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STATUS OF KEK-PF STORAGE RING

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Introduction

The 2.5 GeV electron storage ring constructed at the Photon Factory, KEK, is the dedicated machine for the research work with synchrotron radiation. The principal parameters of the storage ring are listed in Table 1. The ring construction started in April, 1978 and the first synchrotron radiation was obtained in March 1982.

Table 1. Principal parameters of the storage ring

Energy	2.5 GeV max. achieved 3.0 GeV
Stored current	300 mA max. achieved 360 mA
Circomference	187 m
Radius of cuvature	8.66 m
Betatron frequency	horizontal 8.38
	vertical 3.18
Emitance	horizontal 130 nm.rad.
	vertical 2 nm.rad.
RF frequency	500.105 MHz
Harmonic number	312
Number of cavity	4
Radiation loss	400 KeV/rev. 510 KeV with wiggler
Straight section	2 long 5 m
	8 medium 3.5 ∿ 3.75 m
Insertion devices	sc vertical wiggler 5 T
	60 period undulator K=1.78 ∿ 0.1
	26 period MP wiggler 1.5 T
	revolver type undulator 4 ways *
	circular polarized undulator *
	14 period MP wiggler 1.5 T *
	* in construction
SR channel	16 for SR experiment
	3 for beam diagnosis
	4 in construction
Vacuum pressure	3×10^{-11} torr no beam
	4×10^{-10} torr at I=150 mA
Beam lifetime	15 hr at I=300 mA. 30 hr at 150 mA
Injection	2.5 GeV electron rate 1 Hz
Time for injection	1.5 ∿ 10 minutes

Two long straight section are occupied by the 60 period undulator and the 26 period multipole wiggler. Eight medium straight sections are ; two are occupied by two pairs of cavities, one is conserved for the injection system, another one for the vertical wiggler whose magnet is made of superconducting coils, three for new insertion devices in construction and only one is unoccupied. As for the SR channels the ring has twenty eight bending magnets, however, twenty four places are allocated for the SR research works because of the shape of the light source building. Now sixteen SR channels are supplying SR to the users, three are used for the beam diagnosis and four channels are in construction. So, only one place is reserved for a new plan. In short, the PF facility has been used quite efficiently.

OPERATION

The storage ring was commissioned in June 1982. Since then, the ring has been operated quite stably and efficiently for over five years. Fig. 1 shows the ring operation time in each fiscal years. In FY 1982, the total time of ring operation was 1298 hours because of the shortage of the operation budget, specially budget for electric power. The scheduled user time was 611 hours which was 51 % of the total time. At that time, there were many parts which must be improved following the results of the machine study. However,

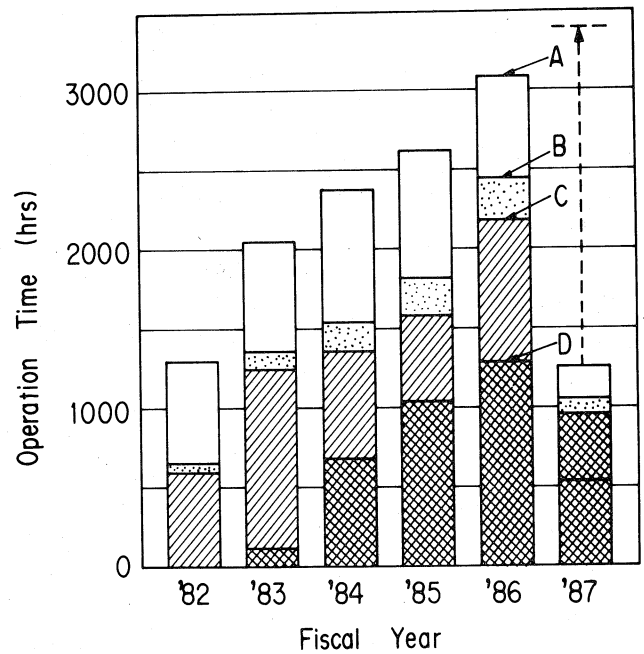

Fig. 1 Ring operation time. In FY '87, the time was counted from April 1 to July 18. A means the total operation time. B: the scheduled user's time. C: the effective user's time excluding the injection time and the machine trouble time. D: the user's time operating the wiggler.

