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OPERATIONAL RESULTS OF OPTICS HANDLING AND CLOSED ORBIT CORRECTION IN THE TRISTAN ACCUMULATION RING

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The optics handling system of the TRISTAN accumulation ring (AR) is facilitated by the general purpose computer of KEK as well as the machine control computers and has been dealing with many kinds of optics successfully since November 1983. Also a series of correction procedures has reduced r.m.s. values of closed orbit distortion(c.o.d.) at position monitors from 8.5mm to 0.6mm horizontally, and from 2.3mm to 0.3mm vertically in the typical optics of AR. Using the estimated errors, the pre-correction facility has been installed in AR to make an orbit correction possible in a completely new optics before beam injection.

Introduction

Although the original function of AR [1] is to accumulate e^+ and e^- beams supplied by the PF linac of 2.5 GeV and accelerate them to 8 GeV for the injection to the TRISTAN main ring (MR), AR is currently serving as a γ-ray supplier [2] for the calibration of detectors that should be ready for the coming e^+e^- colliding experiments at MR in the fiscal year of 1986. Colliding experiments are also possible at AR itself and recently some people began thinking it seriously. Moreover a proposal to use AR as a synchrotron light source has been accepted. Besides the above mentioned roles of AR, varieties of optics must be prepared for the AR machine studies. So the optics handling system should work to satisfy these wide range of requirements.

As the construction work of MR is still going on near by AR, the floor level of the AR tunnel may be changing rather widely. This makes the once established correction of c.o.d. doubtful after some intermission especially in case of error sensitive optics. It could be helpful for us to apply a rough correction to c.o.d. of new optics before an injection of beam.

In the following sections, introduced are the optics handling and the orbit correction systems of AR that execute optics handling and orbit correction easily, quickly and accurately and also presented are the operational results of them with some developments related to the pre-correction scheme of c.o.d.

Lattice

The AR lattice is made up of four quadrants. In the middle of the quadrant are four normal cells of FODO type and two mirror symmetrical points at the both ends are called a collision point and a rf symmetry respectively. QC1,......,QC8 are matching Q-magnets of the collision point and QR2,......,QR8 are those of the rf symmetry.

The numbers of orbit correctors are 66 horizontally and 44 vertically. The numbers of position monitors are 83 both horizontally and vertically.

Systems Overview

In Fig. 1 schematically illustrated is the optics handling and the orbit correction systems of AR. In the central control room of the TRISTAN accelerators(CCR), operators communicate through the touch panels with these systems that work under the supervision of the KEK NODAL system [3]. The operation computers(OP0, OP1 and OP2) are directly

