DEVELOPMENT OF A TUNE KNOB FOR THE HLS-II STORAGE RING*

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Abstract

A tune knob is a useful tool for lattice setup and machine studies in a storage ring. It is used to adjust the transverse tunes with a small impact on the beam dynamics. A global tune knob is designed for the Hefei Light Source (HLS). In the tune knob, the quadrupoles are grouped into four families and are symmetrically adjusted. Methodical Accelerator Design-X (MAD-X) is used to calculate the coefficients of the tune knob and the Accelerator Toolbox (AT) is used to double check the accuracy of the tune knob. The chromaticity is corrected by the sextupoles in the storage ring. This paper reports preliminary simulation results of the tune knob for HLS. The beta function deviations are also studied.

INTRODUCTION

Transverse tunes, ν_x and ν_y, of a storage ring, are important parameters. When performing machine studies, like studying coupling or beam dynamics around resonance, the tunes need to be adjusted. The Duke Storage Ring engages a set of quadrupoles in the straight section to change the tunes of the storage ring [1]. The PEPII uses a tune knob system to optimize the parameters of the interaction point (IP) [2].

It is necessary to develop a tune knob in the HLS storage ring to offer machine study opportunities. The main operation parameters of HLS are listed in Table 1 [3]. Due to its short circumference and small tune, the phase advance in the straight line section is small, thus a global tune knob design is proposed. The tune knob engages all quadrupoles in the storage ring and they are grouped into four families. The strengths of quadrupoles in each family are simultaneously adjusted assuring that the tune is adjusted to the designated value gradually and that the symmetry of the lattice is preserved. This paper introduces the details of the tune knob for HLS and reports preliminary simulation results.

TUNE KNOB FOR THE HLS STORAGE RING

The operating HLS lattice is consisted of two superperiods. Each superperiod is composed of two DBA cells [4]. The elements are symmetrically distributed in each cell. The tune knob engages all the quadrupoles to adjust the tune according to

$$\Delta\nu_{x,y} = \frac{1}{4\pi}\oint \beta_{x,y}\Delta K ds, \quad (1)$$

Table 1: Main Operation Parameters of HLSII

Parameters	Value
Circumference	66.13 m
Total current	300 mA
Horizontal emittance	36 nmrad
Lifetime	6 h
Energy	800 MeV
Harmonic number	45
Bunch length	50 ps
Horizontal tune	4.4448
Vertical tune	2.3598

where ΔK is the adjustment of quadrupoles and $\beta_{x,y}$ are the transverse beta functions [5]. In each cell of HLS, there are 8 quadrupoles. The strengths of the 8 quadrupoles in one cell are adjusted simultaneously with different adjustment coefficients. The strengths of the quadrupoles in other cells are adjusted accordingly to preserve the symmetry of the lattice.

Adjustment Coefficients of the Tune Knob

The adjustment coefficients of the tune knob are calculated with MAD-X [6]. The constraints $\alpha_x = \alpha_y = 0$ at the centre of the straight line section are added to preserve the symmetry of the lattice. The constraints $\beta_x, \beta_y < 25$ m are added to make sure the beta functions do not change too much. Only one direction of the transverse tune is adjusted at one time and the adjustment range of the tune is set to be ± 0.1 respectively. The relation between the quadrupole strength adjustment (ΔK) and tune change ($\Delta\nu$) is nearly linear (Fig. 1).

The quadrupole strength adjustment coefficients of the tune knob are fitted by $\Delta K = b\Delta\nu$. The coefficients b are fitted and shown in Table 2, in which K1 through K8 are used to denote the 8 quadrupoles in each cell. For these coefficients, only one transverse tune (ν_x or ν_y) is adjusted. The tune is gradually changed when the quadrupole strengths are simultaneously adjusted accordingly.

Beta Function Deviations

The beta function deviations are calculated each time when the tune is adjusted. The deviations of the beta functions when adjusting ν_x and ν_y are plotted in Figs. 3 and 4 respectively. The deviations are compared with the nominal beta functions plotted in Fig. 2. The shape of beta function deviation is similar to that of the nominal beta function. The deviations of beta functions are bigger at places where the nominal beta functions are bigger. The figures also show