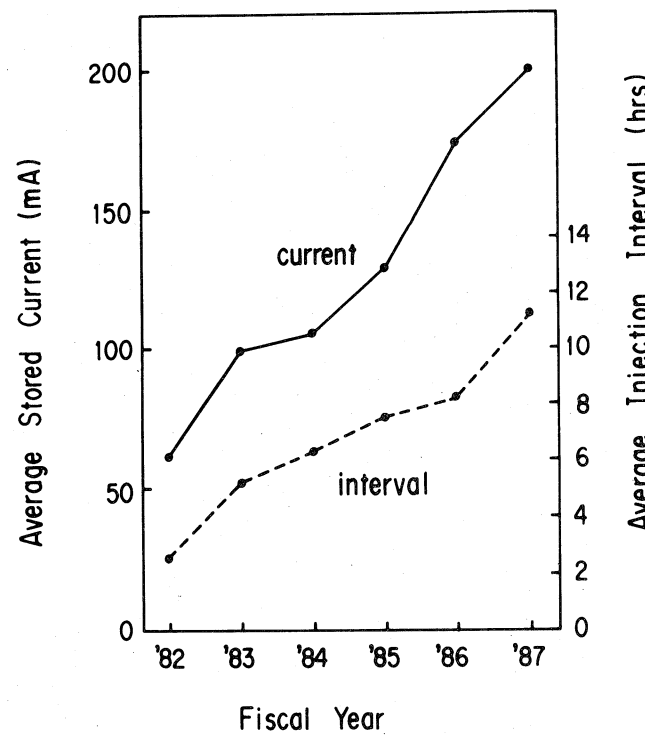

Fig. 2 The average stored current and the average injection interval during user time.

the operation budget has increased year by year and, in FY 1986, the ring operation time exceeded over 3000 hours. The percentage of the user time in the total ring time also has increased to 79 %, because, during the time for the injector linac study, the ring could maintained its stored electron beam without any reinjection for one day and supply SR to the users. Though the machine failure time is about 1 % of the scheduled user time, it took much more time for the injection when the vertical wiggler was operating. The wiggler has superconducting coils with a narrow magnetic gap, so that the wiggler operation must take many complex procedure before and after reinjections. As the result, the effective user time remained 90 % of the scheduled user time.

The average stored current and the average injection interval during the user time has been increased remarkably as shown in Fig. 2. These progresses were mainly attributed to the improvement of the vacuum system of the ring. Untill summer 1985, the initial stored current was limited within 150 mA, because a part of the water cooling system of the vacuum chamber was not satisfactory. Now the initial current is 300 mA when the wiggler is not in operation and is 250 mA during the wiggler operation. The limitation is due to the lack of RF power, however, a new power supply for a klystron is in construction and we are expecting that the initial current with wiggler operation will be reached to the design goal, 500 mA, during FY 1988.

Untill the end of FY 1984, the ring started its operation at nine O'clock on Tuesday morning and ended at nine O'clock on Saturday morning. We called this as one week mode. Then, two weeks mode of the operation began, in which the ring was operated from Wednesday morning through Saturday morning of next week, that is 240 hours continuous operation . In November 1986, the TRISTAN ring which is a 30 GeV electron - positron collider was successfully commissioned at the energy of 25 GeV. The TRISTAN experimental groups wanted a long period operation. The injector linac is common for PF and TRISTAN, so that the PF ring must make a three or four weeks mode of the operation.

LOW EMITTANCE OPERATION

In the old design, the horizontal beam emittance was 400 nm rad., with the betatron frequency number of 5.38 in the vertical direction and 4.18 in the horizontal direction, respectively. During the summer shutdown in 1986, four quadrupole magnets newly fabricated were installed into the ring and four power supplies which excited twenty four quadrupole magnets were enforced. On February 3, 1987, the low emittance mode operation was started. It took three hours to change connections of cables at the power supplies of the quadrupole magnets. The betatron frequency number was measured. In the horizontal direction, the number was changed from 5.38 to 8.38 and, in the vertical direction, from 4.18 to 3.18, respectively. The betatron functions were measured and corrected. So the horizontal emittance was reduced to 130 nm rad. The brilliance of SR was expected to increase 2 ∿ 20 times depend on beam channels.

Since February 1986, we had measured continuously the position of the light axis at beam channel No.21. The position was 12 m apart from the light source. To our surprise, the position of the light axis suddenly began to move violently after the low emittance mode started. Fig. 3 shows the long term deviation of the light axis. A in Fig. 3 was the case when the ring was operated in normal emittance. In this case, the position was not normalized by the stored current, so that the position change was estimated to be within 20 μm. B in Fig. 3 was observed after the low emittance was started. Two different periods were observed : one had a period of about 15 minutes and another was about one hour. The cooling water system for magnets and vacuum chambers had two fans. One was always in active and when the water temperature reached 25 degree, the second fan was switched on. After three minutes, the

