Beam Perfomance and Upgrades of the Storage Ring

Installation of Long Magnet-free Straight Sections

The initial lattice structure (Phase-I optics) of the SPring-8 storage ring was composed of 48 unit cells (DBA lattice). The ring has four long straight cells with missing bending magnets at intervals of eleven cells. In the summer of 2000, the long straight cells were changed into the long magnet-free straight section of approximately 29 m long by re-arrangement of the quadrupole and sextupole magnets. The new lattice structure and its optics (Phase-II optics) are shown in Fig. 1 together with the Phase-I lattice.

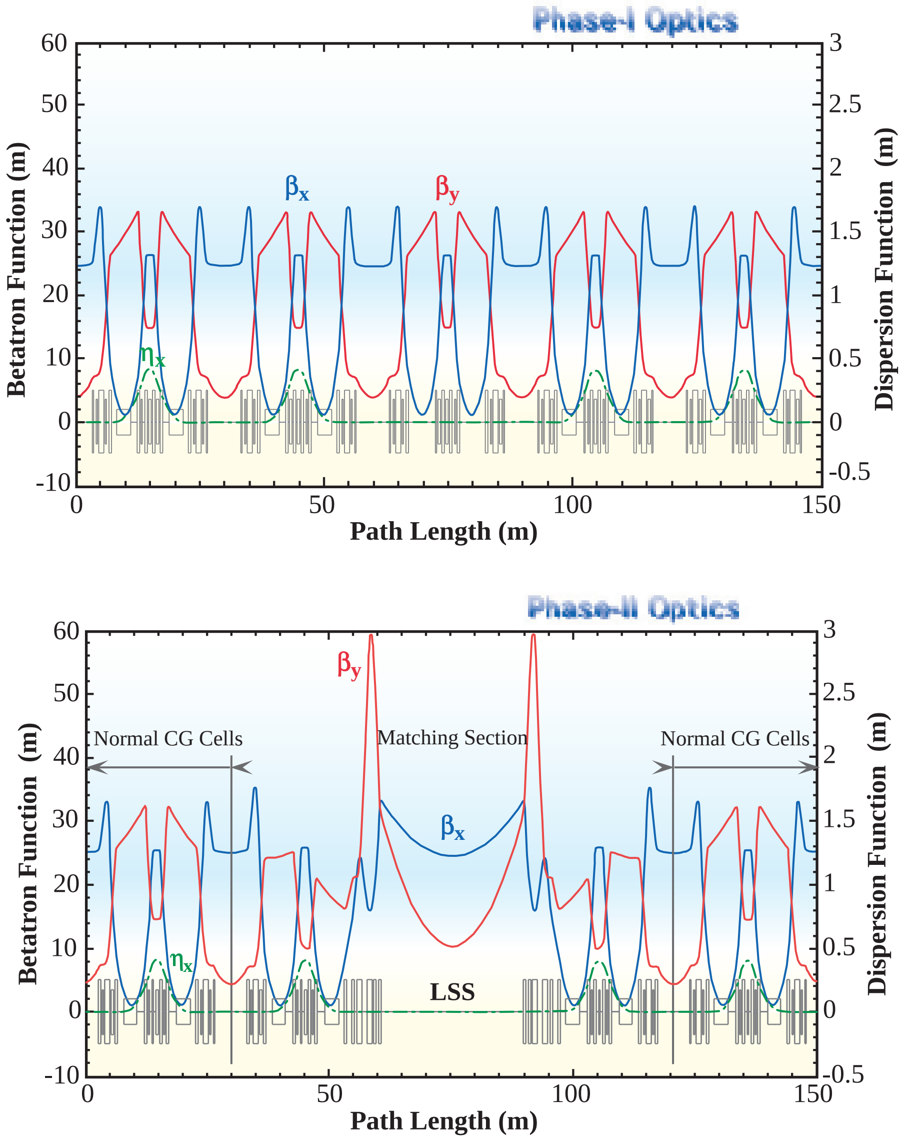

Fig. 1. Lattice structure and typical optical functions for Phase-I and Phase-II optics.

The beam commissioning of this Phase-II optics was started on August 28th, 2000 and within the same day, the first beam storage of 0.22 mA was achieved by on-axis-like injection. The commissioning was successfully completed in about three weeks, and user service operation commenced in the beginning of October.

