THE ACTUAL SITUATION OF CSA-RING AND ITS BEAM TRACKING

Y. Takahashi, T. Hattori, H. Muto, Y. Oguri, Y. Ishii, M. Okamura, T. Hirata and K. Yoshida*

Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology
* Institute for Nuclear Study, University of Tokyo

Ookayama, Meguro-ku, Tokyo 152, Japan

Abstract

The CSA (Compact Storage and Acceleration)-ring for FEL was projected in 1989. Its circumference is 15 m. The lattice of the CSA-ring is a double bend double achromatic type. Although the short circumference, it has two long variable straight sections for the undulator.

In 1991 August fabrication, the bending magnets were completed and their magnetic field strength was mesured. In this paper, we present the design and the characteristics of the ring. Measured distribution of magnetic field and results of beam tracking are also reported.

Introduction

Recently some large electoron synchrotrons for SR have been built or projected in many reserch institutes in the world. On the other hand, small storage rings with laboratory size, have become also more attractive gradually.

Consequently, we designed the CSA-ring for FEL as a "4th generation" SR-ring, and an undulator as an insertion device for the ring was completed in 1989. Then, spontaneous-emitted light (595nm) from the undulator by using a 145MeV electoron linac was detected in 1991[1].

Basic design of CSA-ring

As shown in Fig. 1, the feature of the CSA-ring is race track shape. The magnetic lattice is double bend double achromatic and low emittance type. The ring was designed by the following basic concepts.

(1) There are two long straight sections for insertion devices such as undulators.
(2) The length of straight sections is variable in order to follow that of the undulator.
(3) Dispersion free at straight section.
(4) The beam is focused at straight section.
(5) Low emittance, small energy dispersion.
(6) Compact size for limitted spaces.

Characteristics of the CSA-ring

Main parameters of the CSA-ring are shown in table 1. The ring as a light source has the following characterisitics:

(1) The light wave length is variable by changing beam energy, or undulator gap.
(2) The intensity and the spot of lasor are variable by changing the strength of the Q-magnets.
(3) Even the case with the beam sent from puls electoron linac, it is possible to improve its intensity and quality.

Table 1 Machine parameters of CSA-ring

BEAM ENERGY (MAX ENERGY)		150 (330) MeV
CIRCUMFERENCE		15 m
AVARAGE RADIUS	R	2.39 m
BENDING MAGNET	No.	4
	RADIUS	0.6 m
	FIELD STRENGTH	8.33 (17.0) kG
QUADRPOLE MAGNET	No.	10
	LENGTH	0.18 m
	FIELD GRADIENT	0.33, -0.37
		0.62 kG/cm
LONG STRAIGHT SECTION	No.	2
	LENGTH	2.43 m
BETATRON NUMBER	ν_X	~2.25
	ν_Y	~1.35
RF FREQUENCY		100 MHz
RF VOLTAGE		≧20kV
HARMONIC NUMBER		5
MOMENTUM COMPACTION FACTOR		0.11
RADIATION LOSS		8.2×10^{-2} keV
PRESSURE		1.0×10^{-9} Toor
RADIATION DUMPING TIME	τ_X	0.34 s
	τ_Y	0.18
	τ_E	0.51
NATURAL EMITTANCE	ε_X	2.18×10^{-7} mrad
	ε_Y	2.20×10^{-8}
BEAM CURRENT		≧200 mA
BEAM LIFE TIME		≧45 min

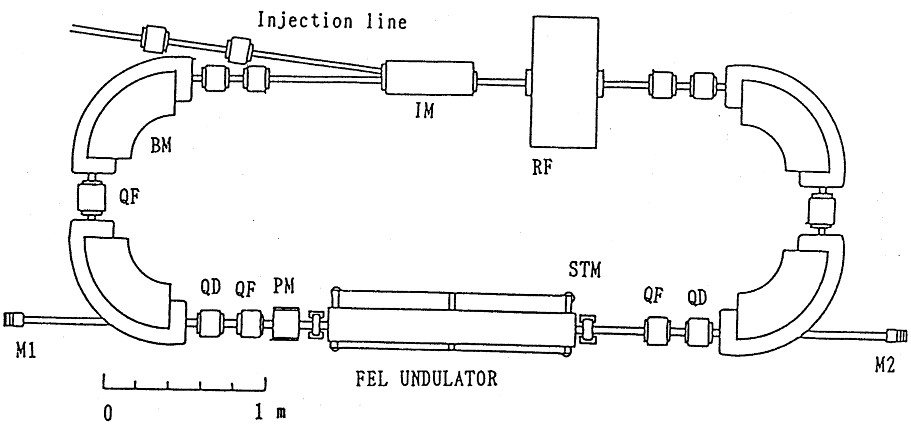


Fig. 1

Plane view of the CSA-ring

BM bending magnet
QF foucusing magnet
QD defocusing magnet
SM steering magnet
IM inflection magnet
RF RF cavity
PM perturbation magnet
M1, M2 mirror

Lattice of the CSA-ring

The lattice of the ring was designed with the SYNCH program. Beam optical functions are shown in Fig. 2. Fig. 3 shows a results of tracking calculations in Horizontal phase space after injection.