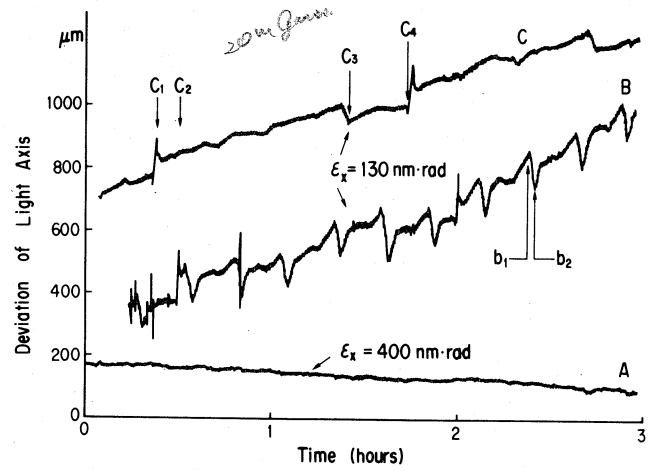

Fig. 3 Vertical deviation of light axis in long term. A : January 31, 1987, when the operation mode was high emittance. B : Feb. 4, in the low emittance mode. b_1 corresponded to the time when the second fan of the cooling tower began to operate and b_2 fan stopped. C : Feb. 5, after the second fan switched off. C_1, C_2, C_3 and C_4 corresponded to the time when the TRISTAN energy was 0, 6, 25 and 40 GeV, respectively.

temperature went down to 24 degree and the second fan stopped. This period was just corresponded to the former period. The deviation was 120 μm. After stopped the second fan, we observed C in Fig. 3. These sudden deviation was corresponded to the operation status of the TRISTAN magnet. The TRISTAN magnet had no return winding and it produced weak magnetic field at the PF ring. A measurement and the calculation showed that the maximum field of 20 m gauss in the vertical direction gave 160 mm vertical deviation of the light axis.

The light axis deviation has a long term shift as can be seem in Fig. 3. This shift has an one day period and the amplitude was reached about 1 mm. Some user claimed to stop the low emittance operation. Then, the ring was again operatd in the normal emittance for one week. During this time, the light source group prepared a feed back system ; the light axis deviation was measured at BL-21 with a split ion chamber and when the deviation reached 10 μm, one digit signal was generated and was sent to the power supplies of the vertical steering magnets set around the ring to correct the position of the electron closed orbit. With this feedback system, the amplitude of the light axis shift was reduced to 20 μm at BL-21, 60 μm at BL-12 and less than 200 μm at other channels except BL-4 which had a large ampletude of 400 μm, respectively. Since then, the ring has been operated in the low emittance mode.

To reveal the cause of the light axis shift, the amount of feedback, the outdoor temperature and the change of weather were recorded at every O,clook for nine days. From the amount of feedback, the light axis shift was calculated and is shown in Fig. 4 with other records. We found that one degree change of outdoor temperature gives 60 μm of the shift. Snowfall and bright sunshine give large shifts. On the contrary, rainfall gives a small shift of the light axis. Though the inside of the light source building is air-conditioned, the outdoor temperture, snowfall and sunshine heat and cool the outer wall of the building to distort its shape. This distortion gives an alignment error to quadrupole magnets of the ring. The amount of the alignment error was estimated to be an order of 0.1 mm. The next generation ring dedicated to the SR research work will be a low emittance one, so that our experience above mentioned must give an invaluable suggestion how to design the light source

