SLAC–PUB–12055
August 2006

Implementation of Double-Waist Chicane Optics in SPEAR3[*]

J. Corbett, M. Cornacchia, T. Dao, D. Dell'Orco, F. Rafael, D. Harrington, R. Hettel,
X. Huang, Y. Nosochkov, T. Rabedeau, H. Rarback, A. Ringwall, J. Safranek,
B. Scott, J. Sebek, J. Tanabe, A. Terebilo, C. Wermelskichen, M. Widmeyer
Stanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park, California 94025

Moohyun Yoon
POSTECH, Pohang, Korea

Abstract

The SPEAR3 accelerator upgrade opened up two 7.6m racetrack straights in the magnet lattice. In one of these straights, we recently added a magnetic chicane to separate two insertion device (ID) beam lines by 10mrad. A quadrupole triplet in the center creates a 'double focus' optics with ßy = 1.6m at the middle of each ID, hence the term ‘double-waist chicane’. The new optics also reduced ßy in the four matching straights adjacent to the racetrack straights to 2.5m. In this paper, we outline design features of the optics and physical implementation of the lattice.

Presented at the 10th European Particle Accelerator Conference (EPAC 06)
Edinburgh, Scotland, UK, 26-30 June, 2006

---

[*] Work supported in part by the US Department of Energy Contract DE-AC02-76SF00515 and Office of Basic Energy Sciences, Division of Chemical Sciences.

.

IMPLEMENTATION OF DOUBLE-WAIST CHICANE OPTICS IN SPEAR3[§]

J. Corbett, M. Cornacchia, T. Dao, D. Dell'Orco, F. Rafael, D. Harrington, R. Hettel, X. Huang, Y. Nosochkov, H. Rarback, T. Rabedeau, A. Ringwall, J. Safranek, B. Scott, J. Sebek, J. Tanabe, A. Terebilo, C. Wermelskichen and M. Widmeyer (SLAC, Menlo Park, USA)

Moohyun Yoon (POSTECH, Korea)

Abstract

The SPEAR3 accelerator upgrade opened up two 7.6m racetrack straights in the magnet lattice. In one of these straights, we recently added a magnetic chicane to separate two insertion device (ID) beam lines by 10mrad. A quadrupole triplet in the center creates a 'double focus' optics with β_y=1.6m at the middle of each ID, hence the term ‘double-waist chicane’. The new optics also reduced β_y in the four matching straights adjacent to the racetrack straights to 2.5m. In this paper, we outline design features of the optics and physical implementation of the lattice.

INTRODUCTION

Along with improvements in beam brightness and orbit stability, the SPEAR3 upgrade produced two 7.6m and four 4.8m straight sections. The lattice is shown in Figure 1. The East racetrack straight has recently been converted to a ‘double-waist chicane’ configuration to direct two ID beams through the same exit port [1]. A quadrupole triplet in the center re-focuses β_y to two 1.6m minima. As shown in Figure 2, the downstream minima contains the ID source for BL12-2, a 1.5m adjustable-gap, in-vacuum undulator (IVUN).

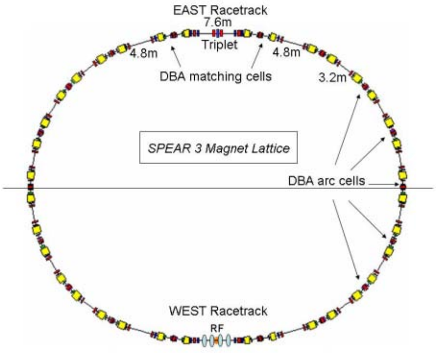

Figure 1: SPEAR3 map showing 7.6m and 4.8m straights.