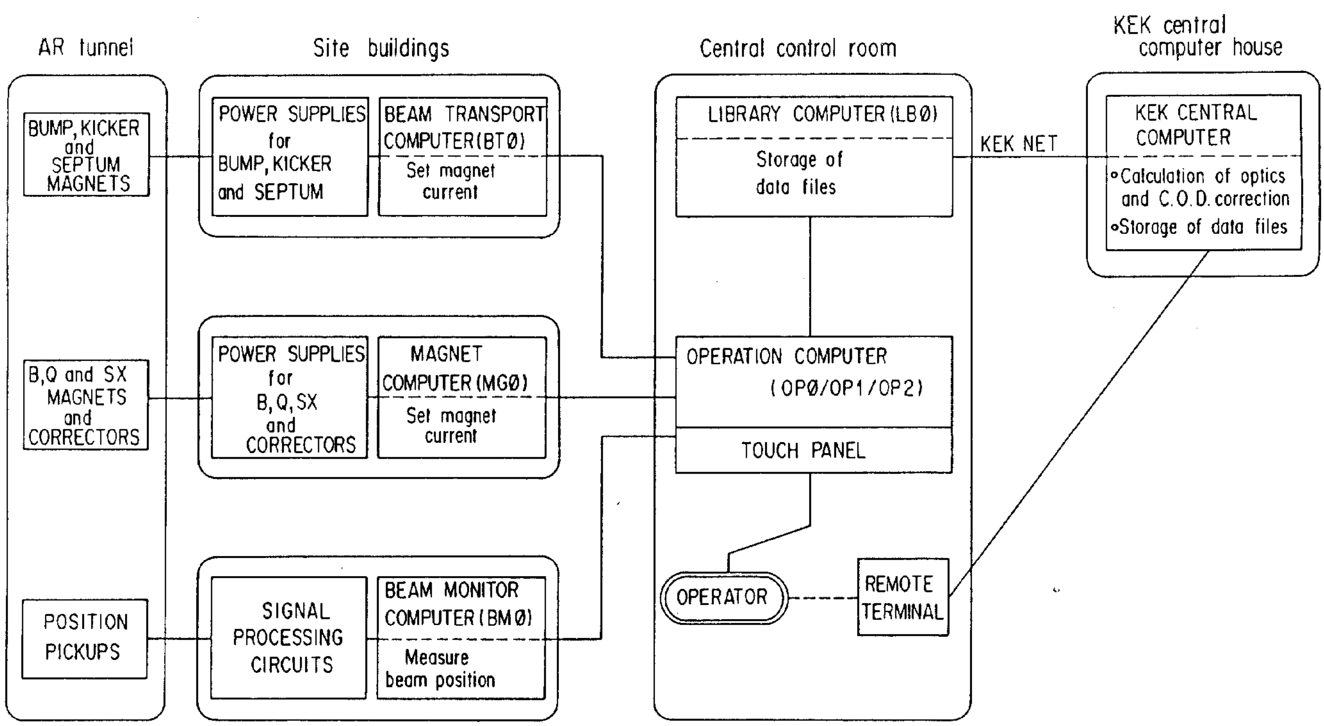

Fig. 1 Schematic diagram of the optics handling and the c.o.d. correction systems in the TRISTAN AR

connected to the touch panels and control whole stream of jobs. The KEK central computer placed 1 km away from CCR is a general purpose computer and connected to our systems via KEKNET [4]. It works in an optics calculation by MAGIC and an orbit correction by PETROK and also offers large amount of data storage area. The library computer(LBO) works in the data exchange process through KEKNET and also offers data storage. The hardware computers used in the present systems are the magnet computer(MGO), the beam transport computer(BTO) and the monitor computer(BMO) and they are located in the respective site buildings.

Optics Handling

In the calculation of optics, two optics programs are available. One is written in NODAL, works on the operation computers and adopts the Newton-Raphson method in the minimization process. MAGIC is the other one that was developed at SLAC [5] and converted at KEK [6] to work for machine control on the KEK central computer. In the both programs, the calculated optics will be given in the form of Q-magnet tracking ratio $B'l_Q/B\rho$ and displayed on a screen with its β and η (dispersion) functions as shown in Fig. 2. Either in a pattern generation mode or a fine adjustment mode, the tracking ratio will be converted into magnet currents by the magnet computer according to the excitation table [7]. In the pattern generation mode, the conversion is done at all stages of the magnet excitation and takes about 8 minutes. In the fine adjustment mode, it is limited to a present stage of the excitation, takes less than 1 minute typically and optics change may be performed in keeping beams.

The strength of the kicker, bump and septum magnets is calculated also by the operation computers to improve the injection efficiency.

