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DESIGN AND CONSTRUCTION OF A SUPERCONDUCTING VERTICAL WIGGLER

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Abstract We discuss a new vertical wiggler which will be installed into the KEK-PF ring in Aug. 1989. The wiggler has 5 magnet poles and is operated in the permanent current mode with the field strength of 5 Tesla. In the permanent current mode the liquid helium consumption is about 0.1L/h and the current will be restored every 300 hours.

INTRODUCTION

A new superconducting vertical wiggler will be installed into the KEK-PF ring in Aug. 1989. A superconducting vertical wiggler[1] which has been operated since 1983 is replaced by the new wiggler. A characteristics and schematic drawing of the new wiggler are shown in Table 1 and Fig.1, respectively. The wiggler has 5 magnet poles and the direction of field is alternately in horizontal plane. The maximum field strength is 5 Tesla on the beam orbit and the characteristic wave length of the synchrotron radiation is shift to 0.6 A from 3 A which is produced by bending magnets of the storage ring. The electron (positron) wiggles in the vertical plane and emitted photon is polarized in the plane.

The wiggler is operated in the permanent current mode by using superconducting switches. The heat inflow into the helium vessel is reduced as small as possible by putting two layers of thermal shields. Most of residual heat inflow comes from current leads. The current leads are pull up from the helium vessel in the permanent current mode. Helium consumption at the mode is about 0.1L/h.

When the current is supplied, the current leads are connected to the superconducting magnet in the helium vessel and also the superconducting switches are warmed up. The helium consumption increases to be about 10L/h. The cycle of the filling of the current is

TABLE 1 Characteristics of the wiggler

Maximum field strength on the beam orbit		5 Tesla
Magnet gap		66 mm
Number of magnetic poles		5 poles arrenged every 200mm
Rated exciting current		220 A at 5 Tesla
Superconducting wire	NbTi : Cu	1 : 1
	size	1.70 X 0.85 mm^2
	number of turn	2520
Liquid helium consumption in the permanent current mode		0.1 L/h
Life time of the permanent current		$3x10^4$ hours

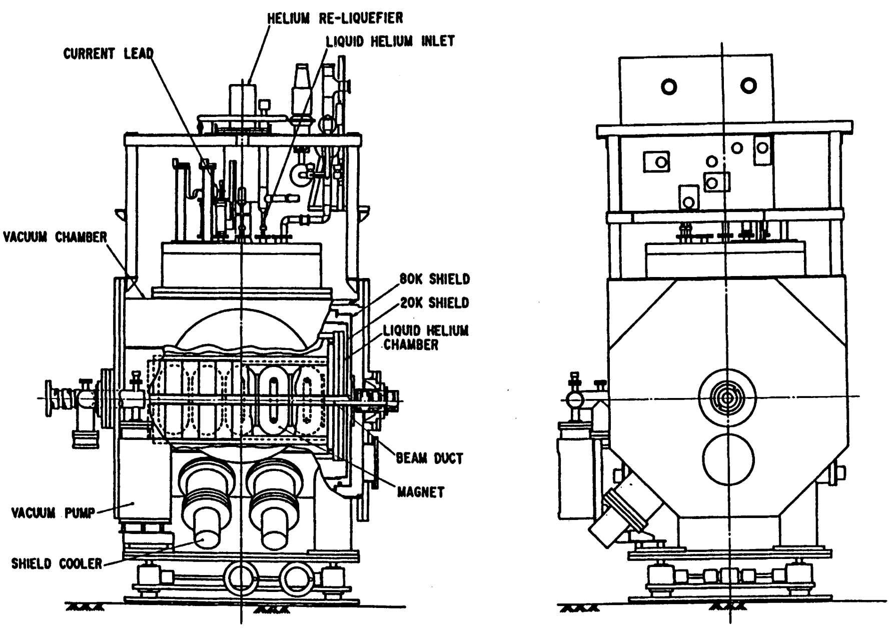

FIGURE 1 Side and front view of the superconducting wiggler.

desirable to be longer. The current gradually decreases with the life time of $3x10^4$ hours due to the resistance of the junction between the coils. The current decrease has influences on the distortion of the closed orbit and wave length of the synchrotron radiation. The orbit distortion is corrected by steering magnets. The current will be restored every 300 hours, during which the decrease of the current is 1%.

WIDTH OF WIGGLER DUCT

The width of the wiggler duct is determined by taking into consideration the horizontal beam size during the injection. The beam size during the injection is measured by inserting an absorber into the ring near the position of the wiggler. The injection rate vs the horizontal position of the absorber is shown in Fig.2. The half width of the beam is about 14.8 mm. Emittance during the injection is calculated to be 27mm.mrad.

