COMMISSIONING OF THE PHOTON FACTORY WITH A HIGH BRILLIANCE OPTICS

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Abstract

The Photon Factory storage ring was successfully commissioned with a new high brilliance optics. The measured emittance was 29 nm-rad, which is close to the goal, 27 nm-rad. The beam current of 400 mA could be stored with this emittance. The beam lifetime is limited by both residual gas scattering and Touschek scattering. The users operation with the new optics will be started in this May.

1 INTRODUCTION

The Photon Factory storage ring, a 2.5 GeV synchrotron light source, has been operated since 1982. As a result of many developments and improvements during these 16 years, the average beam current reached to 300 mA with a very long lifetime of 60 hours[1]. In 1987, the emittance was reduced from 460 nm-rad to 130 nm-rad[2]. However, this value was still larger by one order of magnitude than the typical value of the 3rd generation light sources. In Japan, two universities have proposed constructions of third generation light sources in VUV and soft X-rays[3]. However both of these projects are still not yet approved so far. To meet strong demands for high brilliance VUV and soft X-ray radiation, a new low emittance optics was designed and proposed for the Photon Factory[4].

The new optics is realized by doubling the numbers of the quadrupoles and sextupoles in the normal cell sections. The emittance can be reduced down to as small as 27 nm-rad. This results in 10 times brighter synchrotron light from the existing undulators. Main beam parameters of the old and new optics are summarized in Table 1. The optical functions of those optics are shown in Figure 1.

A design report for this program was published in 1993[5]. Soon after, the R&D's on the accelerator components were started. Until the end of 1996, developments and fabrications of all the components were completed. The storage ring had been shut-down from Jan. to Sept. in '97. All the reconstruction works were completed during these 9 months. The details of the reconstruction works were described elsewhere[6].

In this paper, the commissioning status is described.

Table 1 . Beam Parameters

	old	low-ε(135deg)
Circumference[m]	187	---
Energy[GeV]	2.5	---
Emittance[nm-rad]	130	27
Energy Spread	$7.3x10^{-4}$	$7.3x10^{-4}$
Mom. Comp. (α)	0.016	0.0043
Betatron Tunes	(8.44,3.30)	(10.85,4.20)
Chromatisity	(-13.5,-9.0)	(-16.1,-13.3)
RF voltage[MV]	1.7	---
Synchrotron Tunes	0.023	0.011
Bunch Length[cm]	1.52	0.84

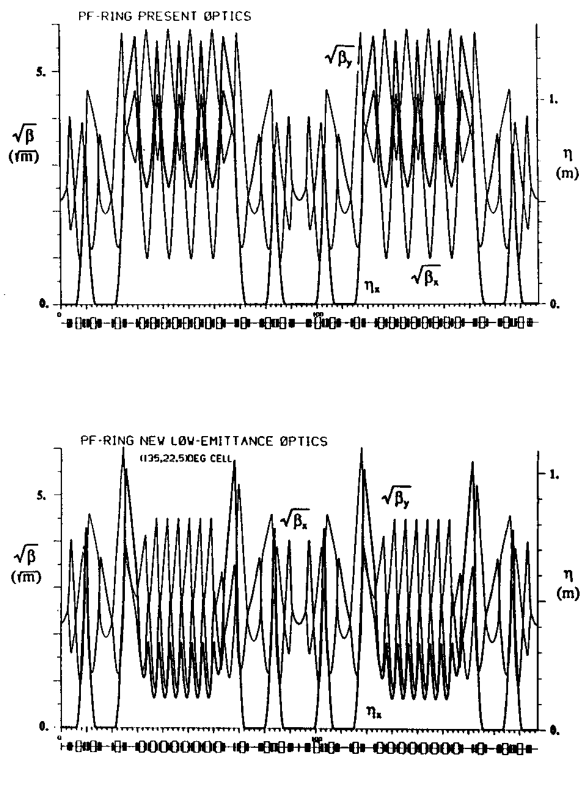

Figure 1 . Old (upper) and new (lower) optics

2 COMMISSIONING; FIRST STAGE

The commissioning of the reconstructed machine was started in Oct. '97. Since we should have started the users operation as soon as possible, we decided to start the commissioning and also the users operation with the old optics which were familiar to us. Even after the reconstruction, we can operate the machine with the old optics[5].

