LATTICE UPGRADE PLAN FOR CRAB CROSSING AT THE KEKB RINGS

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Abstract

We plan to install two superconducting crab cavities into the rings at January, 2006. In our plan, we will install one crab cavity per one ring into the NIKKO straight section where the cryogenic infrastructure is already operated for the superconducting accelerating cavities. For crab crossing, we have to enlarge the horizontal beta function(200m for HER) and have to adjust the horizontal phase advance between the interaction point and the crab cavity. In this paper, we will report the lattice modified for the crab crossing and the study results about the single beam dynamics.

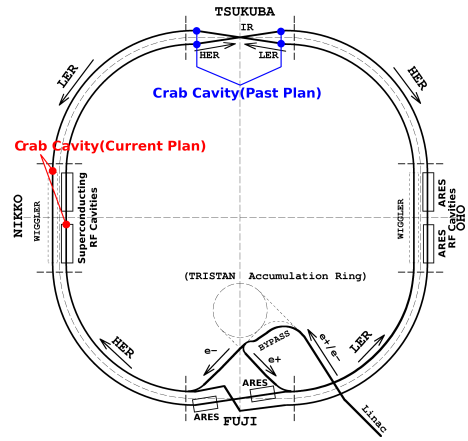

Figure 1: KEKB ring and candidate position for installing crab cavities.

INTRODUCTION

In the design stage of the KEKB, the crab crossing is proposed as a backup scheme for the failure of the finite angle crossing. In this backup scheme, two crab cavities per one ring are installed in the TSUKUBA interaction region[1]. For localizing the crabbing motion into the TSUKUBA interaction region, one cavity is installed upstream of the interaction point(IP) and the other cavity is installed downstream of the IP, that is shown in Fig. 1 as "Past Plan". The horizontal beta function of the IP and the transverse kick voltage of the crab cavity are 0.33m and 1.44MV, respectively. The horizontal beta function at the crab cavity is 100m for the high energy ring (HER) and 20m for the low energy ring (LER).

At the present KEKB operation, the finite angle crossing works well and the design luminosity is achieved. The crab crossing as the backup scheme is not required now, however, simulations predict that the beam-beam limit of the crab crossing is about twice as large as the beam-beam limit of the present finite crossing[2]. It means that the luminosity of the KEKB is doubled by using the crab crossing if everything works out.

At now, we are preparing the crab crossing in order to study the beam-beam effect and to upgrade the luminosity.

INSTALLATION PLAN

The crab cavity planed to install is constructed by using superconducting technology. In order to install the crab cavities into the TSUKUBA interaction region, we have to prepare the new cryogenic infrastructure, because the present cryogenic system can not accept new refrigerating load. On the other hand, the cryogenic system at the NIKKO straight section, which was constructed for the TRISTAN project, has a surplus refrigerating power. The current load of the NIKKO cryogenic system, the superconducting accelerating cavities of the HER, occupies almost half of the capacity. In order to use the NIKKO cryogenic system at the TSUKUBA interaction region, we have to construct a long transfer line for liquid helium. Both the cost to install a new cryogenic refrigerator and the cost to construct a long transfer line are very expensive, therefore we choose to install the crab cavities into the NIKKO section in order to use the unused port of the transfer line at a low price. The crabbing motion of the beam bunch is appeared around all ring, because the transverse kick exciting crabbing motion is only given at the NIKKO section. On the other hand, the nonlocalized crabbing motion is suitable for the beam study, because the crabbing motion can be observed everywhere around the ring. The configuration, which has a long arc between the IP and the crab cavity, is convenient for optimizing the betatron phase advance between the IP and the crab cavity.

Requirement for Optics Reconstruction

The transverse kick voltage of the crab cavity, is developed for the backup scheme, is 1.44MV. In the present operation, the horizontal beta function of the IP is about 0.6m, therefore the horizontal beta function required for the single crab cavity is 200m for the HER and 40m for the LER. To obtain maximum crabbing angle on the ring, the horizontal betatron phase advance between the interaction point and the crab cavity must be adjusted to $\pi\nu + n\pi$ rad. The horizontal dispersion at the crab cavity is chosen as zero to remove potentially risk of synchro-beta coupling.

In order to protect the superconducting crab cavity from the strong synchrotron radiation, the bending magnet at just upstream of the straight section for the crab cavity must be