To implement the double-waist chicane optics, the accelerator modification was divided into two phases: in Phase-I (2005) we installed the quadrupole triplet, 7 new power supplies and 13 supply controllers. This allowed user operation in the nominal optics with the possibility to activate the triplet during periods of machine development. Phase-I modifications split previously ganged quadrupole families to allow double-waist tuning but did not yet install the dipole chicane magnets. Spare vacuum chambers, triplet magnets and accelerator rafts were used throughout. Machine development tests included calibrating the new power supply/controller configuration with beam, injection optimization, aperture and lifetime studies, and characterization of both linear and non-linear lattice properties [2]. Nominal double-waist optics, low-emittance optics and low-alpha optics were tested with the triplet activated. About 25 Phase-I machine development programs totaling over 125 hours were devoted to commissioning and characterization of the double-waist optics. Although tracking simulations predicted performance similar to the nominal optics, a thorough development program was needed to demonstrate and optimize machine performance prior to installation of the chicane magnets and BL12-2 ID.

Phase II (2006) includes installation of the final vacuum system, the chicane dipole magnets, 12 more power supplies and 6 more supply controllers. The Phase II supply configuration provides greater flexibility to match betatron and dispersion beats originating in the chicane region. Phase II also includes installation of the BL12-2 IVUN [3], the associated beam line [3], and a host of accelerator diagnostic components.

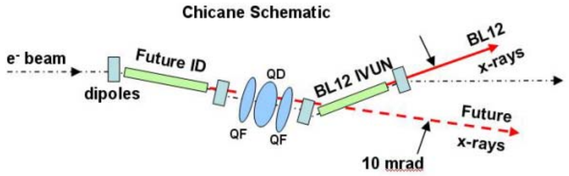

Figure 2: Schematic of the double-waist chicane showing 4 chicane dipoles, quadrupole triplet and photon beam orientation.

DOUBLE-WAIST OPTICS

The 18-cell SPEAR3 ‘racetrack’ lattice did not have space for auxilliary (harmonic) sextupoles in the outboard DBA quadrupole doublets. Instead, to optimize dynamic aperture, the betatron phase-advance through the arcs cells was set to μ_x~0.75, μ_y~0.25 to enhance cancellation of geometric aberrations originating in the chromatic sextupoles [4]. The phase advance through the

---

[§] Work supported in part by the US Department of Energy Contract DE-AC03-76SF00515 and Office of Basic Energy Sciences, Division of Chemical Sciences.

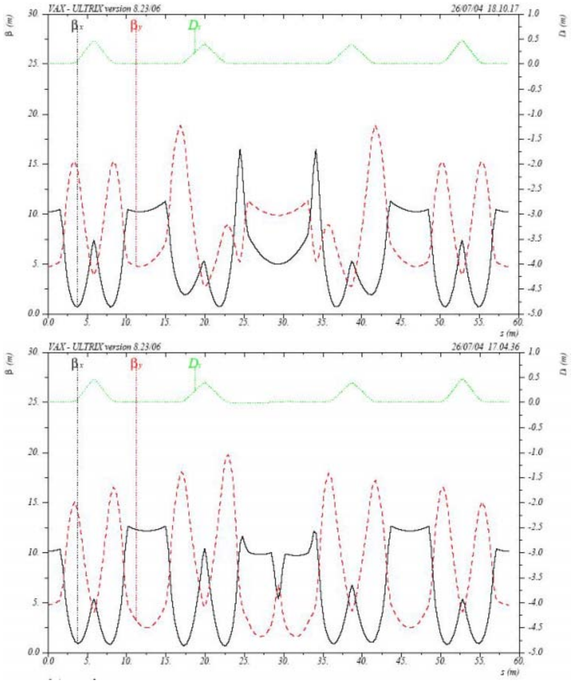

Figure 3: Lattice optics across the East racetrack straight for (a) Nominal SPEAR 3 lattice and (b) double-waist lattice with two β_y=1.6m minima and two adjacent β_y=2.5m minima.

arcs and 'matching cells' leading to the racetrack straights was balanced to achieve a working point of [ν_x=14.19, ν_y=5.23]. Two sets of SF/SD sextupoles (one in the arcs, one in the matching cells) were adjusted to optimize off-energy dynamic aperture [4]. With an eye toward the future, the matching cells were constructed with quadrupole triplet magnets leading to the racetrack straights [5].