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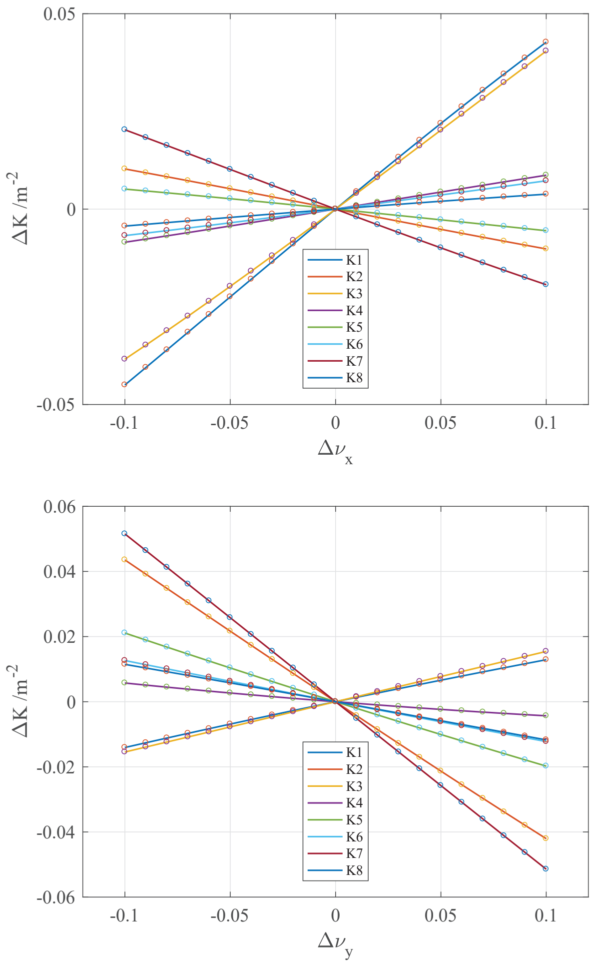

Figure 1: Quadrupole strengths adjustments with respect to the tune change (upper) $\Delta\nu_x$ and (lower) $\Delta\nu_y$.

Table 2: Quadrupole Adjustment Coefficients b in $\Delta K = b\Delta\nu$

Quadrupoles	$b(\Delta\nu_x)$	$b(\Delta\nu_y)$
K1	0.4410	0.1348
K2	-0.1030	-0.4288
K3	0.3968	0.1546
K4	0.0863	-0.0503
K5	-0.0536	-0.2044
K6	0.0706	-0.1244
K7	-0.1994	-0.5151
K8	0.0411	-0.1161

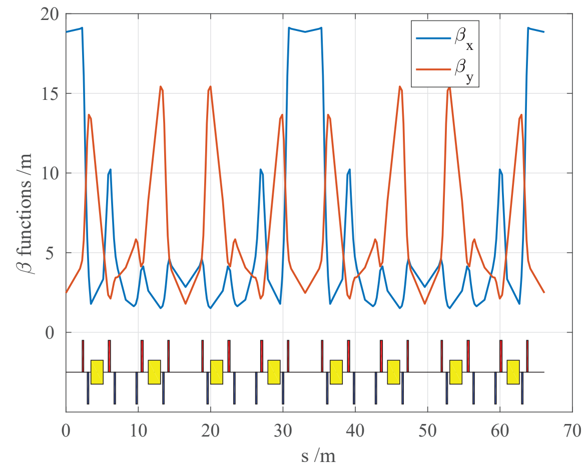

Figure 2: HLS nominal beta functions.

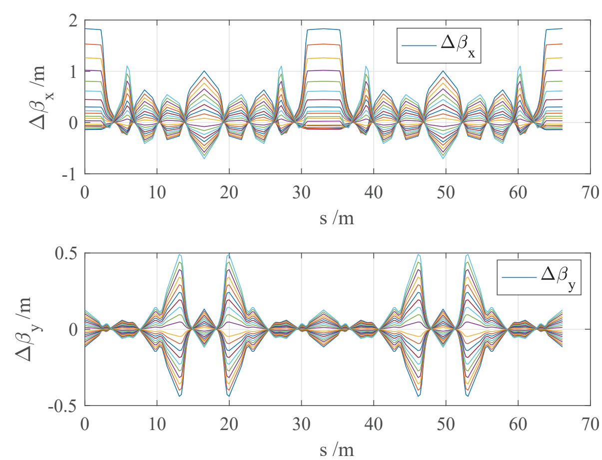

Figure 3: Beta function deviations $\Delta\beta_x$ (upper) and $\Delta\beta_y$ (lower) when adjusting ν_x.

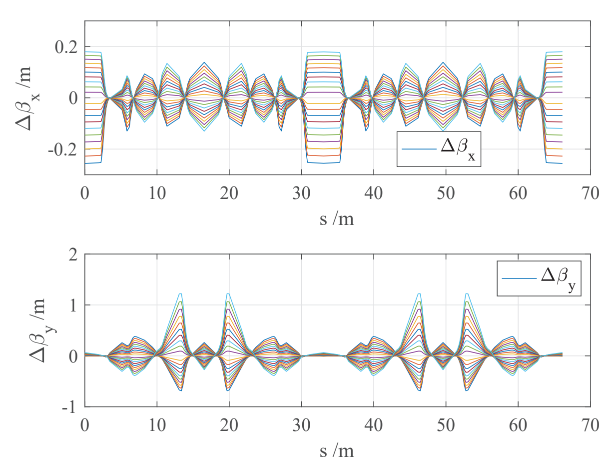

Figure 4: Beta function deviations $\Delta\beta_x$ (upper) and $\Delta\beta_y$ (lower) when adjusting ν_y.

that when adjusting ν_x, the deviation of β_x is bigger and that of β_y is smaller. The similar result holds respectively when adjusting ν_y. It is also shown that the beta function deviations are symmetric because the quadrupoles are adjusted symmetrically.