The beam performance achieved in the Phase-II optics is similar to that of the Phase-I except for the beam lifetime. The over-all beam performances (Table 1) demonstrates that the beam lifetime is still improving, resulting from the beam self-cleaning effects of the photon absorbers installed in the new vacuum chambers. In December 2000, the beam lifetime achieved more than 100 hours for a total beam current of 100 mA in multi-bunch mode.

Other Research and Development

The following research and developments were performed:

- Improvement of the orbit stability.
  Orbit oscillation due to current fluctuations (1 Hz) in the main quadrupole magnets power supplies, and synchrotron oscillation (2 kHz), resulting from RF noise in the synthesizer, were eliminated.
- Analysis of the error field in the storage ring and the fine tuning of optical functions.
- Analysis of beam instability, such as fast ion trapping.
- Beam loss analysis in the injection process to realize a top-up operation.
- Emittance measurement.
  The beam size of the SPring-8 storage ring has been measured utilizing a newly developed, two dimensional interferometer, employing the visible part of synchrotron radiation emanating from a bending magnet. The optical system is shown in Fig. 2 and the typical two-dimensional interference pattern in Fig. 3. The measured horizontal and vertical beam size is typically 150 µm and less than 20 µm, respectively.

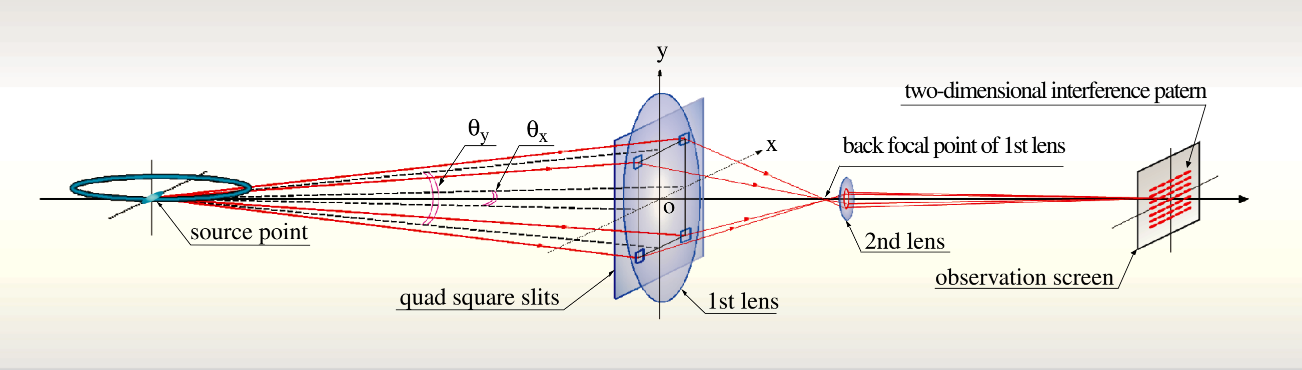

Fig. 2. Optical system of the two-dimensional interferometer.

