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TUNE SHIFT DUE TO UVSOR WIGGLER

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ABSTRACT

A superconducting wiggler was installed in the UVSOR storage ring, which has 3 magnetic poles and the maximum field is 4 T. Since the width of the wiggler coil is finite, the quadratic term of the radial distribution of the magnetic field is not negligile. The horizontal and vertical tune shift are estimated and are in good agreement with the measured shift.

INTRODUCTION

The UVSOR storage ring is operated as a synchrotron radiation light source for experiments of the molecular science and its related field. The critical wavelength of the synchrotron radiation from the bending magnets at the beam energy of 600 MeV is 5.7 nm. To extend the coverage of the wavelength, a superconducting wiggler was inserted into the ring[1]. The maximum strength of the wiggler field was designed to be 4 T to aim the critical wavelength less than 2 nm. Because the useful length of the long straight section of the ring was limited to 70 cm, we decided that the wiggler has 3 magnetic poles. To suppress the field inhomogeneity due to the finite length of the coils in the radial direction, the shape of the coils was chosen to be a racetrack. The length of the straight section of the coils was restricted by the electromagnetic force by which makes the superconductiong wire swing. These coils are settled into the liquid helium vessel and cooled to the superconducting temperature directly.

STRUCTURE OF THE UVSOR WIGGLER

The magnetic field is produced with the 6 superconducting coils. Two of these coils are arranged to be faced each other across the beam pipe and make a dipole magnet. Three sets of the dipole magnet are arranged in the longitudinal direction and produce the three magnetic poles. The main coil set produces the wiggler field and the inner and outer sizes of the coil are 30 mm_W x 110 mm_L x 55.8 mm_H and 118.4 mm_W x 198.4 mm_L x 55.8 mm_H. The auxiliary coil sets, which are set at the front and the rear of the main coil set, are used to correct the beam deflection and the inner and outer sizes of the coil are 30 mm_W x 136 mm_L x 40.8 mm_H and 97.4 mm_W x 203.4 mm_L x 40.8 mm_H. These coils were tightly inserted with some impregnant into the outer frames by shrinkage fit method in order to prevent the coils from shaking at the wiggler excitation.

These coils are cooled directly to the superconducting temperature by liquid helium. The helium vessel is surrounded by vacuum insulation layer and a heat shield wall which is taken the thermal anchor of the liquid nitrogen.

TUNE SHIFT

At the midplane of the wiggler, the vertical magnetic field at some excitations were measured and the quadratic term of the radial distribution of the field is not negligibly small. The measured coefficients of the term at the field of 2 T and 4 T are 130 m^{-2} and 90 m^{-2} respectively, which are shown in Fig. 1. In Fig. 1, the peak field strength of the auxiliary coils is shown and in usual operation, the two auxiliary coil sets are operated at the same current.

To estimate the tune shift due to the wiggler field at some exitation and beam energy, the longitudinal field distribution was assumed to be sinusoidal. This simplification is shown in Fig. 2 ; the solid and broken lines show the measured and simplified field strengths.

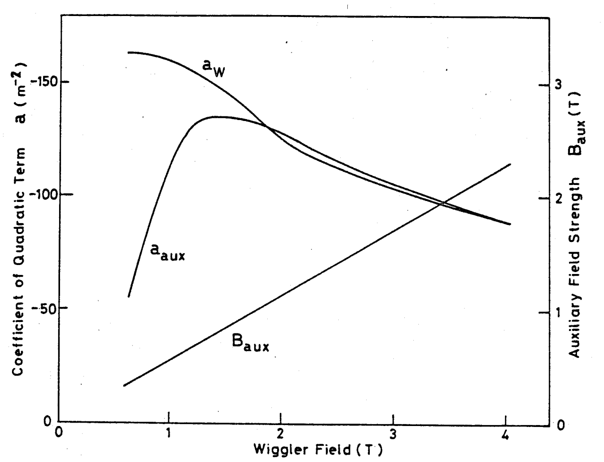

Fig. 1 Coefficient of the quadratic term of the radial distribution of the UVSOR wiggler depends on the field strength. a_W is the value at the peak of the main field and a_{aux} is that of the auxiliary field. The auxiliary field strength B_{aux} is nearly proportional to the strength of the wiggler field.

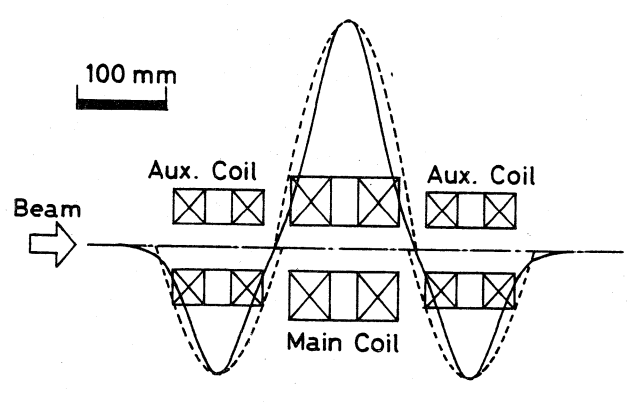

Fig. 2 Vertical field of the UVSOR wiggler along the longitudinal direction.