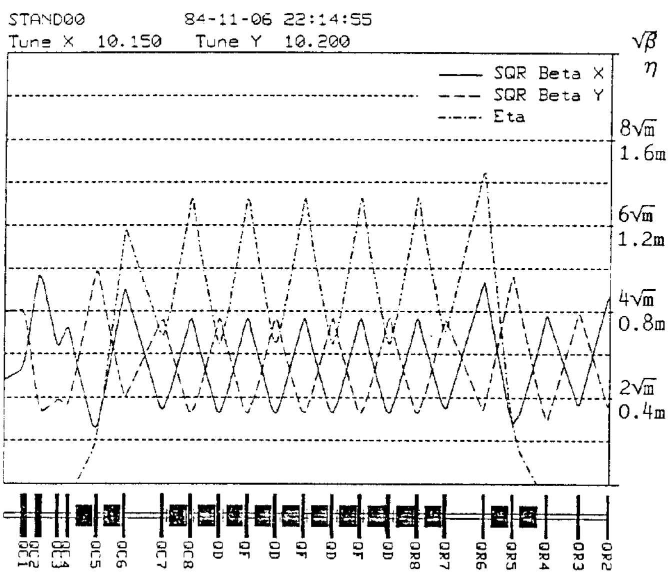

Fig. 2 β and η functions along the quadrant of TRISTAN AR

c.o.d. Correction

The computation of orbit correction is performed on the KEK central computer by the computer code PETROK that is a KEK version of PETROS originally developed at DESY and modified to include the least square minimization program MICADO [8] in its subroutines.

The input data for PETROK is made up of the measured c.o.d., the measured betatron tunes, the tracking ratio of Q-magnets, the present strength of correctors and some conditions for the correction. The measured tune is only necessary when it is rather far from the calculated one. Unavailable correctors and doubtful position data can be omitted from the calculation by setting the flags.

PETROK deals with the correction issue as in the following.

i) Choose the most effective corrector among the available ones and find the strength for it.

ii) Choose the most effective corrector among the remaining ones and find the strength for them.

iii) Choose the third corrector in the same way and find the strength for these three.

iv) And so repeats the step until the number of chosen correctors reaches the previously specified one.

The output data of PETROK consists of the corrector strength and the expected residual c.o.d. after the correction. Looking at these data on screen, operators judge whether this correction should be installed into AR or not.

For further investigation of c.o.d. correction, PETROK is furnished with the following functions that work on demand.

a) In the reset mode, the number of working correctors are made zero before the correction. In the usual mode a new correction is added to the previous one, then the total number increases after each correction.

b) In the momentum correction mode, the rf-frequency corresponding to the momentum error is given.

c) In the simulation mode, an expected c.o.d. is calculated for an arbitrarily given strength of correctors.

Operational Results

Optics Handling

In the early stage of AR operation, a series of works was done to improve the agreement of betatron tune between the calculated and the measured ones. To treat the edge and fringe field properly, a special matrix was introduced into the optics calculation model according to the measured data of field distribution in B-magnets. The excitation tables of Q-magnets were corrected to trace the measured data more faithfully. Nevertheless, any fudge factor to reduce the difference only in appearance has not been introduced into our optics handling system .

In Table 1, some of the AR optics are shown with their principal parameters. The STANDOO is a optics for the beam transfer to MR and has rather smooth β and η-functions along the lattice as shown in Fig. 2. The MM7 is a low-β optics for the e^+-e^- collision. The N60D is a optics only for machine studies and characterized by its $\pi/3$ phase advance in the normal cell making a contrast with $\pi/2$ phase advance of the others. The IT01 is a optics for the internal target operation of AR as a γ-ray supplier and has been working most frequently.

As the disagreement of vertical tune seems to suggest some systematic errors, the agreement will be improved further in future.

Table 1 Examples of the AR optics

optics name	STANDOO	MM7	N60D	IT01
ν_H	10.15	10.15	7.75	10.15
ν_H (measured)	10.16	10.16	7.79	10.16
ν_V	10.20	10.20	9.25	10.20
ν_V (measured)	10.25	10.26	9.31	10.24
β^*_H	5.6 m	1.6 m	5.6 m	7.9 m
β^*_V	16.0 m	0.1 m	24.6 m	30.1 m
β_{Hmax}	22.3 m	60.0 m	24.0 m	26.7 m
β_{Vmax}	23.6 m	75.8 m	24.9 m	30.7 m
η_{Hmax}	1.4 m	1.5 m	2.4 m	1.5 m
ϵ_{0H}(2.55GeV)	4.6×10^{-8}m	4.5×10^{-8}m	1.3×10^{-7}m	4.5×10^{-8}m
ξ_H	-14.0	-19.3	-10.1	-14.3
ξ_V	-13.2	-24.0	-12.8	-14.6
α	1.29×10^{-2}	1.27×10^{-2}	2.41×10^{-2}	1.25×10^{-2}

c.o.d. Correction

In the IT01 optics, the orbit deviations at the monitoring pickups before correction are 8.5 mm and 2.3 mm in the horizontal and the vertical r.m.s. values, respectively. The previously described procedure of correction was applied to them repeatedly and it is shown in Fig. 3 how well they were corrected by the iteration. The specified numbers of correctors are 15 for the first step and 10 for the successive steps and the total numbers of working correctors are 33 horizontally and 31 vertically at the final step of this iteration.

