CHARACTERISTICS OF THE SUPERCONDUCTING VERTICAL WIGGLER AND OPERATION STATUS IN THE PHOTON FACTORY

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INTRODUCTION

The superconducting vertical wiggler[1 2 3] of the Photon Factory has been installed in the storage ring in October 1982. The first operation with 2.5 GeV electron beam was successfully achieved in February 1983. The wiggler radiation was observed by a fluorescent plate via a Be window in the beam line. The spectra of the wiggler radiation were measured with a solid state detector, by changing the field strength of the wiggler, under the condition of small current.

From November the operation of the wiggler started again. The main purpose of the operation in November and December was tuning-up of the wiggler itself, such as to decide the wiggler excitation pattern which does not introduce closed orbit distortion, and to find the best operating tunes with respect to the beam lifetime.

At the same time, experimental beam lines were tuned up using the wiggler radiation. Since February 1984, the wiggler has been operated in the user's time in parallel with other beam lines.

ORBIT CORRECTION

The vertical wiggler magnet of Photon Factory is a 3-pole superconducting magnet. The schematic drawing is shown in Fig. 1. There are a central coil of nominal field strength of 6 Tesla and two outer coils of 3 Tesla. Three coils are connected in series and excited by a main power supply. Also, two auxiliary power supplies are connected to the outer coils.

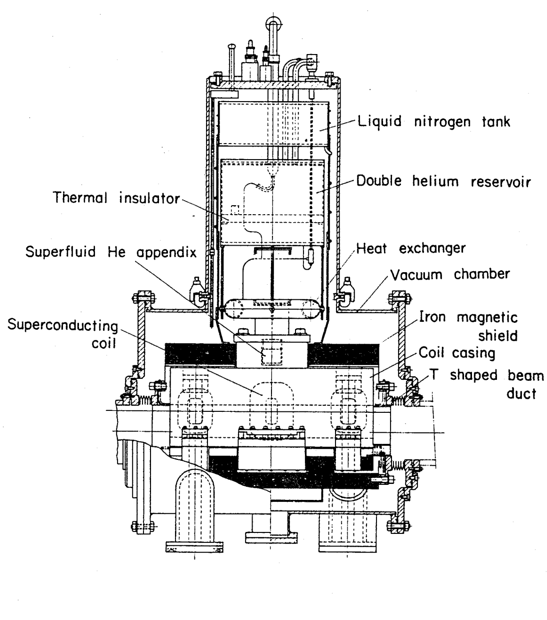

Fig. 1 Cross-sectional view of the superconducting vertical wiggler.

The closed orbit during excitation is corrected by applying appropriate correction currents on two outer coils, so as to keep the position of electron orbit unchanged, which is observed by the beam profile monitor[4].

Figure 2 shows the correction current as a function of the main current. The correction current is a complex function of the main current especially at low fields because of the each iron pole and magnetic shield is in different magnetized state in the process of excitation.

In order to make the residual orbit distortion small enough not to disturb the experiments using photons, the correction currents have to be controlled with an accuracy of 0.01 ampere. Actually, the exciting currents are controlled by a pattern generator using a micro-computer, so as to ascertain the reproducibility of the excitation.

The reproducibility of the beam position have been confirmed by observations at several experimental stations and turned out to be satisfactory.

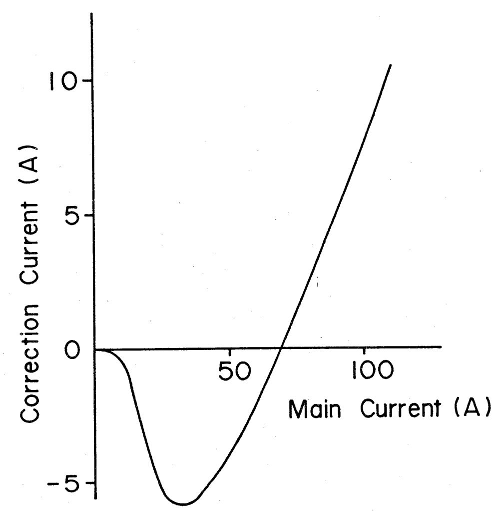

Fig. 2 Correction current as a function of the main magnet current.

TUNE SHIFT OF THE BETATRON OSCILLATION

As the wiggler consists of three short dipole magnet with parallel pole edge and generates magnetic field in the horizontal direction, the betatron tune should be shifted only in the horizontal plane by an amount of $\Delta\nu$ given approximately by

$$\Delta\nu = \frac{\beta_w \theta}{\pi\rho} = 2.1 \times 10^{-3} B_w^2$$

where β_w is the betatron function at the location for the wiggler, θ is the half bend angle in the central pole with radius ρ, and B_w is the excitation of the wiggler in Tesla.

Figure 3 shows the variation of the betatron tune as a function of wiggler field. As seen in Fig. 3, the horizontal tune shift agrees well with calculated value. However, the betatron tune varies also vertically due to the non-linearity in the magnetic field of the wiggler. Details on this problem will be discussed elsewhere in this Proceedings[5]. As increasing the wiggler excitation, dangerous resonances appear near of the operating point. Therefore, precise control of betatron tunes is essential to obtain the long enough lifetime. The tune shifts are corrected automatically, so as to keep the operating point unchanged in the tune diagram. This is done by changing currents of the ring quadrupole Q_F and Q_D, by the aid of a control computer.

