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STATUS OF THE PHOTON FACTORY STORAGE RING

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Abstract The Photon Factory (PF) storage ring is a dedicated synchrotron radiation source with a critical photon energy of 4 keV. As a progress of experiments using synchrotron radiation, photons with high brightness and high stability are strongly required. Though the stability of circulating beams becomes the most important subject for dedicated sources, it is not easy to obtain. Extensive modifications of the PF storage ring for high-quality beams have been carried out. Though significant upgrades in the brightness have been obtained, many difficulties have simultaneously arisen from various beam instabilities.

INTRODUCTION

The Photon Factory is a user-based facility for synchrotron radiation research at the National Laboratory for High Energy Physics (KEK). It consists of a 2.5-GeV storage ring and an electron/positron linac. The main parameters of the storage ring and the linac are listed in Table I. Construction was started in 1978 and accelerators were commissioned in 1982. Since then, several important changes have been made on the storage ring: (1) improving the vacuum system[1] in 1985, (2) reducing the beam emittance by changing the magnet system[1,2], (3) renovating the rf-cavities[1,3] for the suppression of beam instabilities in 1987, and (4) initiating positron operation[1,4] from 1988.

The number of users has been increasing by 25% per year, and now is more than 2000. Over 250 proposals are submitted every year and, accordingly, the time for experiments has become very tight.

In the Photon Factory there are 23 spaces in which front-ends (beamlines) can be installed for introducing synchrotron radiation into the experimental hall. Eighteen front-ends are already available and has been commissioned for experimental studies, two are now under construction and three are still being discussed.

TABLE I Parameters of the Photon Factory linac and storage ring

Injector Linac	
Energy	2.5 GeV
Repetition	25(50) pps
Peak current (e^-/e^+)	50/10 mA
Pulse width	1-1.5 ns
Positron Generating Linac	
Energy	0.2 GeV
Peak electron current	10 A
Conversion target	Ta, 2 rad. lengths
Positron energy	0.25 GeV
Storage Ring	
Energy	2.5 GeV max. achieved 3.0 GeV
Stored current	350 mA max. achieved 500 mA
Circumference	187 m
Radius of curvature	8.66 m
Betatron tunes	8.38 (horizontal), 3.14 (vertical)
Horizontal emittance	126 nmrad
RF frequency	500 MHz
Harmonic number	312
Number of cavity	4
Radiation loss	400 keV/turn (no insertion devices)
Vacuum pressure	3×10^{-11} Torr no beam 4×10^{-10} Torr at 300 mA
Injection	2.5 pps (e^-), 25 pps (e^+)
Time for injection	2-10 min (e^-), 20-40 min (e^+)

OPERATION OF THE STORAGE RING

A summary of the operation times of the storage ring is given in Figure 1. Since July 12, 1988, the storage ring has been operated with positrons. Though the injection rate of positron beams has been very low, about 0.05 mA/sec at the beginning, it has now been increased to 0.5-0.6 mA/sec. Initial stored currents are 300-400 mA and the beam lifetime is 15 hrs at 300 mA. A stored current of 500 mA was achieved with positrons in January, 1989.

Insertion devices[1] have been installed into six straight sections of the PF ring and are now all in operation. They are (1) an undulator with 120 poles which supplies synchrotron radiation at energies between 0.4 and 0.9 keV in the fundamental mode, (2) a superconducting vertical wiggler which works as a wavelength shifter and provides X-rays with energy less than 100 keV, (3) a 54-pole wiggler/undulator which supplies VUV

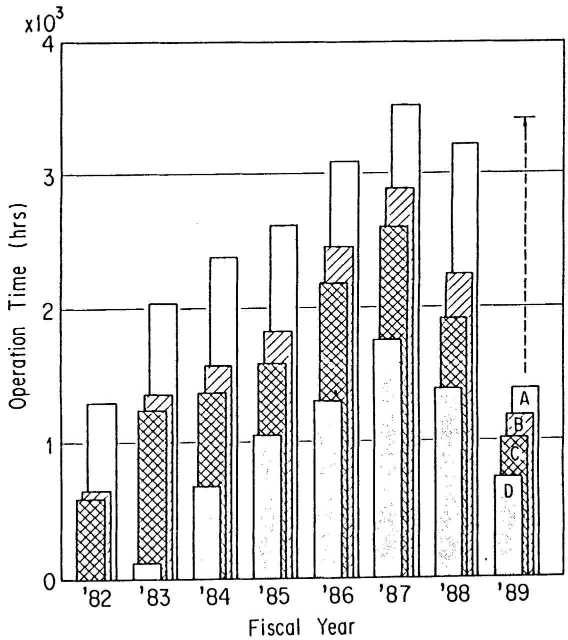

FIGURE 1
Operation times of the storage ring.
A: Total operation time.
B: Scheduled user time.
C: Effective user time. D: Wiggler operation time.