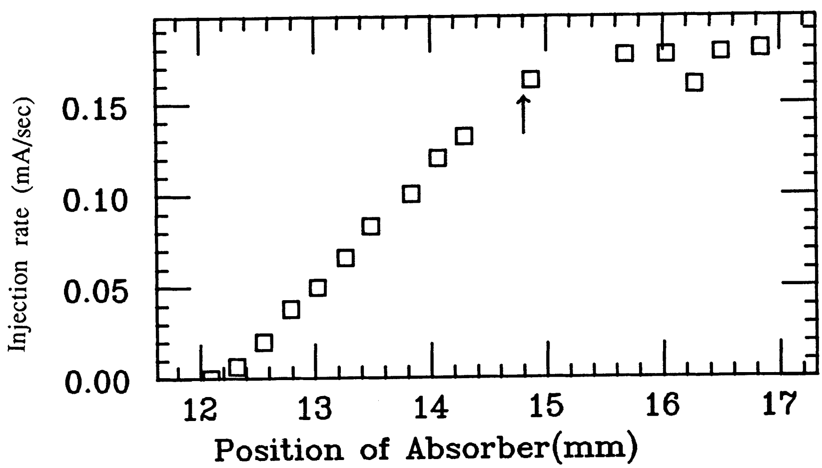

FIGURE 2 Measurement of beam size at the beam injection.

The emittance at the injection is estimated as 15.4mm.mrad from the geometric arrangement of the PF injection system[2]. Few dozen of nonlinear magnets (sextupoles and octapoles) are inserted in the PF ring. Then beam tracking including the nonlinear magnets is tried and we find that the emittance grows up to be about 26mm.mrad and is good agreement with the measurement.

The full width of the wiggler duct is determined as 45mm, where the acceptance is 36 mm.mrad.

The field of wiggler does not have any influence to the beam size, if tune shift and beta distortion coming from the edge focusing of wiggler magnet is corrected by the manner discribed next section. The wiggler will be continued to be excited during the beam injection.

MAGNET

The wiggler magnet consists of 5 pairs of superconducting coils with iron poles as shown in Fig.3. The gap of the magnet was chosen to be 66mm. Each coil is turned around the iron pole of 40mm in width and 260mm in height and is arranged every 200mm. The three inner pairs produce the maximum field strength of 5 Tesla at the center of gap and the two outer pairs are used to correct the beam orbit.

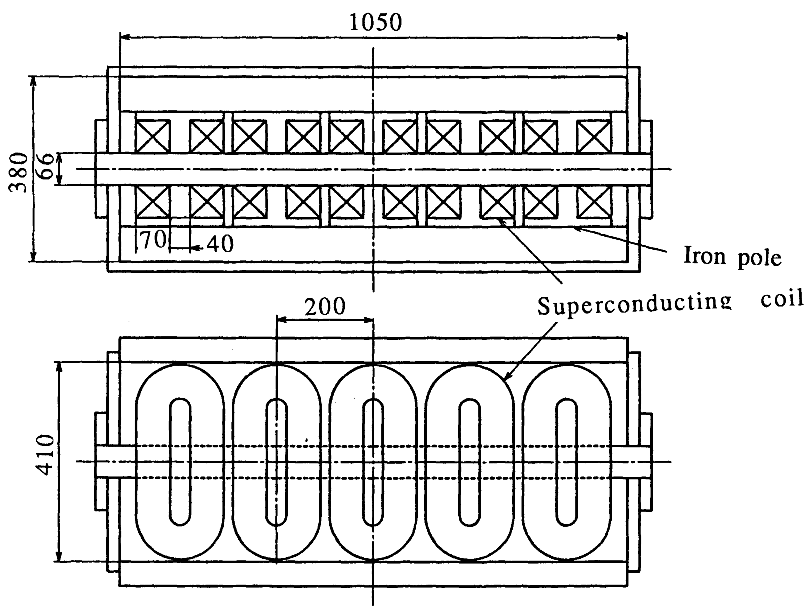

FIGURE 3 Magnet of superconducting wiggler.

The field strength in the coil is considered to be larger than that at the center of gap. Maximum field strength on the coil is about 7.2 Tesla by the calculation. The 3 dimensional field calculation is done by using the program code JMAG[3]. We use a superconducting wire which contains NbTi and copper equally. A current density in the superconducting wire is 313 A/mm^2 and a critical field strength at the current density is about 9 Tesla. The strength is same as 80% of the critical strength.

