STATUS OF THE HIGH ENERGY RING OF THE PEP II B-FACTORY *

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Abstract

The PEP-II High Energy Ring is a 9 GeV electron storage ring currently under construction at SLAC. It is one of the two rings of the PEP-II B-Factory, an asymmetric high-luminosity e^+–e^- collider. The ring will be housed in the existing PEP tunnel. Main challenges to the design of the ring arise from the high beam current of nominally 1 A. In this paper, overall design and recent progress are presented.

I. INTRODUCTION

The PEP-II[1] storage rings—the 9 GeV High Energy Ring (HER) and the 3.1 GeV Low Energy Ring (LER)—will be housed on top of each other in the existing PEP tunnel (Fig. 1). In order to reach the design luminosity of 3×10^{33} at a moderate beam-beam tune shift of 0.03 relatively large circulating currents of about 1 A and 2.1 A will be accumulated in the HER and the LER, respectively. The bunch length is about 1 cm to take advantage of small values of β^*; the focusing required to achieve these short bunches is provided by a 14 MV rf system at 476 MHz.
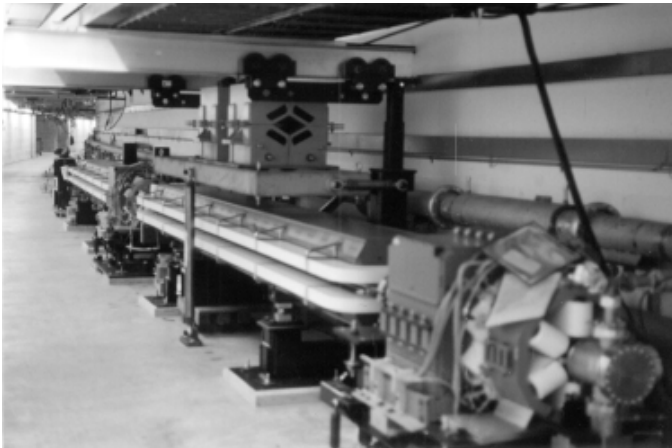

Figure 1. First cell of HER underneath LER mockup

II. THE HER MAGNET LATTICE

The geometric layout of the HER lattice fits into the existing PEP tunnel; this determines the sixfold symmetry. A FODO lattice with 60° phase advance/cell and 32 cells/arc has been adopted with three-cell dispersion suppressors to match into dispersion-free straight sections. The beam emittance is set by controlling the dispersion function in the arcs at a nominal value of 48π mm-mrad. A layout of the ring is shown in Fig. 2. A modulation in the β functions is introduced in the arcs adjacent
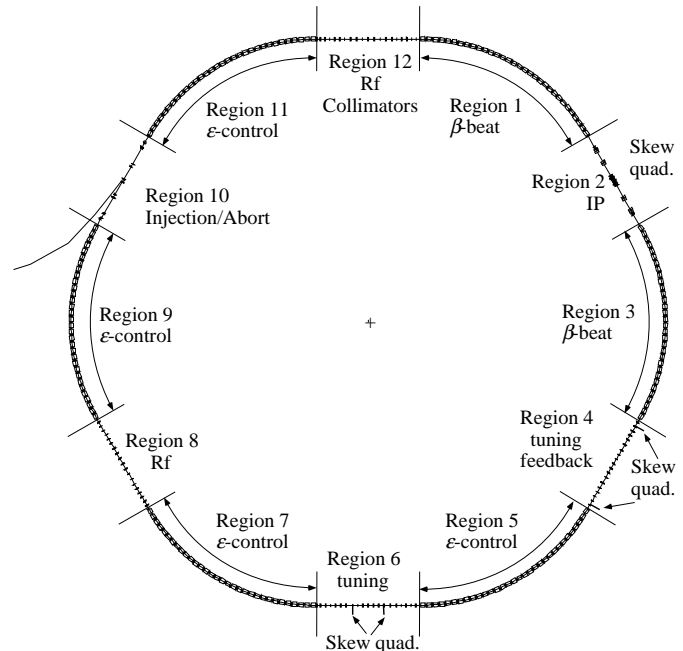
Figure 2. HER Layout

to the interaction region; in this way a semi-local correction of the chromatic aberrations introduced in the final focusing quads is achieved, improving the linearity of the lattice.

