PRESENT STATUS OF AN ELECTRON STORAGE RING NIJI-IV DEDICATED TO FEL

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Abstract

The beam size and the bunch length of the NIJI-IV were measured. The measured beam size is in agreement with the calculated one. The bunch length in the 16 bunches operation is 2 times larger than the one in the single bunch operation. The two sextupole magnets were installed in the ring. The chromaticity correction was completed by them.

Introduction

A storage ring "NIJI-IV" dedicated to FEL was constructed by Kawasaki Heavy Industries in cooperation with Electrotechnical Laboratory in December 1990[1][2][3]. In August, 1992 the first FEL lasing on the NIJI-IV was accomplished at 595nm[4][5]. And In September,1992 FEL lasing at 488nm has been done. At present, preparations for a FEL experiment in UV region is being made.

In this paper, the measurements of beam size and bunch length and the chromaticity correction on the ring are discussed. The beam size and bunch length are important parameters for estimation of FEL gain. Because these parameters directly contribute to the electron peak current. They were measured by a charge coupled device (ccd) camera and a streak camera respectively. The measured beam size is in agreement with the calculated one. It is well known that chromaticity of minus value causes the head-tail instability and limits maximum single bunch current. In order to correct the chromaticity in the present FEL operation mode, two sextupole magnets were installed in the ring. The chromaticity correction of NIJI-IV was completed by using the sextupole magnets.

Beam size measurement

The measurement system of the beam size and bunch length is shown in fig.1. The profiles were observed at 25 degrees source point of BD3 by using a ccd camera and a focusing lens. The output of the ccd camera was recorded by a video tape recorder. The dynamic range of the sensitivity of the ccd is not enough for the SR light. So the ccd camera was corrected by using neutral density filters and an SR light source of the ring. The optics calculation with an optical klystron at 310MeV is shown in fig.2. The horizontal and vertical distributions of the beam intensity are shown in fig.3(a) and (b). The measured and calculated beam sizes at BD3 are shown in table.1. The measured beam size is in good agreement with the calculated one.