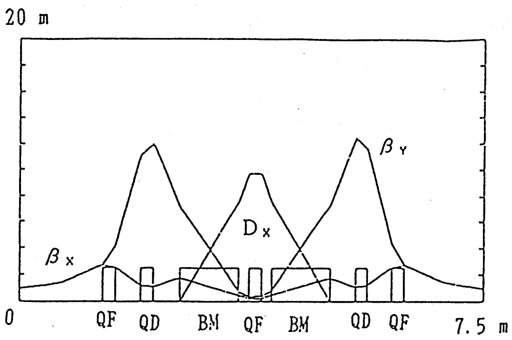


Fig. 2 Betatron and energy dispersion functions of one cell

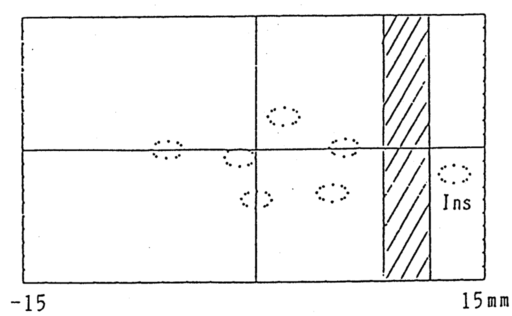


Fig. 3 Phase space after injection (horizontal)

Design of the bending magnets

Since one of the basic concepts of the CSA-ring is its compact size, then the bending magnets have been designed to be as smoll as possible. The structure of the bending magnet is illustrated in Fig. 4, 5, 6 and 7.

The bending magenet is the C-shaped type and its deflection angle is 90°. The height is 500mm and the gap width is 26mm. The height of the sim is 0.4mm. The end of each pole piece is cut along Rogowski's curve.

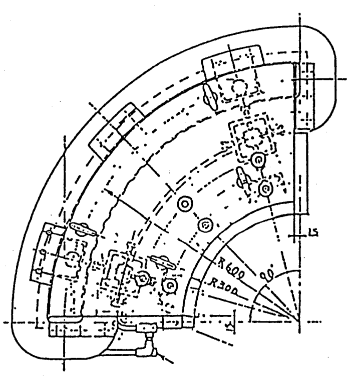


Fig. 4 Plane view

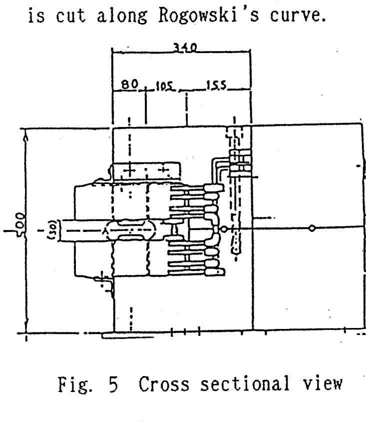


Fig. 5 Cross sectional view

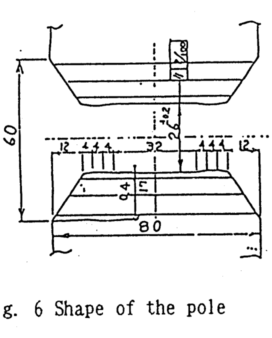


Fig. 6 Shape of the pole

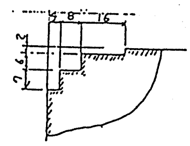


Fig. 7 Pole end

Mesurement of bending magnet

Measured field distributions of bending magnets is plotted in Fig. 8, 9, 10. The good field regionwidth ($\Delta B/B \leqq 1/1000$) is about 30mm. The effective lengthis about 9mm at 1 T, which is about 7mm shorter than the expected one.