On the first day, after adjusting the injection position and angle by utilizing a single pass beam position monitor[7], we confirmed the beam circulation of about 100 turns without RF. On the second day, a beam could be stored with RF on. 10 days later, the maximum beam current reached to 500 mA.

The new vacuum chambers were not baked after the installation. The vacuum conditioning was performed only through SR irradiation in the high current operation. The result was satisfactory as shown in Figure 2. About one month later, the average pressure normalized by beam current reached to $1x10^{-9}$ [Torr/A].

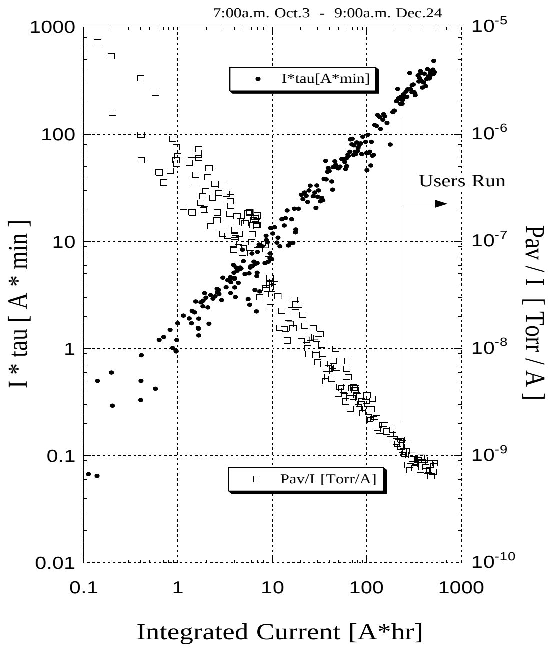

Figure 2. The result of vacuum conditioning. The black circles are the lifetime multiplied by the beam current. The white squares are the average pressure normalized by the beam current. The horizontal axis is the integrated current as a measure of time. The data from Oct. 1 to the end of 1997 are shown. The start of the users operation is indicated in the figure.

The new damped RF cavities were successfully commissioned[8]. No beam instabilities caused by the higher order modes of the cavities was not observed for the beam current as high as 400 mA.

A new beam position monitor system and a new orbit stabilization system were also successfully commissioned[9]. We can measure the closed orbit with an accuracy of 1 µm (rms) and a sampling speed of 100 Hz. By using these data, the orbit can be stabilized within 10 µm with a feedback cycle of 10 Hz.

After all these machine tunings, the user's operation was started on Nov. 4 with the old optics. The beam injection is twice a day (9 a.m. and 9 p.m.). The maximum beam current is 400 mA.

3 COMMISSIONING; SECOND STAGE

The study on the low emittance optics was started in parallel to the users operation, by utilizing the machine study time assigned on every Monday.

In figure 3, the emittance is shown as a function of the horizontal phase advance of the normal cells. The emittance has a minimum at 135 degree. A tracking study showed that, as the phase advance is increasing, the dynamic aperture gets smaller[10]. Thus, we started the low emittance operation at 90 degree. Then we increased the phase advance step by step as shown in Figure 4.

We could store a 400 mA for the phase advance between 90 degree and 125 degree so far. The design emittance for 125 degree optics is 30 nm-rad. We tried to store the beam at 135 degree, but we still cannot. The main reason of this seems to be a small dynamic aperture. A further study will be done in near future by utilizing a dynamic aperture measurement system[11].

In Table 2, the results of the low emittance operation are summarized. From a beam size measurement[12], the horizontal emittance was estimated to be 29 nm-rad for the 125 degree optics, that is very close to the design value, 30 nm-rad and is not so far from the minimum emittance of the new lattice, 27 nm-rad. As for the vertical emittance, a preliminary measurement by using an interferometer was carried out. The result suggests a XY coupling of about 1%.