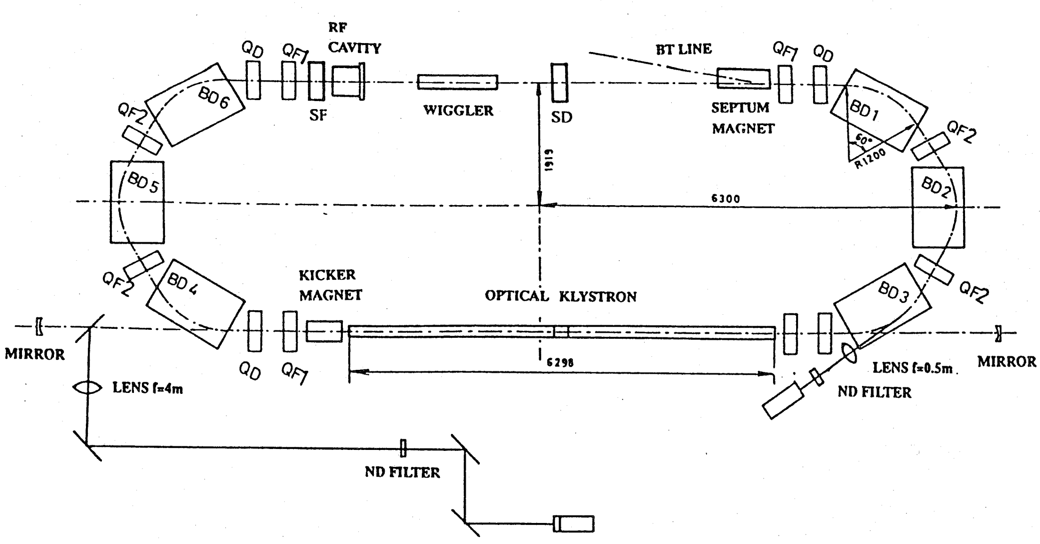

Fig.1 Measurement system for the beam size and the bunch length

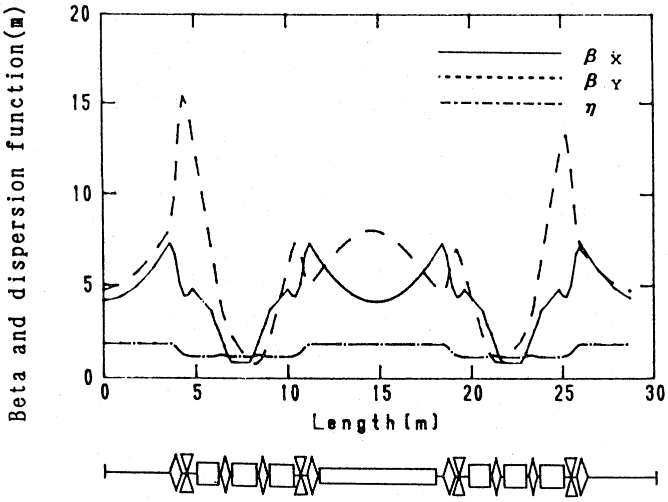

Fig.2 Betatron and dispersion function

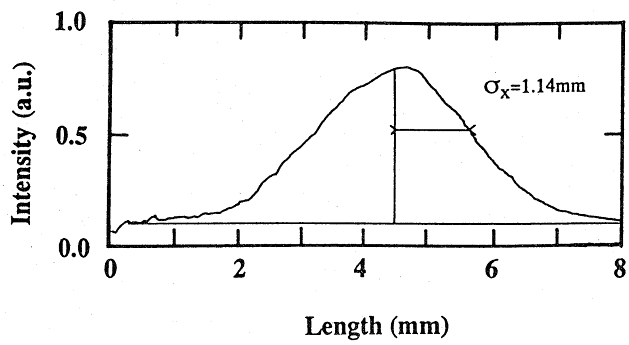

Fig.3 (a) The horizontal distribution of the beam at 25 degrees source point of BD3 (The stored beam current was below 1mA)

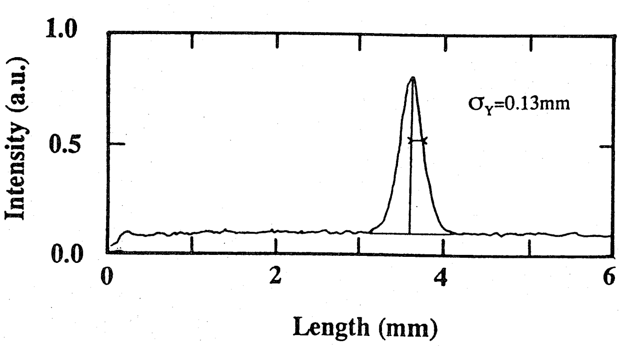

Fig.3 (b) The vertical distribution of the beam at 25 degrees source point of BD3

Table.1 The beam size at BD3

	β_x (m)	β_y (m)	η (m)	ρ_x (mm)	ρ_y (mm)
calculation	4.03	2.27	1.21	1.00	—
measurement	—	–	–	1.14	0.13

Bunch length measurement

The structure of the undulator light depends on the electron bunch length. The bunch length at the beam energy of 310MeV was measured by using the streak camera. Fig.4 (a), (b) show the results in the 16 bunches operation and the single bunch operation respectively. The bunch length in the 16 bunches operation was about 2 times as large as the one in the single bunch operation. It is thought that a longitudinal coupled-bunch instability causes the bunch lengthening. And the measured bunch length 5.3cm in the single bunch operation was a little larger than the calculated one 3.9cm.

Chromaticity correction

In the single bunch operation by using the RF-KO method the maximum stored current is about 12mA. The head-tail instability was still not observed on the NIJI-IV. At present the single bunch injection method with an electron gun of short pulse operation is being prepared. It is expected that the injection efficiency is improved and the maximum stored current is increased. So in order to stave off the head-tail instability, the two sextupole magnets SF(focus) and SD(defocus) were installed in the ring as shown in fig.1.