Initial designs for the double-waist optics used a single triplet in the center of the East racetrack straight to produce two β_y minima [6]. Further study showed that by adding more degrees of freedom (quad supplies) we could reduce β_y in the four penultimate 'matching cell straights' from 4.8m to 2.5m [7]. The new lattice thus provides two 1.8m-long, β_y=1.6m straights (in the chicane), and four 4.8m long, β_y=2.5m matching-cell straights.

Table 1: Minimum $\beta_{x/y}$ and $\sigma_{x/y}$ in 3.2m(standard), 4.8m(match) and 7.6m(chicane) straights; 1% coupling. The working point changes from [14.23,5.19] to [14.13,6.22] to optimize dynamic aperture and the ε_x=18.0nm-rad emittance stays fixed.

	Standard before/after	Match before/after	Chicane before/after
β_x	10.1/10.2	10.2/12.2	5.0/9.8
σ_x (micron)	429/437	429/479	300/429
β_y	4.8/4.8	4.8/2.5	9.9/1.6
σ_y (micron)	29/30	29/22	42/17

The West racetrack straight contains four PEP-II style RF cavities but similar phase-advance to balance the optics. Since the additional phase-advance could not be absorbed in the arcs without spoiling lattice dynamics, the vertical integer tune was increased by an integer. Table 1 summarizes the lattice modifications in terms of minimum $\beta_{x/y}$ and beam size in the SPEAR3 straights. The before- and after lattice optics are shown in Figure 3.

INSERTION DEVICE AND BEAMLINE

The BL12-2 insertion device [8] is a 1.5m long in-vacuum hybrid undulator designed and manufactured by NEOMAX. The magnet features 66 full periods of 22mm length. At 5.5mm minimum gap, the peak field is 1.11T, the K-value is 2.28, and the rms phase error is less than 2.0°. A 110μm thick Ni-plated Cu sheet covers the upper and lower magnetic arrays to reduce resistive wall impedance. The flange-to-flange ID length is 1.9m. Based on vertical scraper tests, it was found a vertical ID gap of 5.75mm is consistent with the A_y=4.5mm-mrad acceptance elsewhere in the ring (Figure 4).

The BL12-2 beam line consists of three 3.6mrad incident Rh-coated Si mirrors; a standard SSRL LN monochrometer with dual Si(1111)/Si(220) crystal sets, and the SSRL-standard robotic PX data collection and analysis system. The 12-2 beam line is designed to accommodate the future 12-1 ID beam line in the chicane.

CHICANE HARDWARE DESIGN

In order to direct both ID beams through a single exit port, a four-magnet chicane 'bump' was developed with deflection angles [-2.0, -4.833, +14.833, -8.0]mrad. Referring to Figure 2, the upstream beam line is directed inward -2.0 mrad toward the center of the ring while the downstream beam line is directed +8.0 mrad outward. To minimize photon beam power density on the first optic of the future beam line (potentially utilizing a super-conducting ID source), the IVUN and associated beam line hutch are installed in the downstream straight.

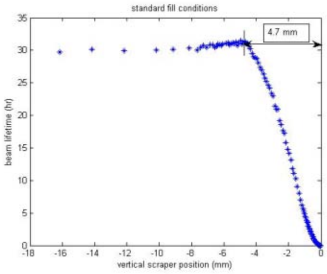

Figure 4: Vertical scraper measurements of 4.5mm-mrad ring acceptance. β_y =4.9m at the scraper location.

Figure 5 shows the Phase-I quadrupole triplet installed in the SPEAR3 tunnel. The triplet axis is in-line with the nominal beam axis. Phase-II has a similar triplet assembly but with chicane dipole magnets at each end of the ID straights. In this case, the chicane will rotate the central QD magnet about the vertical axis by -6.833mrad and offset it horizontally by x=-12.216mm. Both the 60cm QD and the 34cm QF triplet magnets are of nominal SPEAR3 quadrupole design [9]. Interestingly, the chicane increases the ring path length by +13µm, or Δf_{rf}=-265Hz.

Figure 5: In-situ Phase-I quadrupole triplet.