to X-rays in the energy range 0.03-70 keV, (4) an undulator of four array revolver type which supplies VUV in the range 0.01-1.1 keV by the rotation of four undulators, (5) a multipole wiggler/undulator and (6) an undulator which supplies elliptically polarized synchrotron radiation.

POSITRON BEAM OPERATION

Under the electron operation we have long been annoyed with various destructive effects due to both ion-trapping and micro-particle trapping, such as sudden beam loss (lifetime deterioration). These phenomena have never been observed[4] with positron beams. As a result, the average lifetimes were about 10% longer with positrons than with electrons (Figure 2) as long as the vacuum pressures and other operational conditions were nearly the same. Though this is a remarkable beneficial point of positron beams, the vertical sizes of positron beams became large at high stored currents (Figure 3); this phenomenon was never observed for electron beams. The reason why such a curious behavior is observed only for positrons is still unknown. To suppress this beam blowup, we must add another octupole field, which results in a shortening of the beam lifetimes, due to a reduction of the dynamic aperture. Table II shows the operation statistics of one-year positron runs.

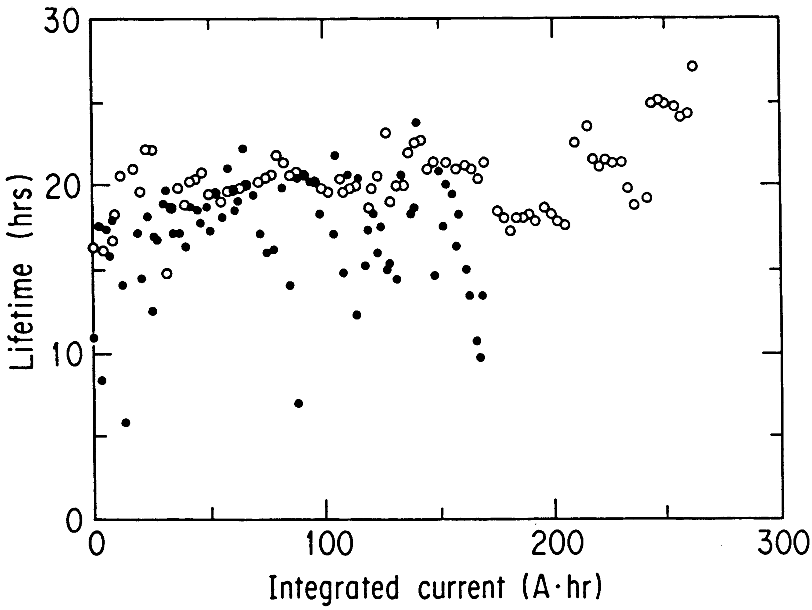

FIGURE 2 Average lifetimes of electron and positron beams at a stored current of 200 mA. Solid circles indicate electron runs (1988/5/20-7/11). Open circles indicate positron runs (1989/5/23-7/28). Sudden beam losses due to the micro-particle trapping caused a scattering of the electron lifetimes.

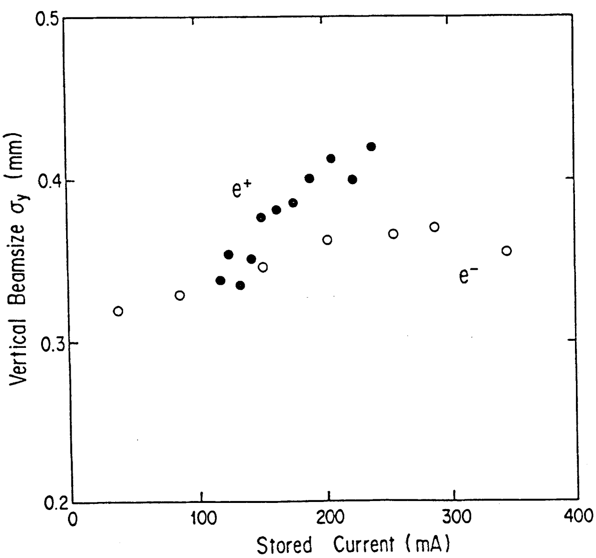

FIGURE 3
Vertical beam sizes of electron and positron beams.