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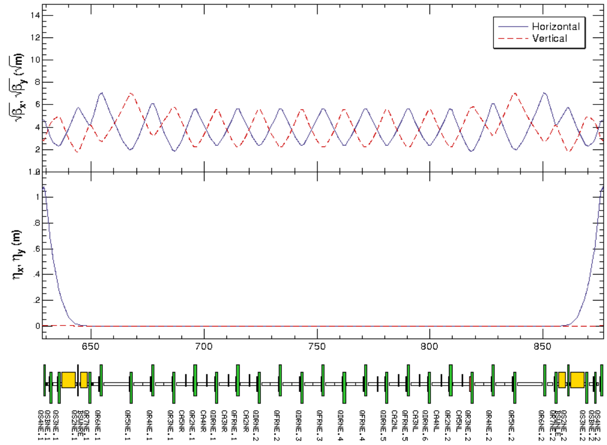
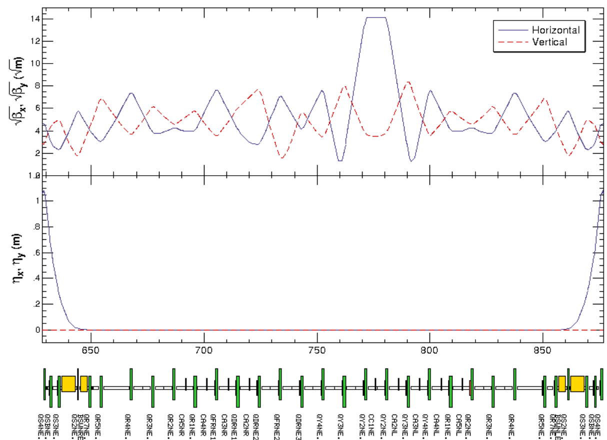
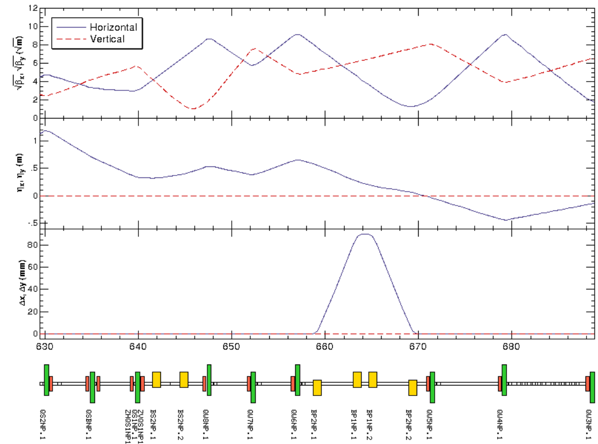


(a) Present Operating Lattice & Optics

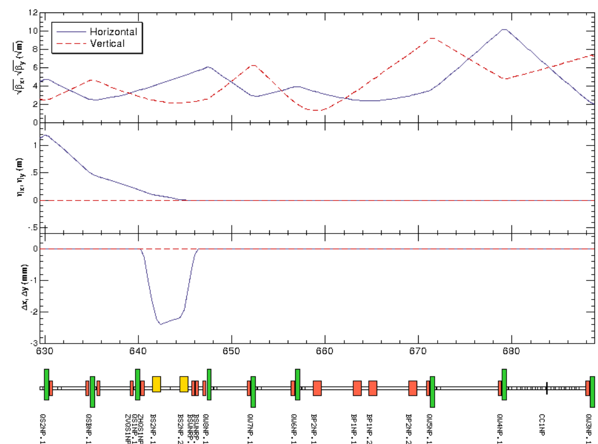


(b) New Crab Lattice & Optics(After Upgrade)

Figure 2: Lattice structure & optics functions of the HER NIKKO section. Electron transits from right side to left side in figure.



(a) Present Operating Lattice & Optics



(b) New Crab Lattice & Optics(After Upgrade)

Figure 3: Lattice structure, optics functions and local bump at the upstream of the LER NIKKO section. Positron transits from left side to right side in figure.

a weak bending magnet. For keeping down the reconstruction cost, the lattice is reconstructed by recombination of the quadrupole family without reallocation of quadrupole magnets and without an addition quadrupole magnet.

HER Crab Lattice

The NIKKO section of the HER is the accelerating section by the superconducting cavities. Therefore the horizontal dispersion is adjusted to zero and the bending magnet at the both side of the straight section is the weak bending magnet. The NIKKO lattice of the present HER is shown in Fig. 2(a). The accelerating cavities are separated into the two groups. One is the upstream side cavities shown in Fig. 2 as CA#NL, the other is the downstream side group(CA#NR). The crab cavity shown in Fig. 2(b) as CC1NE is installed into the empty cell at just downstream of the upstream side group of the accelerating cavities.

In order to make 200m beta function bump at the crab cavity, the crab cavity must be installed between focusing quadrupoles. Thus, the regular FODO structure by 2 families 11 quadrupole magnets (QDRNE and QFRNE family in Fig. 2(a)) is reconstructed into 3 quadrupole pairs around the crab cavity (QY#NE family in Fig. 2(b)) and 5 individual quadrupoles. The polarity of the matching section quadrupoles is exchanged for matching with the quadrupoles of the inner RF section.

Unfortunately, the total betatron tune can't be kept by using the tune adjustment region at the FUJI straight section, because of the large change of the betatron phase advance caused by the beta bump. Thus the operating tune is moved from $(44.512, 41.580)$ to $(43.512, 40.580)$ for satisfying the total tune and the betatron phase condition.