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Checking the Tune Knob with AT

Accelerator Toolbox (AT) is used to double check the accuracy of the tune knob. A tune scan is performed by changing ν_x and ν_y simultaneously. The ranges of tune scan are ±0.05 in both directions. Each time when the tune is changed, AT is used to calculate the tune with the adjusted quadrupole parameters. The checking result is represented by $\Delta\nu_{AT} - \Delta\nu_{set}$, where $\Delta\nu_{AT}$ is the tune change calculated in AT with the adjusted quadrupole parameters and $\Delta\nu_{set}$ is the preset tune adjustment. The results for both x and y directions are plotted in Fig.5 , which shows that the dimension of the difference is about 10^{-6}. The small difference suggests a good accuracy of the tune knob.

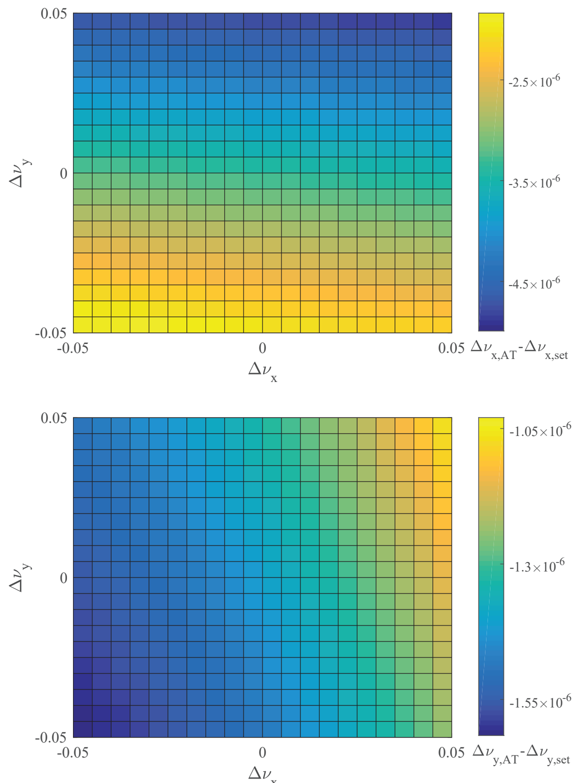

Figure 5: Tune knob checking expressed by $\Delta\nu_{AT} - \Delta\nu_{set}$ with AT.

Impacts on the Chromaticity

Adjusting the quadrupole strengths changes not only the tune, but also the chromaticity as well. The chromaticity deviation is plotted in Fig.6. These deviations should be corrected by the sextupoles in the storage ring. In each cell of HLS, 4 sextupoles can be adjusted simultaneously. The relation between the sextupole adjustment and $\Delta\nu$ is usually nonlinear.

CONCLUSION

A global tune knob design is proposed based on the lattice of the HLS storage ring. The tune is adjusted by symmetrically and gradually changing the quadrupole strengths in

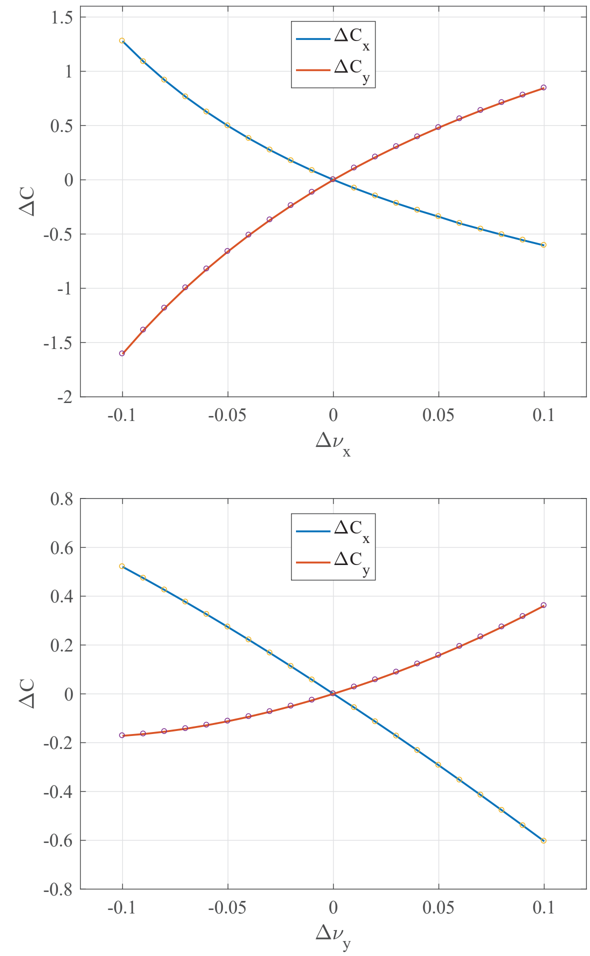

Figure 6: Chromaticity change with respect to the tune adjustment.

the storage ring. The range of tune adjustment is designed to be ±0.1. The results show that the tune knob is accurate and does not have a big impact on the beta functions. The chromaticity should also be corrected each time when the tune is changed. The dynamic properties and other issues can be further studied.

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