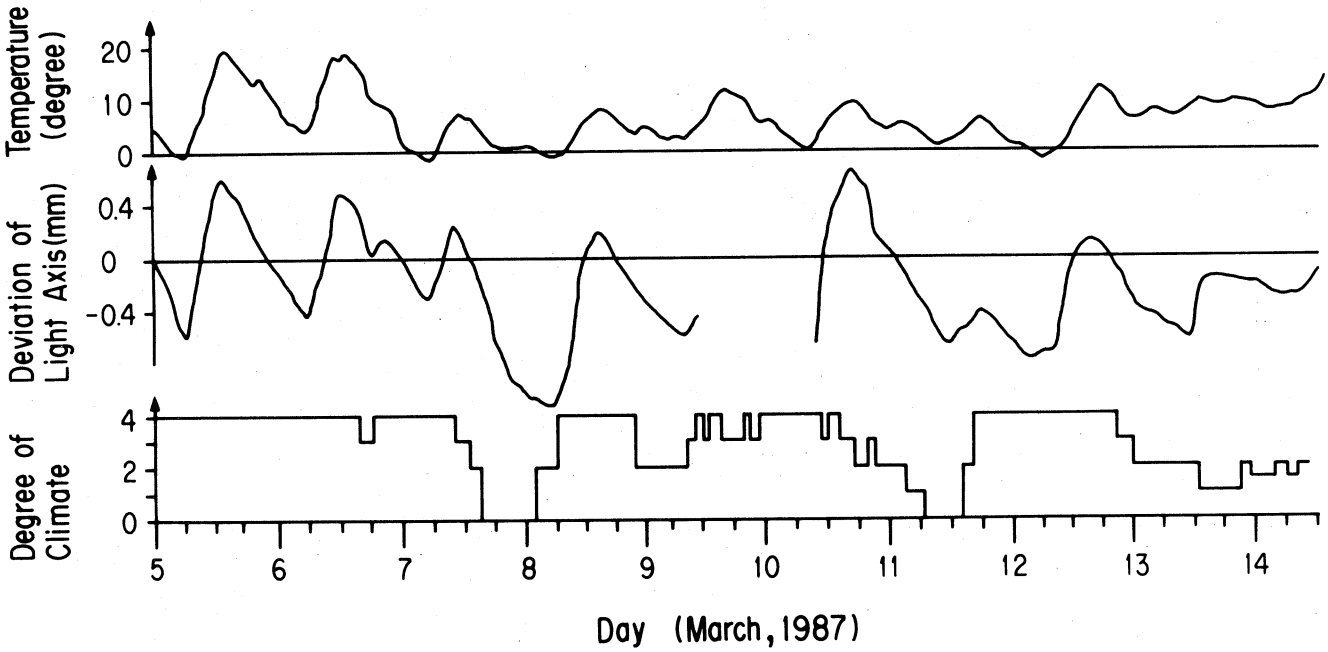

Fig. 4 Correlation between the deviation of the light axis (No.21 channel) and the outdoor temperature and the change of the climate. The deviation was measured at the point 12 m apart from the light source. Degree of climate means : 0 = snowfall, 1 = rainfall, 2 = thick cloud, 4 = thin cloud, 5 = sunshine.

building and its civil engineering.

Since the commissioning of the PF facility, ten percent of the total operation time of the ring has been devoted to the study on the ring itself. Based on these studies, the ring has been improved to increase the stored current and to make a stable operation. During every summer shutdown which was usually for three months, a large scale improvement of the ring was done; installing a new beam channel, inserting new devices, installing quadrupole magnets for low emittance operation and changing vacuum chambers, etc. Fig. 5 shows the progress of the available brilliance of SR at the energy from 0.1 KeV to 100 KeV.

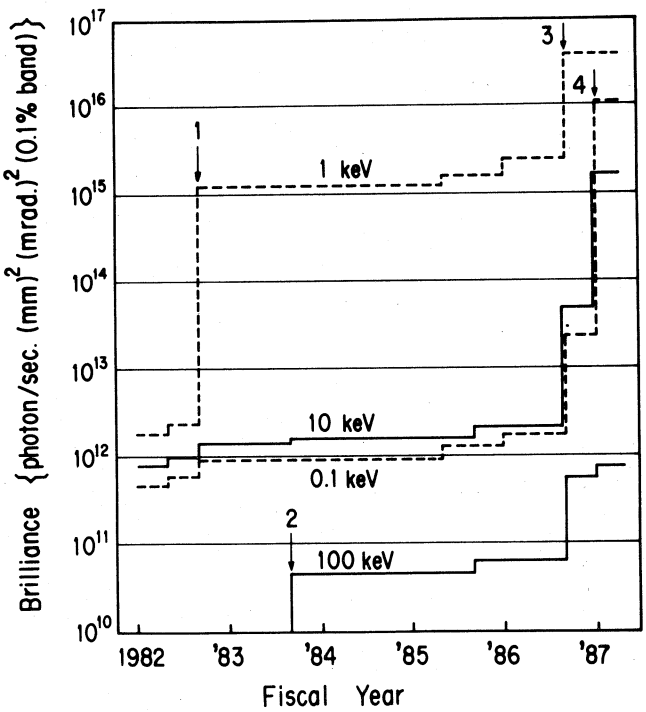

Fig. 5 Available brilliance of SR at the energy from 0.1 KeV to 100 KeV. Numbers indicated in the figure mean ; 1. an undulator was inserted at BL-2, 2. a vertical superconducting wiggler operated. 3. low emittance mode operation started. 4. a multipole wiggler was allocated.

FUTURE IMPROVEMENT

Positron accumulation ; in March of the next year, we will try the positron accumulation with the injection rate of 25 Hz. Four kicker magnets made by ferrite cores with ceramic chambers were already installed in the ring. Now the power supplies of the kicker magnets and two septum magnets and their power supplies are newly fabricating. We are expecting that the positron accumulation will completely cure the two beam instability caused by ion trapping and the lifetime deterioration of the beam caused by dust trapping.

New feedback system for the stabilization of the closed orbit ; at present, the distortion of the closed orbit is measured at one point. In the new system, the distortion will be measured at five points.

Improvement of the vertical wiggler with superconducting coils; Owing to the low emittance operation, the horizontal aperture of the beam at injection can be reduced to 40 mm, so that the newly fabricating wiggler has a 60 mm magnetic gap with five poles. So it is possible to excite the wiggler magnet during the injection time. This reduces the injection time largely to several minutes from 20 ∿ 30 minutes which the present system needed.

The auther would like to express his thanks to all members of the Light Source Department, who have paid great efforts to the progress of the storage ring.