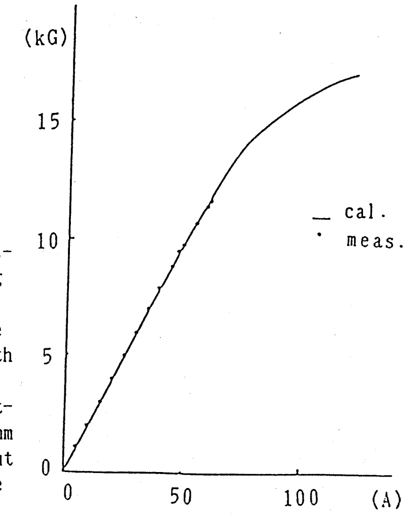


Fig. 8 Magnetic fieldas a function current (at the center of the bending magnet)

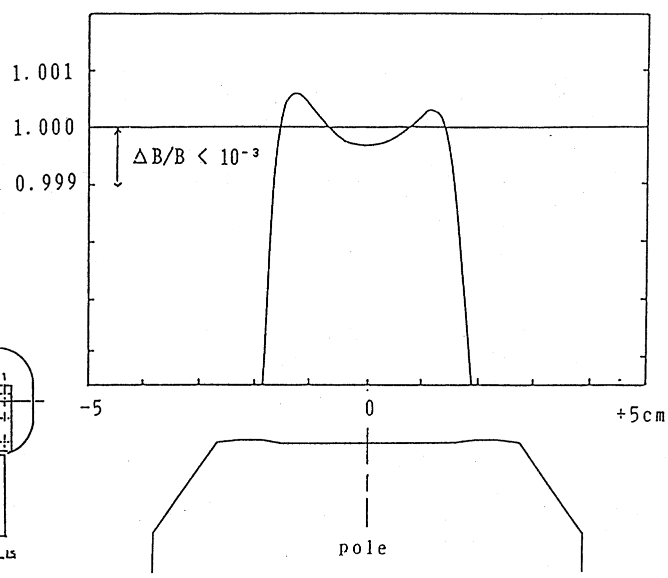


Fig 9 Distribution of B_z in bending magnet

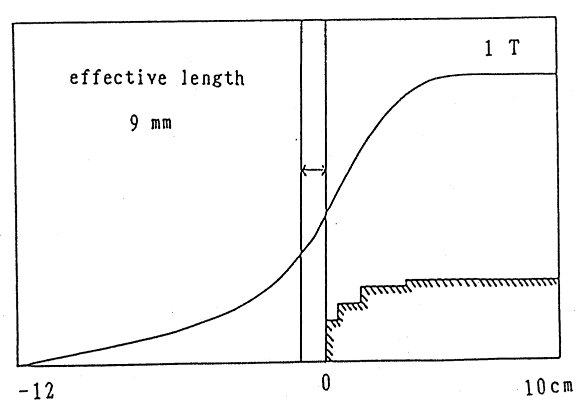


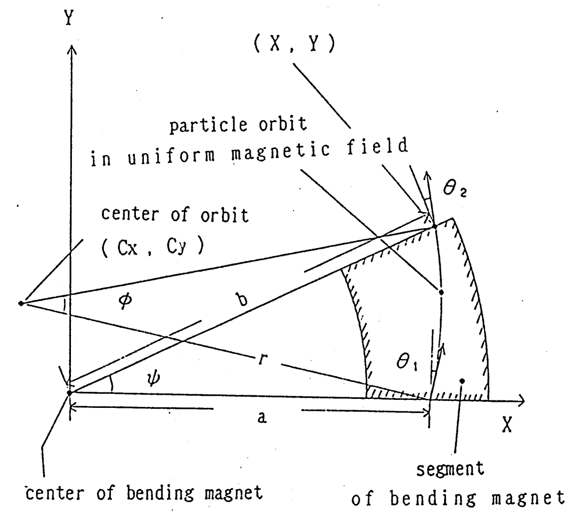
Fig 10 Distribution of B_z at an end of the york

Beam tracking of CSA-ring

As well known, there are some design programs for synchrotorns, such as SYNCH. These computer code, however are not appliable to small storage rings. Because of the spread of ten meters order circumference rings, the necessities of new programs for beam tracking in small ring have been gradualy recognized.

In existing programs for small rings, matrix method or numerical integration method in calcurating the part of bending magnets. The former is an aproximation. The latter alwa ys suffers fromnumerical errors.

Then we have developed a beam tracking code in phase spase by using geometrical method(Fig. 11). The phase space at the center of straight section are illustrated in Fig. 13. Betatron tunes caluculated are shown in table 2. We see defferences between design values and the matrix method. this discripacy is caused by change in the effective length.



