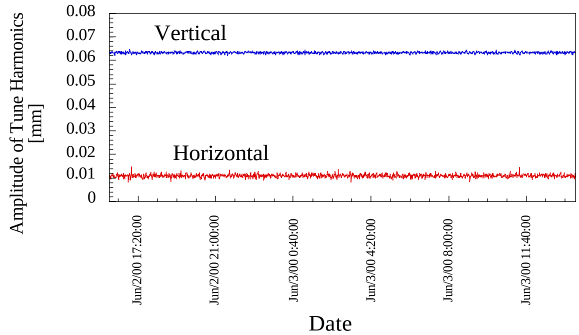

Figure 3: Amplitude changes of tune-harmonics (43rd for horizontal and 21st for vertical) of the COD for one day.

2.3 Beam Lifetime

The averaged pressure readings of the storage ring are $\leq 1\times 10^{-8}$ Pa without electron beam, and the order of 10^{-7} Pa with a beam current of 100 mA. Since then an integrated beam dose of 620Ah has been achieved up to now, and correspondingly, the dynamic pressure rise per stored beam current decreased by two orders of magnitude.

In the summer shutdown of 1999, the fourth RF station was installed and was used for beam operation from April of 2000. With this fourth RF station the total accelerating voltage increased from 12 to 16MV and a beam lifetime increased from 100 to 140 hours in user service mode of the 24/29-filling multi-bunch mode at 100mA.

The lifetime in not only the several bunch mode but also multi bunch mode is limited by Touschek effect. Touschek lifetime is about 25 hours (Vrf=16MV) at the single bunch operation (1mA/bunch) of the nominal machine parameter of the SPring-8 storage ring. As the total lifetime (τ) in the 24/29-filling mode is 140 hours at the beam current of 100mA, a gas scattering lifetime is estimated $\tau_g \approx 190$ hours.

Figure 4 shows the product of the beam current (I) and the beam lifetime (τ) versus the integrated beam dose.

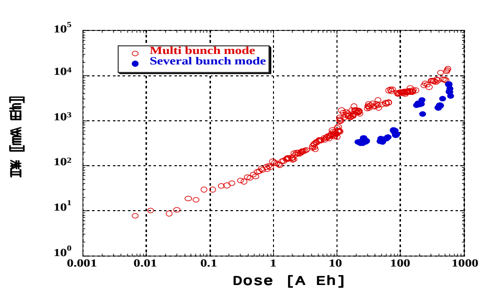

Figure 4: $I\tau$ versus the integrated beam dose.

3 MAGNET-FREE LONG STRAIGHT SECTION

In the present state, the lattice structure of the SPring-8 storage ring is based on the Double-Bend Achromat with 48 unit cells as shown in Fig. 2, which is called a 'phase I lattice'. There are four long straight cells with missing bending magnets at intervals of eleven cells. It is in progress that four magnet-free long straight sections (LSSs), which are about 27m long, are going to be realized in this summer shutdown of 2000 by re-arranging quadrupole and sextupole magnet in the LSSs. New lattice structure is called a 'phase II lattice' as shown in Fig. 5[1]. Construction of the first beamline from a 25-m long undulator with λu=32mm is also in progress. Main purpose of the long straight sections is to install a very long insertion device to get photons of higher brilliance.

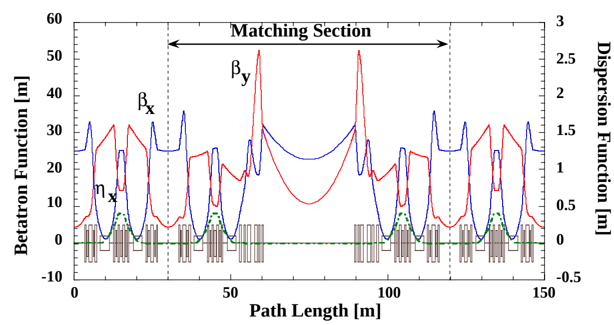

Figure 5: The lattice of LSS ('phase II lattice').

A matching section is composed of a quadrupole sextet and adjacent unit cells of long straight cell as shown in Fig. 5. From the points of view of keeping the symmetry of the optics and the stability of off-momentum particles, we have designed 'a phase II lattice' as taking account of following points: (i) The phase advances of both horizontal and vertical betatron oscillation is matched to a multiple of 2π in the matching section. (ii) Strength of sextupole magnets at the both end of matching section is week, which can be treat as a perturbation. (iii) A working point of the ring is apart sufficiently from the systematic resonance less than third order. As a result of computer simulation with data of magnet alignment, the dynamic aperture for beam injection and for stored beam is ensured sufficiently. A beam commissioning for a 'phase II lattices' scheduled toward the end of this August.

REFERENCES

[1] H. Tanaka, et al., "Optimization of Optics with Four Long Straight Sections of 30 m for SPring-8 Storage Ring", presented in this proceedings.