A side view of the prototype chicane dipole magnet core is shown in Figure 6. All four 110mm long magnets were assembled in-house and share the same laser-cut lamination profile and split-core design. The good-field region extends to over ±20mm horizontally and the multipole specifications are demanding – detachable pole end-packs in the prototype magnet will be iteratively machined and magnetically measured to minimize harmonic content. Each dipole shares the same basic coil pack: three magnets have coils on the poles and one has coils on the back leg. Each magnet has an independent ±30A horizontal trim coil suitable for fast orbit feedback.

Figure 6: Prototype chicane dipole magnet .

As mentioned above, the Phase-I vacuum spools through the chicane section are temporary. For Phase-II, the (empty) upstream straight has new GlidCop chamber transitions with recycled Cu-plated SS spools. The elliptical chamber through the triplet was formed from round SS tube stock and internally Cu-plated to minimize resistive wall impedance. Glidcop-masked bellows mate to SLS-style Be-Cu flex-tapers to accommodate motion of the adjustable in-vacuum ID. In order to increase the available aperture for the BL12-2 ID beam, the outboard mask on the vacuum chamber photon beam exit port is slightly retracted (Figure 7).

The diagnostic systems in the chicane region include standard water flow switches, ion gauges, thermocouples and five sets of BPMs. The BPM modules at each end of the chicane ID straights are used to steer and interlock the electron beam orbit. The triplet QD has an independent trim coil connected to a switched-relay quadrupole modulation system (QMS) for beam-based alignment.

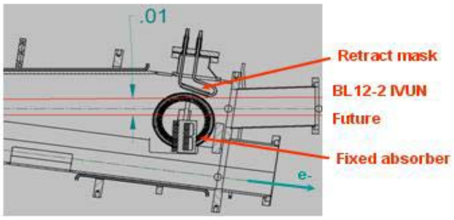

Figure 7: Dual photon beam exit port.

The trim coils on the outboard QF quadrupoles are configured as vertical correctors. Since the corrections are small, the associated multipole fields are minimum.

SUMMARY

One of the 7.6m SPEAR3 racetrack straights has been transformed into a 'double-waist chicane' configuration. The lattice conversion features an asymmetric 4-magnet chicane system and a quadrupole triplet to vertically re-focus the beam forming two β_y=1.6m minima. In the process, we also reduced β_y from 4.8 to 2.5m in four 4.8m straights adjacent to the racetrack straights. Extensive tracking studies, tune optimization and a test-phase implementation of the new lattice helped insure smooth transition. Initially, one of the chicane straights will house a 67 period, U22 IVUN and one of the 4.8m straights will house a 4.5m EPU.

ACKNOWLEDGEMENTS

Conversion of the SPEAR3 lattice to the double-waist chicane optics, the BL12-2 ID and PX beam line were sponsored by the Moore Foundation through the California Institute of Technology [3]

REFERENCES

[1] J. Safranek et al, 'SPEAR3 Double Waist Optics Design Review', SSRL-ENG-NOTE M545, 2006.
[2] J. Safranek, et al, these proceedings.
[3] 'Beam Line 12-2 Conceptual Design Report', SSRL Internal Memo.
[4] J. Corbett, et al, 'Design of the SPEAR 3 Magnet Lattice', EPAC98, SLAC-PUB-7882.
[5] M. Cornacchia, et al, 'Future Possibilities for the SPEAR3 Lattice', SLAC-PUB-10400, April, 2004.
[6] Y. Nosochkov, J. Corbett and T. Rabedeau, 'Study of Low β_y Straight Section in SPEAR3', SSRL-ENG-NOTE 357 and SLAC-PUB-8870, June 2001.
[7] M. Yoon, 'Low β_y Optics in the Matching and Racetrack Straights of the SPEAR3 Storage Ring', Parts I & II, SSRL Internal Memo.
[8] A. Ringwall,'SPEAR3 Beam Line 12 In-Vacuum Undulator Design Specification', SSRL-ENG-NOTE M501, February, 2006.
[9] J. Tanabe, et al, 'SPEAR3 Magnet Design, Measurement and Alignment', Proc. of SSILS, Shanghai, China, 2001.