$Cx = a - r\cos\theta_1$ $\quad Cy = r\sin\theta_1$ $\quad \phi = \psi + \theta_1 - \theta_2$ $\quad k \equiv \tan\psi$

$$X = \frac{\{(Cx+Cyk) - \{(Cx+Cyk)^2 - (1+k^2)(Cx^2+Cy^2-r^2)\}^{1/2}\}}{(1+k^2)}$$

$Y = Xk$ $\qquad b^2 = X^2+Y^2$

$$\cos\theta_2 = \frac{a^2-b^2+2ar\cos\theta_1}{2br}$$

Fig. 11 2-dimensional geometrical method

Table 2 Comparision of betatron tunes

	DESIGN	MATRIX METHOD	GEOMETRICAL METHOD
ν_X	2. 25	2. 24	2. 21
ν_Y	1. 35	1. 37	1. 37

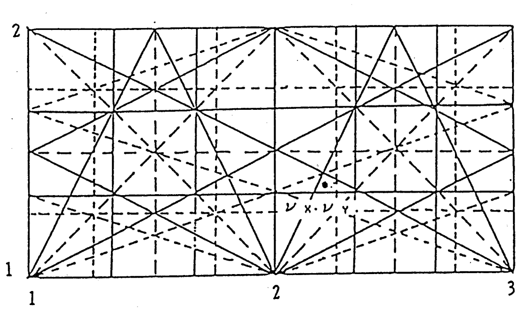


Fig. 12 Tune diagram of CSA-ring

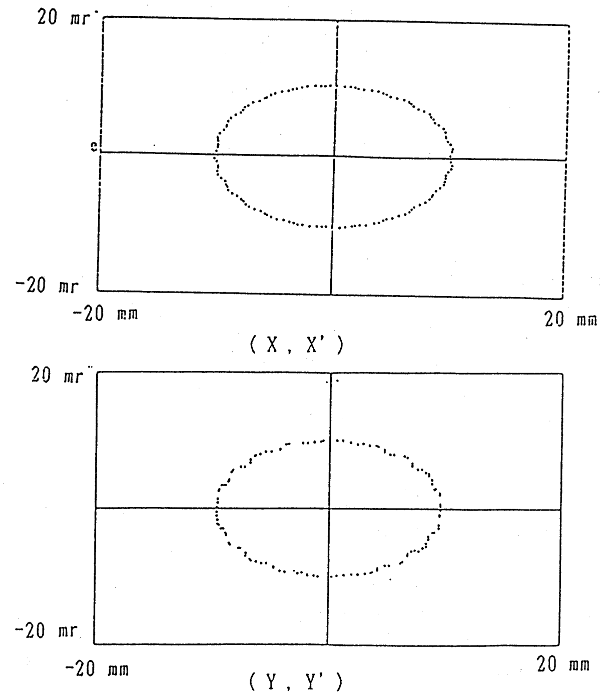


Fig. 13 Phase space at the center of straight section

Conclusion

The lattice of the CSA-ring was designed with SYNCH program. So far four bending magnets were completed and their magnetic field distributions were musured. Phase space at the center of straight section was calcurated with 2-dimentional geometrical method. Also betatron tunes were obtained from this numerical method.

Future of the CSA-ring project

We have already developed 3-dimensional geometrical method. We are planning to calcurate betatron tunes more exactly by using this method. An plane view of the system shown in Fig 14.

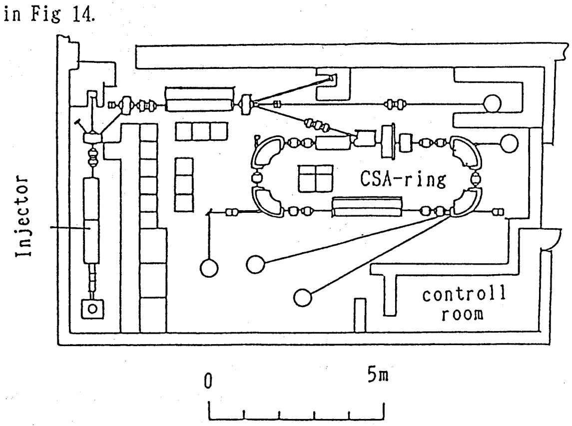


Fig. 14 Plane view of CSA-ring system

Refference

[1] Y. Takahashi, T. Hattri, Y. Ishii, M. Okamura, T. Hirata, H. Muto, Y. Honda, F. Fujimoto and K. Yoshida;Proc. 16th Meeting on Linear Accelerator, P61 (1991)