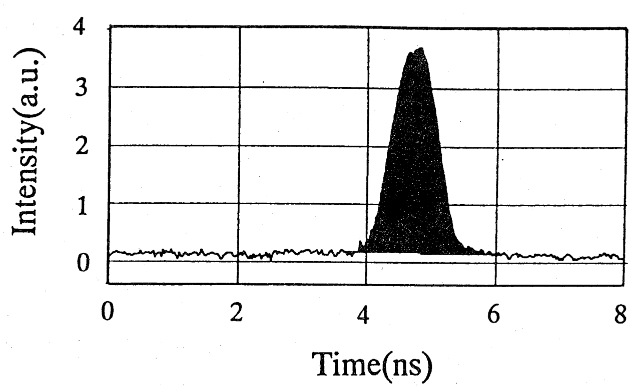

Fig.4 (a) The longitudinal distribution of the beam in the 16 bunches operation (The stored beam current was 6.8mA)

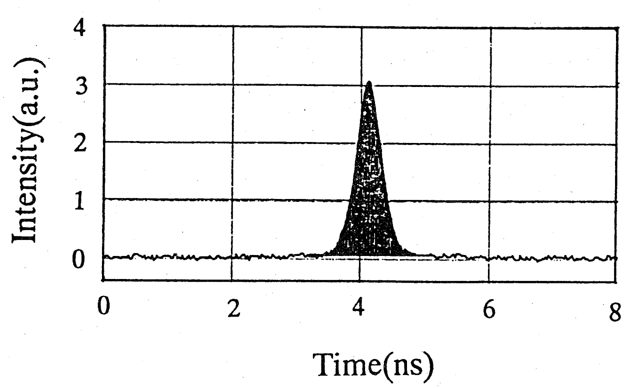

Fig.4 (b) The longitudinal distribution of the beam in the single bunch operation (The stored beam current was 2.3mA)

The chromaticity is roughly shown by

$$\xi_x = \xi_{x0}+(\lambda_{sf}\eta\beta_{x,sf}l_{sf}-\lambda_{sd}\eta\beta_{x,sd}l_{sd})/4\pi \qquad (1)$$

and

$$\xi_y = \xi_{y0}+(\lambda_{sd}\eta\beta_{y,sd}l_{sd}-\lambda_{sf}\eta\beta_{y,sf}l_{sf})/4\pi \qquad (2)$$

where ξ_{x0}, ξ_{y0} are natural chromaticities, λ_{sf},λ_{sd} are sextupol magnet strength $d^2B/dx^2/B\rho$(B, ρ are the magnetic field strength and the bending radius.), η is dispersion, β_x, β_y are betatron functions, l_{sf},l_{sd} are sextupole magnet lengths. The effective length of the magnets of the pole are 0.21m.

As the dispersion in the long straight section is not free, these two sextupole magnets can carry out the chromaticity correction.

The chromaticities were measured by sweeping the RF frequency of the accelerating cavity around 162.07MHz. The result of the measurement without the sextupole magnets is shown in fig. 5(a). The chromaticity is induced from $\xi= -\Delta\nu/\Delta f\alpha f$, where f is RF frequency, ν is tune, α is compaction factor 0.25. The natural chromaticity were measured to be ξ_{x0}=−3.16 and ξ_{y0}= 2.13 respectively. For the magnetic strength of the SF and the SD of 46T/m² and 49T/m² respectively, the chromaticities are plus as shown in fig.5(b). Hence, the chromaticity correction has been completed.