TABLE II Statistics of operation with positron beams for user runs between July 12,1988 and July 28,1989

Scheduled time (hrs)	2499.3
Net user time: T (hrs)	2096.8
Time spend for injection (hrs)*	212.7
Integrated current in T (Ahr)	438.8
Average current in T (mA)	194.5
Number of injection	211
Interval between injections (hrs)	10.0

* Including preparation time for insertion devices.

DAILY DRIFT OF THE LIGHT AXIS[1,5]

Movements of the photon beam axes originate from a large number of sources. Drift in a daily period is the largest one, the amplitudes of which were enlarged by 3-10 times after reducing the horizontal emittance of the circulating beams in 1987. Because the drifts were sometimes over 1 mm (measured 12 m from the source point), the experiments were considerably disturbed. A feedback system was employed in order to stabilize drifting. It corrects the closed-orbit distortions of the entire ring circumference by referring the photon beam position at beamline-21. This correction works fairly well, though not perfectly; drifts of over 200 μm are still observed at several beamlines.

Such drifts are correlated to the weather and temperature of this area; this suggests that a distortion of the Light Source building due to temperature changes, especially of the

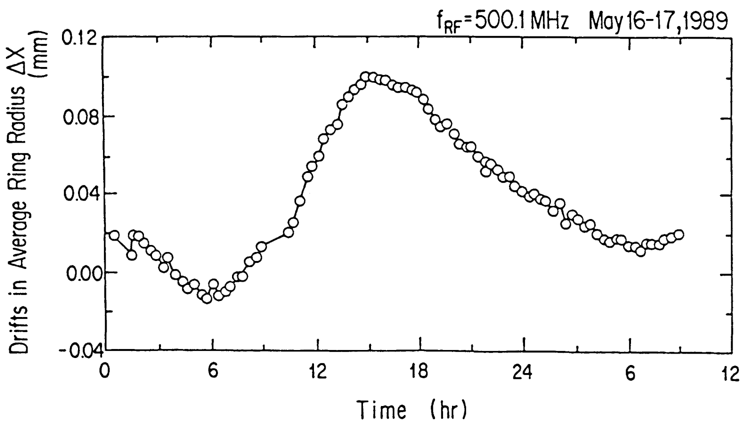

FIGURE 4 Changes in the average ring radius over the course of a day.

building roof, propagates to its floor on which the storage ring is located. Thus, the magnets move by 100-200 μm over the course of a day. Figure 4 shows an example of a change in the average ring radius. The floor also moves vertically by the same amounts. Because the circulating beams pass off-center of the quadrupole magnets, the orbits would be greatly disturbed. As a results, the photon beam position moves greatly at the experimental points.

DEVELOPMENTS IN VERY NEAR FUTURE

(1) Thermal shields of the Light Source Building
The simplest way to eliminate the daily drifts of the light axis is by covering the entire roof with thermal shields. The effectiveness of shielding was studied. Results show that an urethane-foam mat (50 mm-thick) reduces the temperature changes in the concrete roof by 1/20, which is enough to eliminate sunshine effects.

(2) Installation of a new superconducting wiggler
The superconducting vertical wiggler which is now in operation has a narrow horizontal aperture in order to obtain high magnetic fields (maximum 6T). Since this aperture is too narrow for the beam injection, we require a complicated procedure (lifting the whole cryostat up and down and switching the magnet currents OFF and ON) during injection times. The new type wiggler, which is also a vertical bending type, has an aperture sufficiently wide to the beam injections with the magnet fields ON (maximum 5T). If it works, about 30 minutes will be saved during every injection.

(3) Modifications of the undulator for beamline-2
The configuration of the permanent magnets will be changed to the hybrid type. At the same time, the vacuum chamber will be replaced to a new type which accommodates narrower magnet gaps and has a much greater pumping power.

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