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BEAM LOSS SIMULATIONS DURING BEAM DUMPING IN HEPS*

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Abstract

The High Energy Photon Source (HEPS) is a 6 GeV storage ring light source under construction in China. Several collimators installed in the vacuum chamber will be used as beam dump in the storage ring operation. Preliminary simulations showed that the temperature rise caused by the beam power deposited on the collimators will far exceed the melting point of the collimator material. In order to cure this problem, special kickers are proposed to be installed in the ring to modulate the beam during beam dumping, thereby increasing the size of the beam hit on the collimators. In this article, some simulation results of the density of particles on the collimators during beam dumping for different HEPS lattice and different kicker parameters are shown.

INTRODUCTION

The High Energy Photon Source (HEPS) is a 6 GeV storage ring light source under construction in China [1-3]. Several collimators installed in the vacuum chamber will be used as beam dump in the storage ring operation. Since the collimators will be installed at positions with large β_x and large dispersion [4], most of the particles will be lost on the collimators when RF cavities are turned off. This means that very high energy will be deposited on the collimators in a short time. Preliminary simulations showed that the temperature rise caused by this power density will far exceed the melting point of the collimator material. Considering the safety of the collimators when beam dumping in the HEPS ring, the power density lost at the collimators must be reduced. By adding 1 or 2 beam dump kickers in the injection/extraction area, the transverse distribution size of electrons deposited on the collimators during beam dumping can be effectively expanded, thereby reducing the power density. Some preliminary simulation results of the distribution of particles hit on the collimators during the beam dumping will be shown in this paper.

SIMULATION PARAMETERS

In this study, the Elegant code [5] was used for tracking of 100 error lattice seeds based on the HEPS lattice with different kicker combinations, and the same simulation was performed using the error-free lattice as a comparison. The bunch number and the number of macroparticles per bunch were set to the same values for the lattice with or without errors. There were 63 uniformly distributed bunches in the whole ring, and each bunch contained 3000 macroparticles. Due to the heavy computation load, the CPU calculation time required for kicker parameter optimization was very long. The kickers were therefore all set to the same values without optimizing the kicker strength for each error lattice seed separately. In the simulations, one horizontal dump kicker and one vertical dump kicker were placed in the injection area. In the simulations, the effect of each kicker can be tested by not adding kickers, adding one kicker, or adding two kickers. The waveforms of the horizontal and vertical dump kickers were both set to a half-sine waveform with a base width of 1 revolution period of HEPS. The maximum deflection angle of the vertical kicker was set to 0.17 mrad, and the maximum deflection angle of the horizontal kicker was set to 0.25 mrad. These deflection angles were given by the optimization results using the error-free HEPS lattice. The vertical kicker was turned on at the 50th turn of the beam, and the horizontal kicker was turned on a half-period earlier than the vertical kicker, so that all beams can feel a certain deflection. See Fig. 1 for the waveform diagram of the kickers. The collimator aperture setting refers to the HEPS collimator aperture simulation results [6]. In the simulations shown in this paper, the collimators in lattice with errors were set to be a circle with a radius of 4.0 mm, and the collimators in lattice without errors were set to be a circle with a radius of 5.3 mm.

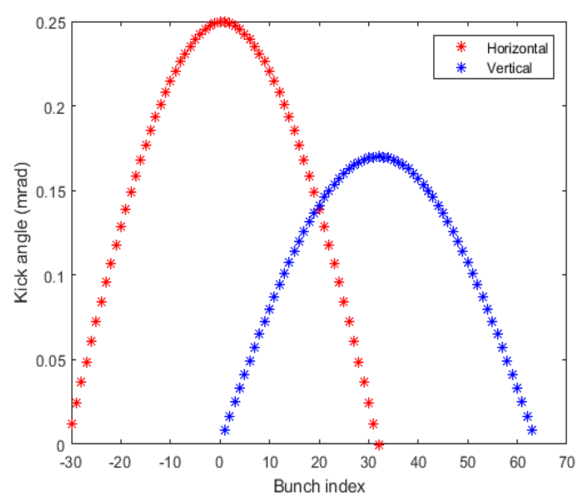

Figure 1: A diagram of kicker waveforms.

SIMULATION RESULTS FOR LATTICE WITHOUT ERRORS

This section showed the simulation results of the error-free HEPS lattice, which was used as a comparison with the results obtained with error lattices [7]. The distribution of macroparticles lost on the collimators under different dump kicker conditions is shown in Fig. 2. The macroparticle densities in this figure were calculated using a plane grid that is perpendicular to the direction of beams and has

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a horizontal and vertical size of 10 µm-by-10 µm. It can be seen from Fig. 2 that when the kickers were not added in the error-free lattice, the maximum macroparticle density on the collimators was 54000 macroparticles/grid; when only the horizontal kicker was added, the maximum macroparticle density on the collimators was 10900 macroparticles/grid; when only the vertical kicker was added, the maximum macroparticle density on the collimators was 1050 macroparticles/grid; when both horizontal and vertical kickers were added, the maximum macroparticle density on the collimators was 229 macroparticles/grid.

