COMMISSIONING THE 90° LATTICE FOR THE PEP II HIGH ENERGY RING*

W. Wittmer†, Y. Cai, W. Cheng, W. Colocho, F.J. Decker, S. Ecklund, A.S. Fisher, Y. Nosochkov, S. Novokhatski, M. Sullivan, U. Wienands, Y. Yan, J. Yocky
SLAC, 2575 Sand Hill Road, Menlo Park, CA 94025, USA

Abstract

In order to benefit from further reduction of the vertical IP beta function of the PEP-II high energy ring (HER) the bunch length should be reduced. This will be achieved by changing the phase advance from 60° to 90° in the four arcs not adjacent to the IR region, thus reducing momentum compaction by about 30% and reducing bunch length from a present 12 mm down to 8.5 mm at low beam current. In preparation to implement the 90° lattice the main HER quadrupole and sextupole strings and their power supplies have been reconfigured. The synchrotron tune initially will be lower but can be brought back by raising the rf voltage. Beam emittance is held at 48 nmr by introducing a significant dispersion beat in the arcs. The lattice was successfully commissioned at currents up to 800 mA in August 2007. In this paper we will compare the actual machine with the predicted behaviour, explain the correction strategies used and give an overall assessment of the operation and the benefit of the new lattice configuration.

INTRODUCTION

For the final PEP II run the original goals were to increase the peak luminosity from 1.2×10^{34} to 2×10^{34}. Part of the plan to achieve this was to reduce the IP spot size by squeezing the vertical β-function. To benefit from the beam size reduction the longitudinal beam size has to be reduced as well since the machine was operated at the hour glass limit. The first is done by using so called local IP tuning knobs [1]. For the latter, the momentum compaction factor has to be reduced. The original HER PEP II lattice has 60° arc cells. By increasing the phase advance per cell to 90° the momentum compaction factor is reduced. The phase advance in the arcs bordering the interaction straight were not changed. This would have demanded a partial redesign and commissioning of the interaction region which was deemed to be too big an impact.

Changing the phase advance in the above described way results in the transverse tune to change by four integers in both planes. A change of this magnitude is comparable with the commissioning of a new machine. To minimize the fallout from this change a special machine development (MD) shift was planned to test the 90° lattice before implementing it during normal operation. In preparation of this test great effort was made to study all possible scenarios and prepare correction mechanisms. This was done by using a machine model in MADX which was generated using MIA data.

LATTICE DESCRIPTIONS

The TWISS parameter of the HER 60° design lattice is shown in Fig. 1. The IR is clearly visible through its high β insertion (black and red curve). The arcs can be identified by the non zero dispersion function (green curve). The β- and dispersion functions in the arcs adjacent to the IR are different compared to the other arcs as they are part of the IR design. A change in this area cannot be made IR transparent and therefore the arc cells in this region were not changed to 90°.

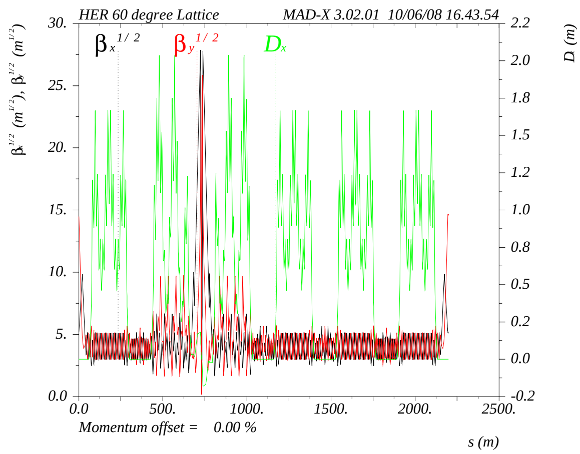

Figure 1: HER 60° design lattice. The black and red curve show the square root of the horizontal and vertical β-function. The green the horizontal dispersion function.

Fig. 2 depicts the TWISS parameter of the HER 90° design lattice. The most significant visual difference are the large oscillations in the horizontal dispersion functions in the arcs to control the emittance. The β-functions at the IP are the same as in the 60° design lattice. The squeeze of the vertical β-function are done separately using IP tuning knobs. Table 1 shows a list of parameter for both lattices. The momentum compaction factor α is reduced by approx. 30%, translating into a bunch shortening by approx. 15% and allowing to reduce the vertical spot size by also 15% before the hour glass limit is again reached.