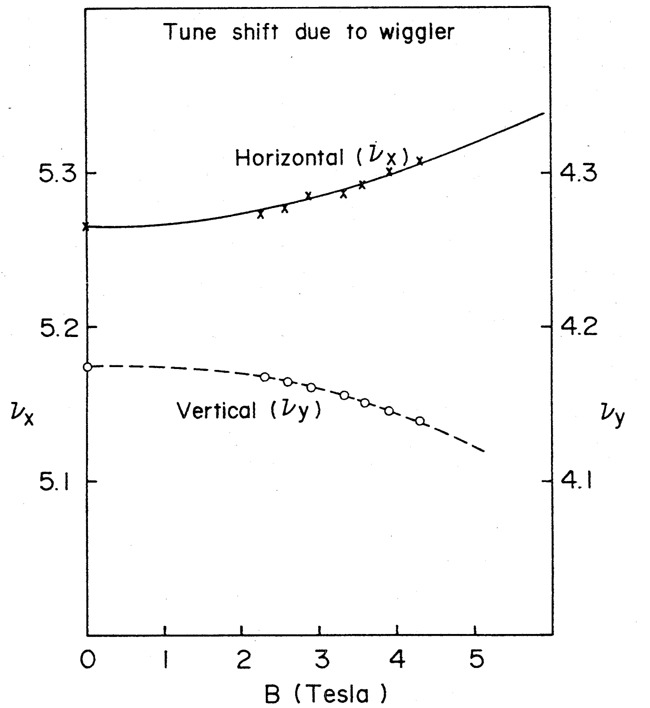

Fig. 3 Variation of the betatron frequency at 2.5 GeV with wiggler excitation, $\circ$, x } measured, ——— predicted from parallel pole edge model.

On the other hand, in the first commissioning of the wiggler with 2.5 GeV electron beams, no correction was needed to excite the wiggler up to 4.5 Tesla. The initial tunes at the first stage of the wiggler operation were measured as $\nu_x = 5.265$ and $\nu_y = 4.174$, respectively. Afterwards, it has become clear through the tune diagram survey that the tune shift curve, such as in Fig. 3, does not overlap the dangerous resonance region if the starting operation point is chosen appropriately. But, correction is need for the present initial tunes, $\nu_x = 5.390$ and $\nu_y = 4.153$ because they are chosen so as to avoid beam instabilities as well as to improve injection efficiency.

OPERATION STATUS

By means of the tune correction, the beam lifetime became longer as in Fig. 4.

The wiggler magnet has operated at 4.5 Tesla usually, because the long lifetime enough for the user's run has not been achieved at the fields more than 5 Tesla.

The beam lifetime is also limited by vacuum pressure. The vacuum pressure in the down stream of the wiggler increase by one order of magnitude due to heating up of the vacuum chamber by wiggler radiation.

The pressure dependence of the lifetime can be seen clearly also in Fig. 4. Liquid helium are supplied with a container by the central cryogenic facility of the low temperature group located two kilometer apart from the storage ring.

Helium are transferred every four hours to the wiggler cryostat through a 12 meters long transfer line from the container which was placed in the service area of the storage ring building.

Consumption of liquid helium is 4 liters per hour, and transfer loss is about 50% of it.

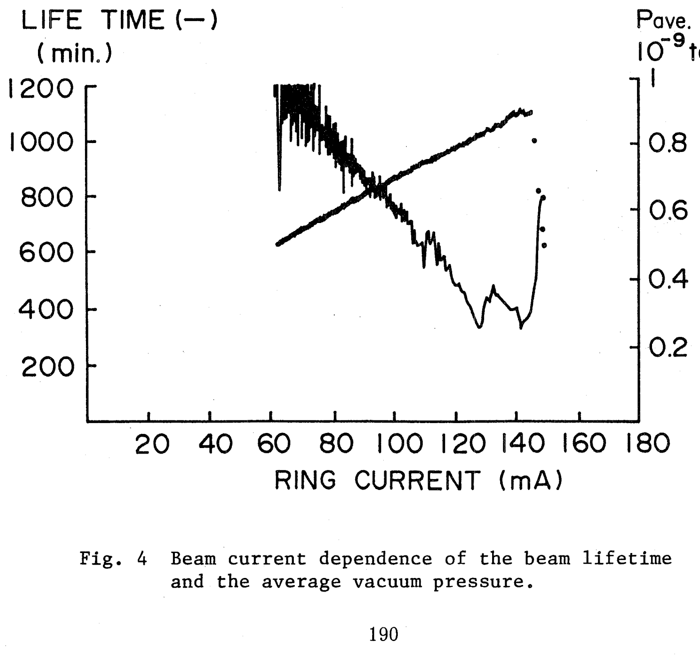

Fig. 4 Beam current dependence of the beam lifetime and the average vacuum pressure.

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