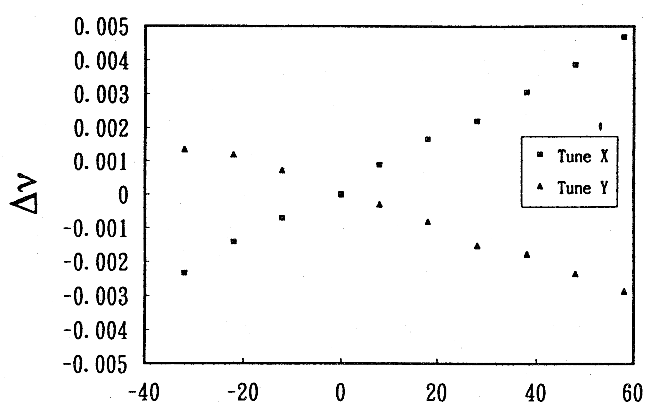

Fig.5 (a) The changes of tunes versus RF frequency without the sextupole magnets

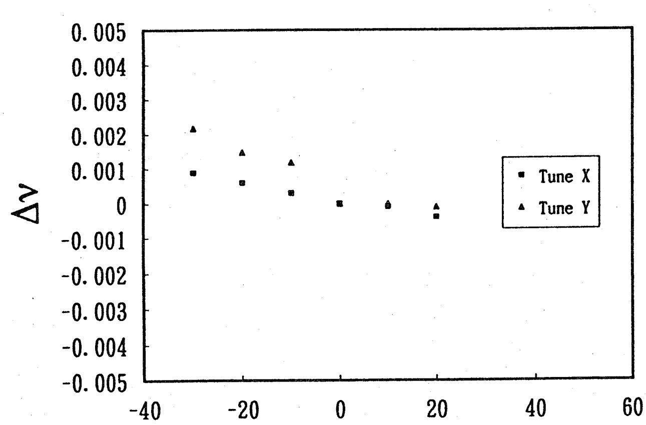

Fig.5 (b) The changes of tunes versus RF frequency with SF=46T/m² and SD=49T/m²

Conclusion

The measured beam size is in good agreement with the calculated value. The bunch length in the 16 bunches operation was about 2 times as large as the one in the single bunch operation. So for FEL gain the single bunch operation has an advantage. The bunch length at the low current was not in agreement with the calculated one. We considering the reason of the result, the focusing of the undulator light into the slit of streak camera was not enough, so the resolving power of the time was limited.

The natural chromaticity by normal optics calculation ξ_{x0}= −2.66, ξ_{y0}= −0.93 are not in agreement with the measured ones. As the reasons,

two originates

1) The sextupole component of the bending magnets in the ring.
2) The NIJI−IV is a small ring. So, ν/η is not negligible.

are thought. The sextupole component of the bending magnet is below 0.1T/m² by the calculation. The change of chromaticity due to it are $\Delta\xi_{x0}$< +0.2, $\Delta\xi_{y0}$> −0.5. So the originate 1. can not explain the difference of chromaticity between the measurement and the calculation. It is known that the chromaticity measured in the small ring differs from the calculated one[6][7]. The estimation of the change of the chromaticity due to the originate 2) needs the calculation of the 2nd order differential equations of the Courant−Snyder formalism. The computer code taken account in it should be made.

Reference

1)T. Tomimasu, S. Sugiyama, H. Ohgaki, T. Yamazaki, K. Yamada, T. Mikado, M. Chiwaki, R. Suzuki, S. Suse, M. Yoshiwa and A. Iwata, Proc. 7th Symp. on Accelerator Sci. Tech., December (1989)347

2)H. Ohgaki, T. Yamazaki, S. Sugiyama, T. Mikado, R. Suzuki and T. Tomimasu Proc. 7th Symp. on Accelerator Sci. Tech.,December (1989)284

3)M. Kawai, K. Aizawa, S. Kamiya, M. Yokoyama, Y. Oku, K. Owaki, H. Miura, A. Iwata, M. Yoshiwa, T. Tomimasu, S. Sugiyama, H. Ohgaki, T. Yamazaki, K. Yamada, T. Mikado and T. Noguchi Nucl. Instr. and Meth. A318(1992)135

4)M. Yokoyama, M. Kawai, K. Owaki, S. Hamada, K. Aizawa, Y. Oku, A. Iwata, M. Yoshiwa, T. Yamazaki, S. Sugiyama, H. Ohgaki, K. Yamada, N. Sei, T. Mikado, T, Noguchi, R. Suzuki, M. Chiwaki and T. Tomimasu 14th International FEL Conference, Kobe, 1992. to be published in Nucl. Instr. and Meth.A

5) T. Yamazaki, K. Yamada, S. Sugiyama, H. Ohgaki, N. Sei, T. Mikado, T, Noguchi, M. Chiwaki, R. Suzuki, M. Kawai, M. Yokoyama and K. Owaki 14th International FEL Conference, Kobe, 1992. to be published in Nucl. Instr. and Meth.A

6)J. Jager, D. Mohl CERN/PS/DL 81−7 (1981)

7)Y. Takahashi, T. Hattori, H. Muto, M. Okamura and K.Yoshida 14th International FEL Conference, Kobe,1992. to be published in Nucl. Instr. and Meth.A