SIMULATIONS

The HER has been tuned over the past seven years to increase luminosity. This has resulted in deviations of mag-

* Work supported by US DOE under Contract DE-AC03-76SF00515
† wittmer@slac.stanford.edu

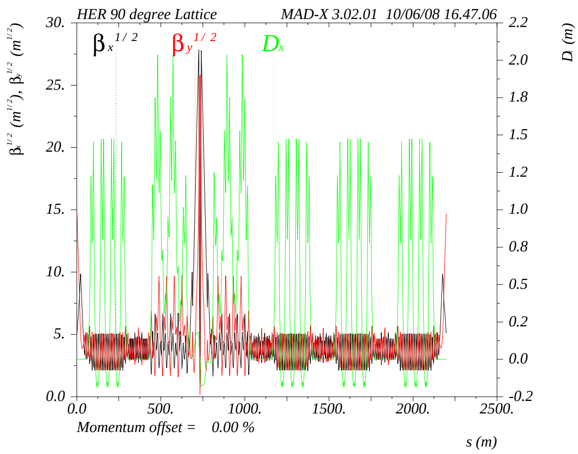

Figure 2: HER 90° design lattice. The black and red curve show the square root of the horizontal and vertical β-function. The green the horizontal dispersion function.

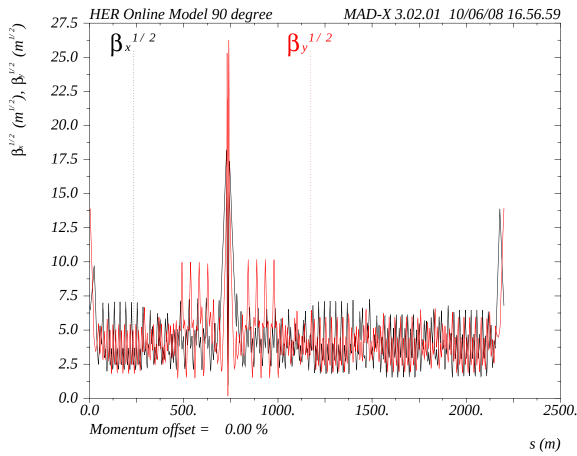

Figure 3: HER 90° design model with errors, measured with the 60° machine on top of the design magnet strength values.

Table 1: Design parameter of the 60° and 90° lattice.

Parameters	60° lattice	90° lattice
α [1]	0.00241	0.00169
ν_x [1]	24.518	28.518
ν_y [1]	23.63	27.63
σ_l [mm]	10.5	8.84

net strength settings in the machine from the design model. Also the beam orbit in the machine is different compared to the model. All this makes it difficult to predict the impact of changing the lattice in such a drastic way. The question of how to take these differences into account was addressed by using the MIAMADX online model. This model is generated by transferring the magnet strength values calculated from MIA [2] measurements into the MAD design model. These data were taken with the 60° lattice. The procedure is setup to add the measured changes to the design lattice as perturbation. This allowed, by simply exchanging the design lattices from 60° to 90°, to model the expected behavior when implementing the new lattice. Fig. 3 shows the 90° design lattice with the measured 60° perturbation added. The most important fact was that this "90° machine model" was stable. This allowed to plan the use of all standard correction tools from the beginning and substantially enhance the chances for succeeding within the planed time frame. With this model the expected errors on the linear lattice functions could be studied and correction methods prepared. The horizontal β beat increased from 20% in the 60° machine to over 250% in the "90° machine model". The studies showed that by changing one of the high β insertion quads the expected β-beat can be reduced below 50%. The information gathered by these studies were a vital input during the planning phase and the execution of the MD.

COMMISSIONING OF THE NEW LATTICE

To have the best possible baseline for comparing changes from the implementation of the new lattice, phase advance and dispersion measurements before and after the implementation were conducted. Additionally after every cor-

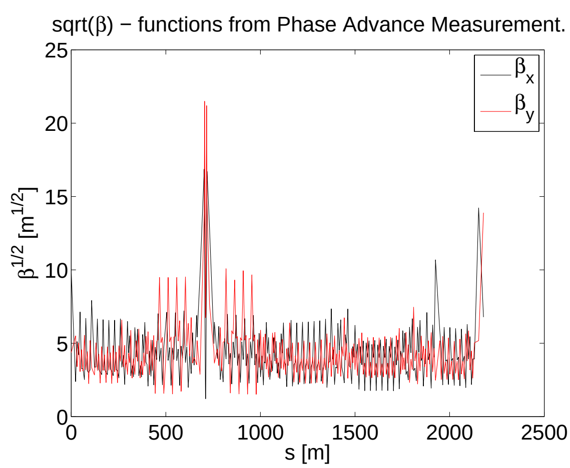

Figure 4: Calculated β-functions from advance measurements after implementation of the new lattice and standardization of the magnets.

rection step the measurements were repeated. For these measurements and during the greater part of the MD a single bunch with approx. 2 mA was used.