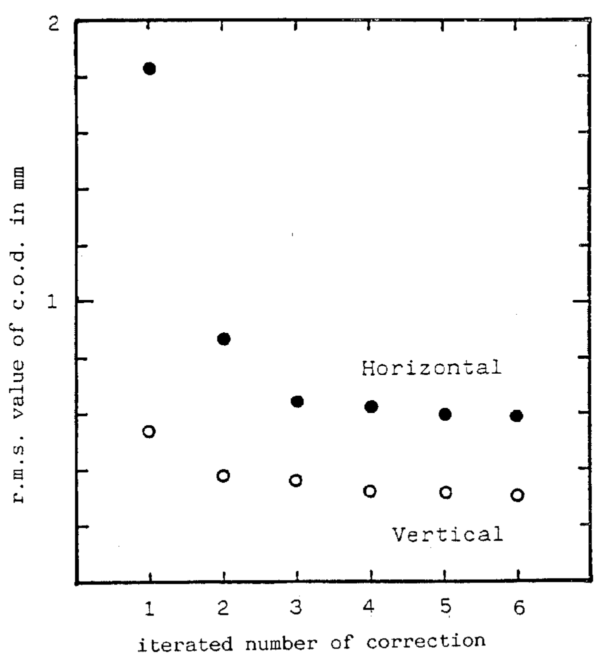

Fig. 3 Improvement of the c.o.d. by the iteration

Refinement of c.o.d. Correction

It is not obvious what is the perfectly corrected orbit in a misaligned lattice. Such an orbit is defined here as one that passes through the centre of Q-magnets even if misaligned. So the position of monitoring pickups should be surveyed against the centre of respective Q-magnets. Unfortunately, the survey has been carried out only for 64 monitors out of 83 ones. From the motive that the absolute position of these remaining 19 monitors should be settled, the investigation to find the source of c.o.d. was made as in the following.

i) Only the misalignment of Q-magnets and the field error of B-magnets are assumed to be the origin of the c.o.d.

ii) Applying many kinds of optics, namely 8, to AR, the c.o.d. is measured at 64 monitoring positions in each optics.

iii) From these c.o.d., the contribution of the B-field error is subtracted according to the measurement.

iv) Solving the following equation for x_i, error displacement of i-th Q-magnet, by the least square method, a guess can be made as to the misalignment of 86 Q-magnets.

$$\begin{bmatrix} z_1 \\ \vdots \\ z_{64n+j} \\ \vdots \\ z_{512} \end{bmatrix} = \begin{bmatrix} A_1 \\ \vdots \\ A_k \\ \vdots \\ A_8 \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_i \\ \vdots \\ x_{86} \end{bmatrix}$$

where

z_{64n+j}, (n=0,....,7 j=1,......,64)
; c.o.d. after the subtraction at j-th monitor in (n+1)-th optics

A_k ; c.o.d. response matrix of (64×86) for error displacement of Q-magnets in k-th optics

Using the measured field of B-magnets and the calculated displacement of Q-magnets, 8 sets of c.o.d. are calculated corresponding to 8 optics. The differences between the calculated c.o.d. and the measured c.o.d. at the uncalibrated monitors are averaged over 8 optics to give the displacement of monitoring pickups. The calibration of monitors in this way made the r.m.s. values of corrected c.o.d. reduced by 30 % compared to the values described in the previous section.

These estimated sources of c.o.d. are used by PETROK to correct an orbit of a new optics before an injection of beams.

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