LER Crab Lattice

The NIKKO section of the LER is the dispersive wiggler section with the chicane for the circumference tuning at both ends of the section. In the LER, we have same structure at OHO straight section. Figure 3(a) and 3(b) show the lattice of the upstream part of the LER NIKKO section. The crab cavity shown in Fig. 3(b) as CC1NP is installed into the empty wiggler cell at the upstream of the present wiggler magnets of the NIKKO section. In order to protect the crab cavity from synchrotron radiation, the chicane bump, which is constructed by BP1NP and BP2NP bending magnets, have to be removed. The circumference displacement as the result of removing the NIKKO chicane is compensated by the OHO chicane.

For satisfying the weak bend condition, the following changes are applied. The new steering magnets, which are shown in Fig. 3(b) as BSWNRP, are installed between the suppressor bending magnet (BS2NP) and the quadrupole at the edge of the straight section (QW8NP). The horizontal and vertical steering magnets denoted by ZHQS1NP1 and ZVQS1NP1 in Fig. 3 are exchanged each other for a quadrupole free local bump. In order to use the new steering magnet as a weak bend, a local bump toward the inside of the ring is made by using the new steering, the suppressor bending and the exchanged horizontal steering. The total kick angle of the new steerings is adjusted with 1.8mrad.

Fortunately, the beta function and the betatron phase at the installed crab cavity are similar to the required values, therefore the optics can be matched without recombination of the quadrupole families. By adjusting the horizontal dispersion of the wiggler to zero, the horizontal emittance of the ring is reduced. For compensating the reduced horizontal emittance, the horizontal dispersion of the OHO wiggler is enlarged.

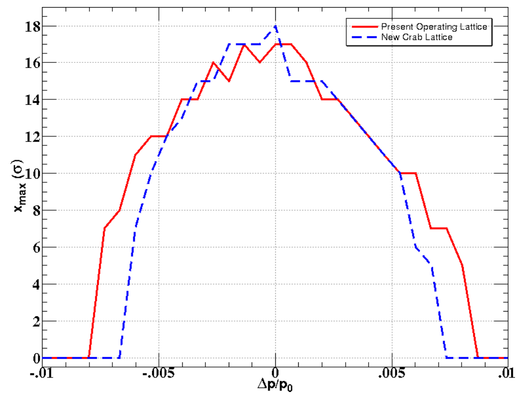
Schedule

The lattice reconstruction for the crab crossing is scheduled for the summer shutdown of the year 2005. From the autumn run of the year 2005, the KEKB operation will be started using the new optics. The installation of the crab cavities is scheduled for January of the year 2006. After the hardware test of the installed crab cavities, we plan to start the beam-beam study of the crab crossing.

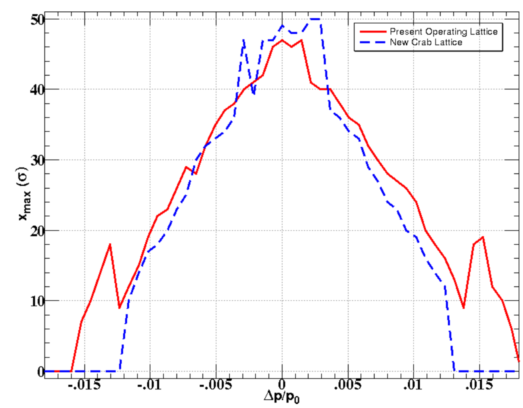
DYNAMICS IN CRAB LATTICE

Figure 4 shows the dynamic aperture evaluated by the single particle tracking at the major operating tune. The crab lattice has almost same dynamic aperture with the present operating lattice. The synchrobetatron stop bands, which is predicted by G. H. Hoffstaetter and A. W. Chao[3], is not found by the dynamic aperture survey under the assumption of the remanent horizontal dispersion at the crab cavity after dispersion correction.

Presently, the obvious side effect of the crabbing motion is the luminosity side effect by R_1 coupling knob. For the luminosity tuning, the four coupling parameters of the interaction point R_1, R_2, R_3 and R_4 are controlled as tuning knobs. In the bunch under the ideal crab crossing, the horizontal offset at the interaction point is proportional to the longitudinal position and the other coordinates are not affected. R_1 coupling knob is the only knob responded to the horizontal offset. The vertical offset proportional to the horizontal offset is induced by R_1 coupling. Thus, the change of R_1 tilt knob makes the vertical crabbing motion. This vertical crabbing affects the luminosity similar to a



(a) HER



(b) LER

Figure 4: Dynamic aperture of HER and LER with 10% coupling. Solid and dashed lines show the present operating lattice and new crab lattice, respectively.

vertical crossing angle. The typical scan width of R_1 knob is about 2mrad In term of the vertical crossing angle, its scan width equals to 22μrad. The vertical crossing angle is controlled by the collision feedback system in the operation and the target angle of the feedback is adjusted for the luminosity tuning with the resolution of 10μrad. Thus, the luminosity change by the vertical crossing angle is observed in the luminosity scanning by R_1 knob. The combined knob between the vertical crossing angle and R_1 knob is required for easy operation.

SUMMARY

At present, the serious problem of the new crab lattice is not found. The activity for installing the crab cavities is progressing on schedule.

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