The beam lifetime was somewhat shorter than expected. In the low emittance optics, the gas scattering and the Touschek effect have almost same beam loss rate[5]. Since the ring vacuum is still not recovered completely, the gas scattering lifetime is shorter than expected at present. By continuing the operation, this will be gradually improved. Touschek lifetime, which was estimated from the observed lifetime in single bunch operation, is also shorter than expected. This is most likely because of the smaller X-Y coupling than 2% that we had assumed in the design report [5].

An undulator spectrum was measured at a beam line both for old and new optics. The measured intensity change agreed well with the calculation[13].

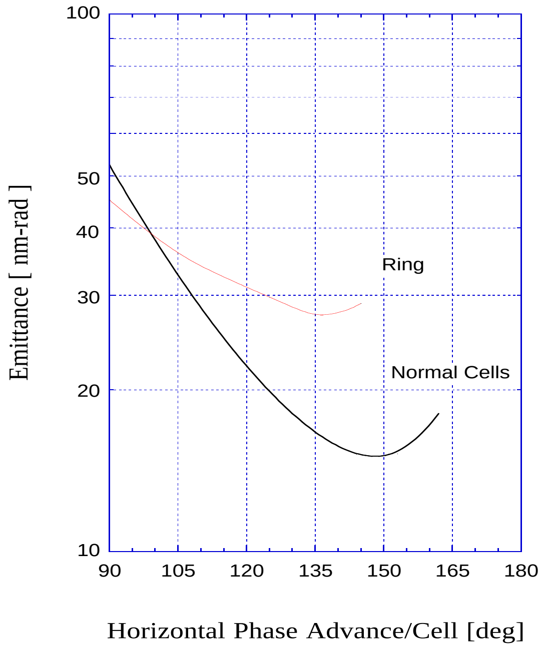

Figure 3. Beam emittance as a function of the horizontal phase advance of the normal cell. The solid line is for the case of normal cells only. The dashed line is for the whole ring.

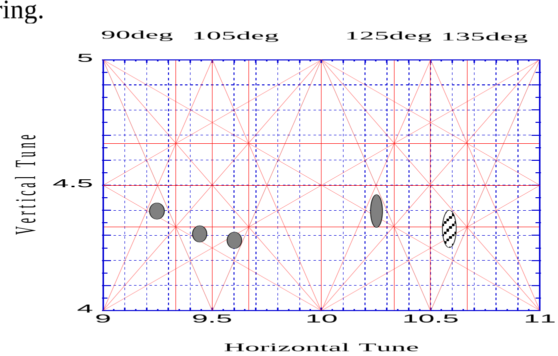

Figure 4. Tune Diagram. We could store 400 mA beam at the shaded area with dots. We could store a few mA beam at the shaded area with lines, without the sextupoles but still cannot inject with the sextupoles on.

Table 2. Summary of the low emittance operation

	design goal	achieved
Emittance	27 nm-rad	29 nm-rad*
XY coupling	< 2%	~1%*
Max. Beam Current	400 mA	400 mA
Beam Lifetime	40 hr	~12 hr (29 nm-rad)
(@300mA)		~20 hr (37 nm-rad)

Note; * These values were obtained from a preliminary measurement for the 125 degree optics.

4 SUMMARY

The Photon Factory storage ring was successfully commissioned after the reconstruction work for high brilliance. The machine operation was started with the old optics first. All the machine tunings including the vacuum conditionings was completed within one month. The users operation was started on schedule with the old optics.

The low emittance optics was also successfully commissioned. The smallest emittance achieved so far is 29 nm-rad, which is close to the design goal, 27 nm-rad. A 400 mA beam could be stored with this emittance. The lifetime is somewhat shorter than expected, probably because of the small XY coupling and of the ring vacuum that is not completely recovered at present. Users operation with low emittance optics will be started in May '98.

5 ACKNOWLEDGMENTS

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