Fig. 4 depicts the measured square root of the β-functions after loading the new lattice and standardizing the rings. This plot can be directly compared to Fig. 3 which was the prediction of this case. Within the measurement uncertainty and hardware errors (bad BPM reading) these plots are the same indicating the good quality of the online model.

After this measurement the β-beat correction from the was applied. Additional standard tuning and corrections, using sextupole orbit bumps and orbit correction, were applied. Fig. 5 shows the measured horizontal 90° dispersion measured after these corrections. Comparing this plot to the design model shown in Fig. 2 (green curve), the same conspicuous oscillations in the changed arcs can be seen, although there is still an apparent dispersion beat.

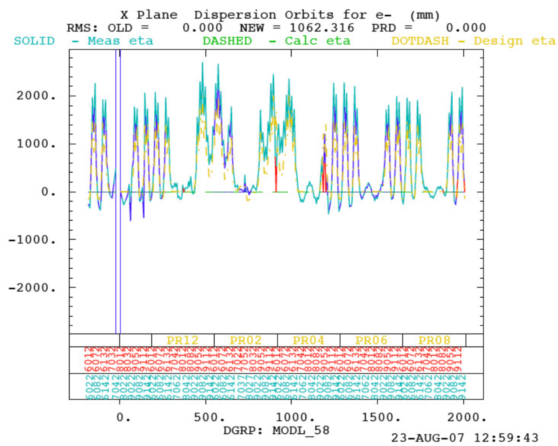

Figure 5: HER 90° horizontal dispersion measured after changing to the 90° lattice, standardizing the magnets and first optic corrections.

Fig. 6 shows the synchrotron frequency measurement. The upper plot depicts the measurement with the 60°, the

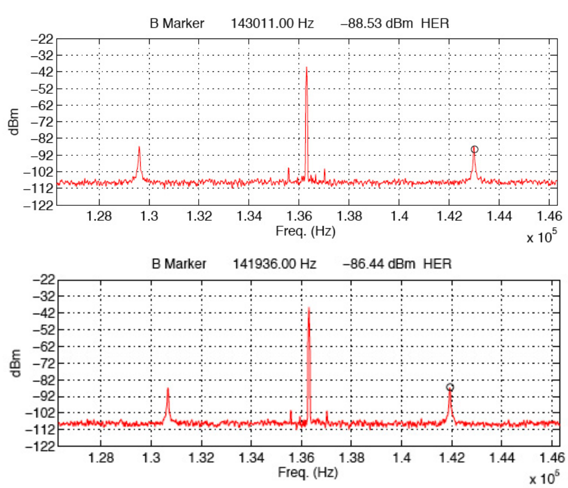

Figure 6: Synchrotron frequency measurement for the 60° (upper plot) and 90° lattice (lower plot).

lower the 90° lattice. The central line is the revolution frequency and the two smaller are the synchrotron side bands with the difference being the synchrotron frequency. The lower shows the same measurement for with the 60° lattice. The measured and calculated numbers are presented in Table 2.

During the actual implementation of the changes in the

Table 2: Measured synchrotron tune and frequency of the 60° and 90° lattice.

Parameters	60° lattice	90° lattice
f_{ref} $[kHz]$	136.3113	
f_s [1]	6.6997	5.6247
ν_s $[kHz]$	0.0492	0.0413

HER a pilot bunch was in the low energy ring (LER). Although no changes were applied to the LER, perturbations were expected through magnetic cross talk in the cable trays and close magnetic elements. After the implementation the LER orbit showed a beat in the order of one mm and was corrected.

Following the single bunch run standard bunch patterns were loaded in the HER (700 mA max) and LER (1 A max) and the beams were brought into collision. The HER current was limited by the fact that the synchrotron tune change demanded a retiming of the bunch by bunch feed backs which was not within the scope of the MD. The specific luminosity was half of its nominal value at these currents and could be increased up to approx. 20% below its nominal value through minor tuning. This was originally not planned and became possible through the very smooth run during the MD. Note that the $\beta_y^\star$ was not reduced in this experiment.

Additionally, the bunch length was measured during the single and multi bunch runs of the MD. Although these are not ideal conditions for the measurement and the acquired data did not give quantitative results on the bunch length, the signal of bunch shortening was observed.

SUMMARY

The test of the 90° optics was very successful at low currents establishing all objectives of the MD. Collisions at intermediate beam current showed the potential of achieving the estimated luminosity gains. All necessary data were taken and machine configuration files were saved as starting point for the implementation in normal operation. The implementation was unfortunately canceled due to the curtailing of the final PEP run and the resulting changes of goals.

REFERENCES

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