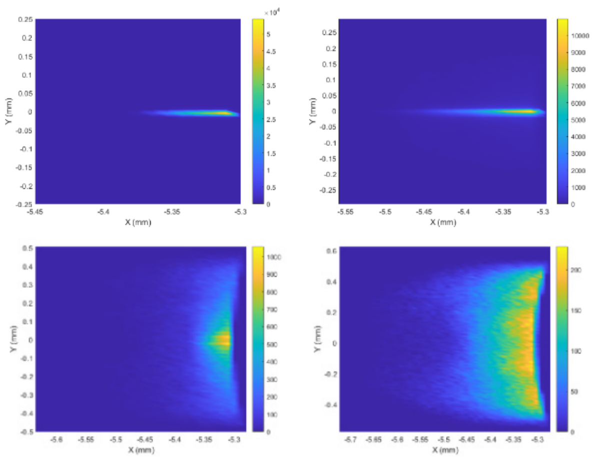

Figure 2: The distribution of macroparticles lost on the collimators under different kicker conditions. The upper left is the result with no kickers, the upper right is the result with a single horizontal kicker, the lower left is the result with a single vertical kicker, and the lower right is the result with both horizontal and vertical kickers.

SIMULATION RESULTS FOR LATTICES WITH ERRORS

In addition to reducing the density of particles lost on the collimators, dump kickers also cause more particles to be lost outside the collimators. In order to study the impact of dump kickers on the particle lost position, simulations were done for four situations with no kickers, only one (horizontal or vertical) kicker, and both horizontal and vertical kickers, respectively. The influence of kickers on the particle loss position is shown in Fig. 3. The addition of kickers will reduce the proportion of particles lost on the collimators. The proportion decrease most significantly for situations with two kickers. However, even when two kickers were added, the proportion of particles lost on the collimators is above 88%.

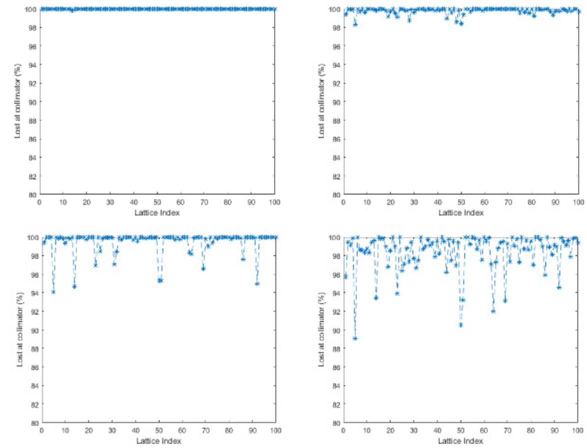

Figure 3: The proportion of particles lost on the collimators. The upper left is the result with no kickers, the upper right is the result with a single horizontal kicker, the lower left is the result with a single vertical kicker, and the lower right is the result with both horizontal and vertical kickers.

The results of the maximum macroparticle density per grid in each tracking were shown in Fig. 4. The macroparticle densities in this figure were calculated using the same grid setting as that used in the simulation for error-free HEPS lattice. From Fig. 4, the following conclusions can be drawn: 1. Without kickers, the density of particles lost on the collimators in the case using lattices with errors is lower than that without errors. However, the particle densities in the simulations for several error seeds were not significantly reduced, so it was still necessary to install dump kickers in the design. 2. Both the horizontal and vertical kickers could reduce the density of particles lost on the collimators. In comparison, the effect of the vertical kicker was more significant.

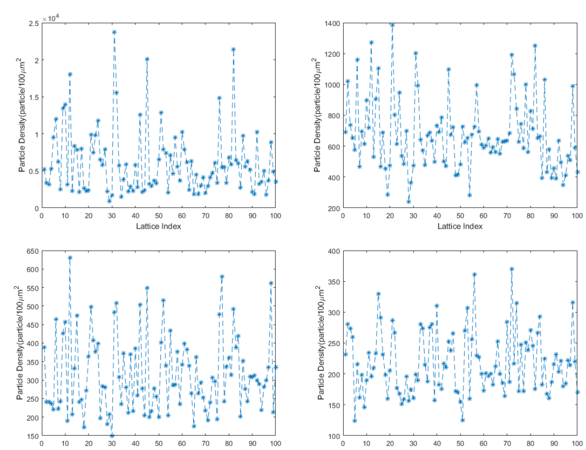

Figure 4: The maximum macroparticle density lost on the collimators. The upper left is the result with no kickers, the upper right is the result with a single horizontal kicker, the lower left is the result with a single vertical kicker, and the lower right is the result with both horizontal and vertical kickers.

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CONCLUSIONS

In this paper, the Elegant program was used to simulate 100 error lattice seeds based on the HEPS lattice, and the influence of the dump kickers on the particles lost on the collimators was studied. The simulation results showed that the dump kickers in the horizontal and vertical directions can effectively reduce the thermal deposition on the collimator during beam dumping. When there were both horizontal and vertical kickers, the maximum thermal deposition on the collimator can be reduced to about 1/200 of that for lattice without errors nor kickers. The density of particles dropped on the collimators when both the horizontal/vertical kickers were added for lattices with no errors is equivalent to that when both the horizontal/vertical kicker were added using lattices with errors. Comparing the effects of the horizontal and vertical kickers, it can be seen that the effect of the vertical kicker was better than the horizontal kicker.

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