Table 1: *Beam Performance*

	Designed values	Achieved values		
		Phase-I ring		Phase-II ring
	Hybrid / HHLV / 30m-LSS	Hybrid	HHLV	New Optics
Energy	8 GeV	8 GeV	8 GeV	8 GeV
Circumference	1436 m	-	-	-
Number of bucket	2436	-	-	-
Revolution time	4.79 ms	-	-	-
Symmetry	24 / 48 / 4	24	48	4
(β_x / β_y) at ID section		(24 / 10), (1 / 8)	25 / 4	(24.35 /5.77) / (23.42 /14.44)
Current: single bunch	5 mA	16 mA	16 mA	-
multi bunch	100 mA	100 mA	100 mA	100 mA
Bunch length (FWHM)	36 ps	36 ps [1]	32 ps [2]	-
Emittance	6.99 / 6.3 / 6.6 nm·rad	6.8±0.5 nm·rad [3]	6 nm·rad [3]	5.9 nm·rad [3]
Tunes (ν_x / ν_y)		51.16 / 16.36	43.16 / 21.36	40.15 / 18.35
Chromaticities (ξ_x / ξ_y):				
natural	(-115.9/-40.0)/(-105.9/-51.2)/(-90.3/-40.7)			
operation		3.2 / 3.9	7.0 / 4.0	7.0 / 6.0
Momentum acceptance	~ 2% [1]	1.3% [1]	1.9% [1] (2.8% [2])	2.0% [2]
Energy spread ($\Delta E/E$)	0.0011	0.0012	0.0011	0.0011
Coupling	less than 10%	≤ 0.06% [4]	≤ 0.04% [4]	~ 0.06% [4]
Lifetime: 100 mA (multi bunch)	24 hr	~ 70 hr [5]	~ 140 hr [6]	~ 110 hr [6]
1 mA (single bunch)	-	~ 5 hr [1]	~ 11 hr [1] (~25 hr [2])	~ 22 hr [2]
COD: horizontal (rms)	-	< 0.1 mm	< 0.1 mm	< 0.1 mm
vertical (rms)	-	< 0.1 mm	< 0.1 mm	< 0.1 mm
Beam size at ID section:				
horizontal (rms)	-	400 µm / 86 µm	390 µm	380 µm
vertical (rms)	-	6.7 µm / 6 µm	3 µm	4.5 µm
Residual dispersion at non-dispersive section:				
horizontal (rms)	0	9.8 mm	7.0 mm	4.4 mm
vertical (rms)	0	2.7 mm	4.5 mm (1.1 mm [7])	1.3 mm [7]
Orbit stability (tune harmonics)				
horizontal (standard deviation)	-	1.1 µm	0.7 µm	1.3 µm
vertical (standard deviation)	-	0.7 µm	0.35 µm	0.35 µm

[1] Vrf=12 MV [2] Vrf=16 MV [3] calculated by using designed β-function [4] single resonace approximation
[5] 2/3-filling, Vrf=12 MV [6] 24/29-filling, Vrf=16 MV [7] with correction by 24 skew Q's

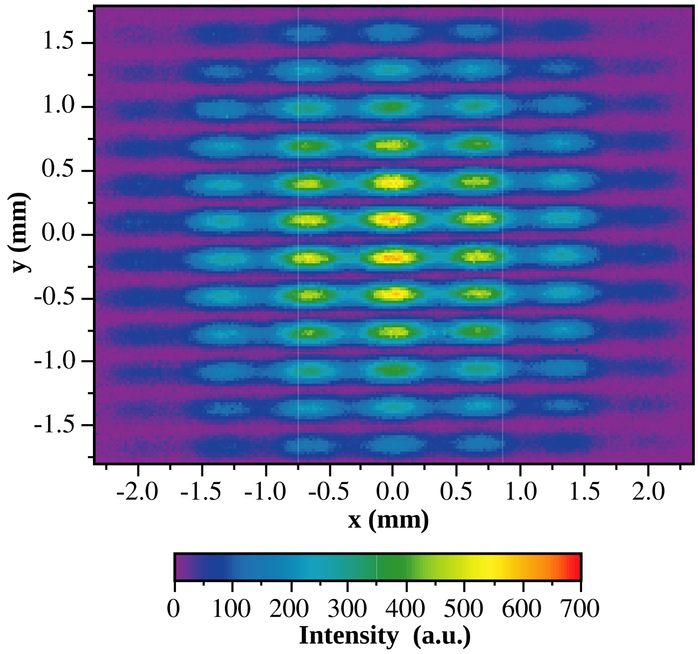

Fig. 3. Two-dimensional interference pattern.

Developments and Upgrades of Linac

Installation of ECS and Single Pass BPM

An energy compressor system (ECS) was installed at the end of the linac to reduce the beam energy spread resulting from beam loading and the energy fluctuation. As a preliminary result, a reduction rate of 50% was achieved in the energy spread.

To improve the orbit stability, 12 single pass BPM's with a position resolution of a few tenth micron (2σ) were installed in the Linac. Operation of this new BPM system will begin in the autumn of 2001.

Development of RF-gun

To realize high quality electron beam of 1 nC, 1 π mm•mrad with bunch length of sub-psec, a development of an RF-gun was carried out in the test bench and high-power RF, up to 27 MW, was fed into the cavity. The maximum electric-field gradient of 140 MV/m is reached on the cathode and the electron beam of 2 nC per bunch was accelerated up to 3.2 MeV. The minimum normalized emittance of 17 πmm•mrad was obtained at 90 MV/m and 0.8 nC/bunch. Also, a three-dimensional beam simulation code has been developed to understand the formation of beam emittance in the RF-gun.

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