The tune shifts, ΔQ_H and ΔQ_V, due to the quadratic term are represented[2] and can be reduced following this simplification, assuming the variation of the horizontal and vertical betatron functions, β_H and β_V, to be small. Then the horizontal tune shift due to the quadratic term of the wiggler can be reduced as

$$\Delta Q_H = \frac{\langle\beta_H\rangle}{4\pi} \left(\frac{0.3}{E} B_W\right)^2 \frac{a}{q_W^2} L_W \quad , \qquad (1)$$

where < > shows the average value over the wiggler, B_W the maximum field strength of the wiggler, E the electron energy (in GeV), a the coefficient of the quadratic term, $q_W = 2\pi/2L_W$ and L_W the effective length of the main coil of 158 mm. In the same way, the vertical tune shift ΔQ_V can be reduced as

$$\Delta Q_V = \frac{\langle\beta_V\rangle}{4\pi}\left(\frac{0.3}{E}\right)^2\left(\frac{B_{aux}^2}{2} + \frac{B_W^2}{4}\right) 2L_W - \frac{\langle\beta_V\rangle}{\langle\beta_H\rangle}\Delta Q_H \quad , \qquad (2)$$

where B_{aux} shows the peak strength of the auxiliary field. Both tune shifts depend on the field strength of the wiggler and the beam energy. The dependence of the tune shifts on the field strength, B_W and B_{aux}, and the beam energy, E, is calculated as shown in Figs. 3-5, using the observed values shown in Fig. 2. In Fig. 5, the first and second terms of Eq. (2) are shown as a broken and dotted lines. The first one is proportional to the inverse of the beam energy, E^{-1}, and the second one is proportional to E^{-2}. For example, the calculated values of the first and second terms at B_W = 3 T and E = 600 MeV are 0.0602 and 0.0234, respectively.

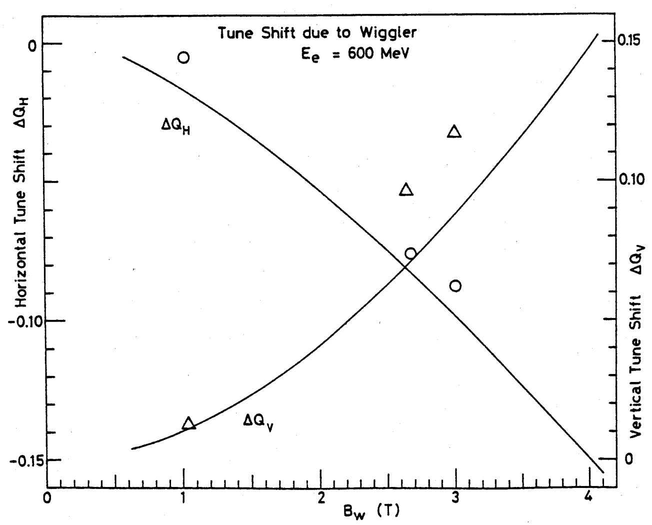

Fig. 3 Tune sfifts due to the wiggler depend on the field strength. The beam energy is 600 MeV.

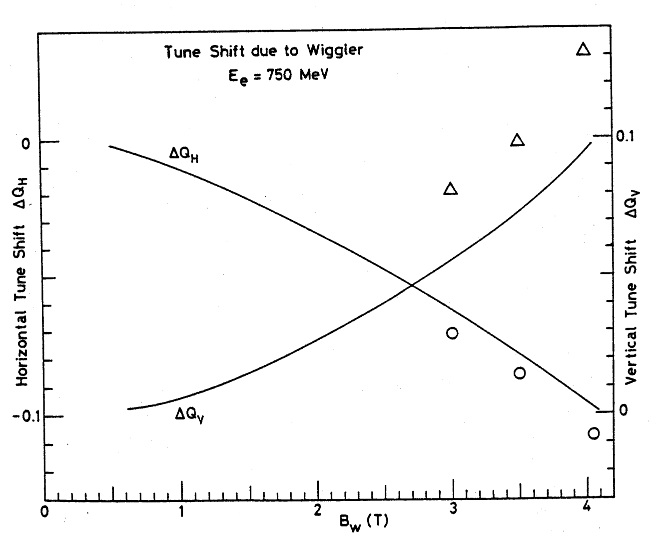

Fig. 4 Tune shifts due to the wiggler depend on the field strength. The beam energy is 750 MeV.

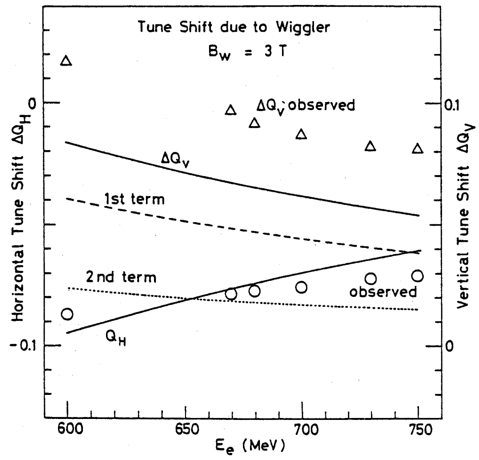

Fig. 5 Tune shifts depend on the beam energy. In this case the field strength of the wiggler is 3 T. Broken and dotted lines are the first and second terms of Eq. (2).

CONCLUSION

The actual tune shifts due to the wiggler were measured with the RF-KO method and shown in Figs. 3-5. The tune shifts expected with Eqs. (3) and (4), are in good agreement with these observed values. At the field strength of 3 T, the beam can be injected into the storage ring and is accelerated up to 750 MeV. After the acceleration, the wiggler is excited up to the maximum strength of 4 T. During the acceleration and the excitation, correction of the tune shifts of the beam is necessary. These tune shifts due to the wiggler depend on the field strength and the beam energy, and can be corrected with the auxiliary coils of the quadrupole magnet system. Futhermore, function generators which determine the auxiliary coil current as the function of the energy and the field strength are now under construction.

REFERENCES

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2) M.W. Poole and R.P. Walker, An Undulator Source for the SRS at Daresbury, DL/SCI/P466A, May 1985.