The magnetic field along the centerline of the wiggler magnet is measured by using a calibrated hole probe. The field distribution by the measurement and the calculation by JMAG is shown in Fig.4. Measured excitation curve is shown in Fig.5. The field strength at the center of the wiggler magnet was achieved 5.01 Tesla with an exciting current of 223.6A.

The beam wiggles on the vertical y plane. The effect of edge focusing gives a finite horizontal tune shift $\Delta\nu_x$, and it cancels out for vertical tune shift $\Delta\nu_y$. The $\Delta\nu_y$ is also caused by the gradient of the nonlinear field on the vertical wiggled orbit. The strength of sextupole field $B''/B\rho$ is $1.4 \times 10^{-2}\ m^{-2}$ by the calculation. For the wiggled orbit of 5mm, the $\Delta\nu_y$ is negligible small. However the $\Delta\nu_x$ by the edge focusing is much serious. In the operation of PF ring with ν_x=8.41, there is no periodic solution in the ring lattice without changing the strength of the quadrupole magnets. The tune shift will be corrected by changing the currents of nearby quadrupole magnets in the same manner[4] as done for the old wiggler.

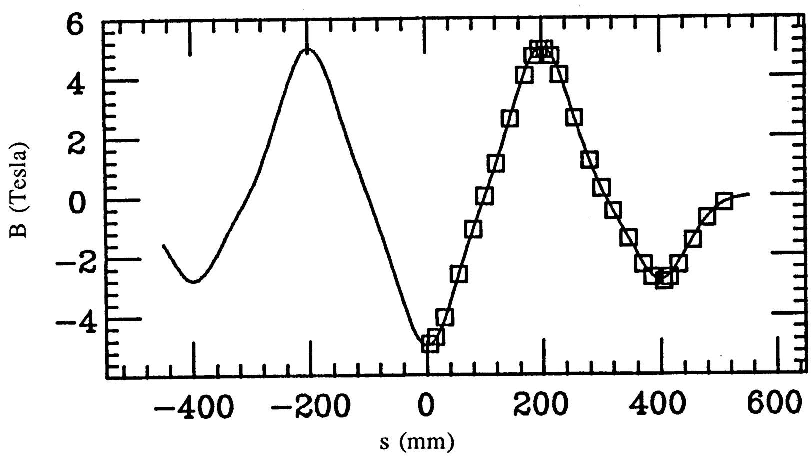

FIGURE 4 Magnetic field distribution along the centerline of the wiggler. Solid line and squire were given by the measurement and the calculation, respectively.

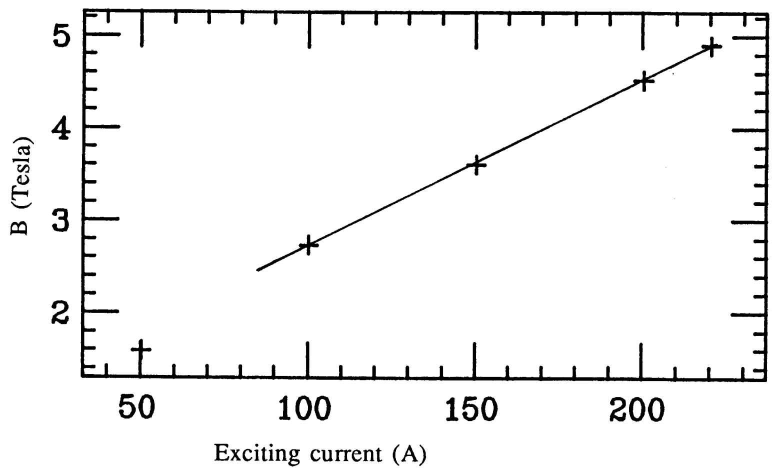

FIGURE 5 Excitation curve of the wiggler magnet.

CRYOSTAT

The wiggler cryostat has two layer of termal shields as shown in Fig.1. The thermal shields are cooled by two refrigerators. The outer and inner shield are connected to the first (80K-60W) and second stage (20K-6W) of each refrigerator. The heat inflow into the helium vessel is reduced to about 2 W by the cooled shields. The helium vessel is connected to a third refrigerator (4.2K-2.5W) which re-liquefies the evaporated helium. The helium consumption has been realized to be 0.04 to 0.25L/h and is expected to be less than 0.1L/h.

CONCLUSION

The wiggler has been operated alone. The wiggler could produce the field strength of 5.01 Tesla by the training of the coils and the helium consumption could be achieved the expected value of 0.1L/h. The wiggler will be in user operation since Oct. 1989.

REFERENCE

1. T.Yamakawa et al., NIM A246(1986)32-36.
2. Mitsuhashi et al. in this proceedings.
3. developed by JAIS.
4. Kato et al. in this proceedings.