The straight sections have different numbers and structure of focusing cells depending on the functions. Rf systems are located in Regions 8 and 12 with 20 cells each. Injection takes place in Region 10 in a high-β region; 8 cells provide the required lattice functions. The machine tune is controlled with phase trombones in regions 4 and 6. The Interaction Point (IP) is at the center of region 2. While the nominal β^* is 1.5 cm, with the semi-local chromaticity correction values as low as 1 cm can be achieved. Figure 3 shows the acceptance of the ring in the presence of misalignments and field errors but absence of the detector solenoid. A detailed discussion of the HER lattice can be found in Ref. [2].

III. THE HER TECHNICAL SYSTEMS

A. Magnets

The HER uses most of the existing PEP magnets, in particular all 192 dipole magnets and all quadrupole magnets with the exception of some of the final focusing quadrupoles. However, since the HER has more focusing cells than PEP had, additional quadrupoles are being built. The additional 560 mm coils needed are being manufactured by BINP, Novosibirsk, under an Inter-laboratory Agreement.
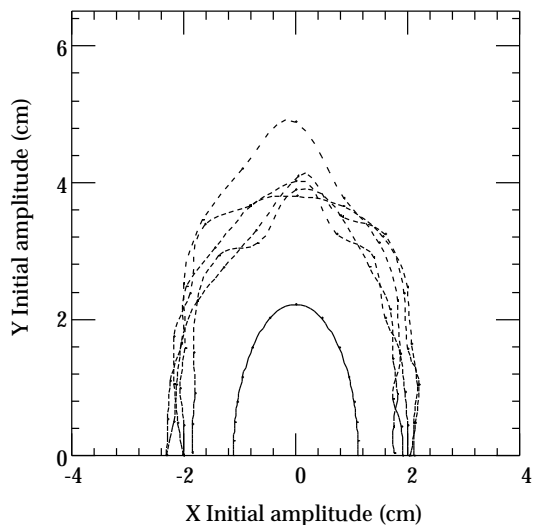
Figure 3. Dynamic aperture of the HER lattice

All existing and converted PEP magnets are being refurbished and tested before acceptance. Dipoles undergo electrical tests, water pressure test and a mechanical straightness inspection before magnetic measurements are being performed. Quadrupoles are being tested electrically and for LCW leaks before magnetic measurements.

The Dipole refurbishment and measurement program has been completed early this year. The magnets have passed the tests and fulfill the magnetic measurement criterion: $\sigma(\Delta \int BdL/I)/(\int BdL/I) < 10^{-3}$. The dipoles will be sorted in three ranges according to their value of $\int BdL/I$ and deployed in a H–L–M– M–H–L pattern (H=high, M=medium, L=low) to reduce horizontal orbit errors due to dipole variations.

The quadrupole refurbishment and measurement program are underway. Measurement data are very close to the values measured during construction of PEP. Since there are many different quadrupole current loops, the quadrupoles will be sorted to reduce the spread in the excitation function for quadrupoles excited by one current loop.

Corrector magnets for the HER are being built in industry. In order to control stray fields on the LER axis these magnets will be of "H" design.

B. Vacuum System

The vacuum system is designed for 3 A beam current to provide margins and an upgrade path. At 3 A beam current, synchrotron radiation power is about 10.5 MW. For beam stability, the impedance presented to the beam is strictly controlled and care is being taken to avoid the possibility of mode trapping in discontinuities of the vacuum chamber.[3]

The arc vacuum system uses octogonal Cu extrusions with cooling channels e-beam welded onto the outside to remove the up to 100 W/cm radiation power.[4] Flanges and bellows are protected from direct hit by synchrotron radiation by masks or chamber offsets.[5] Distributed ion pumps (DIP) are located in each dipole, augmented by lumped ion pumps which also act as holding pumps in the event the main dipoles are turned off. A screen between the DIP and the beam chamber protects the DIP from synchrotron radiation and TEM modes generated by the beam and the beam from particles emanating from the DIP. Prototypes of the DIP and screen are currently under test.[6] Chamber extrusions are starting to arrive and the e-beam welder is scheduled to arrive in June.

The vacuum system in the straight sections uses LCW cooled stainless steel chambers.[7] Here the maximum power dissipation is much less, between 30 W/cm and 5 W/cm, but LCW cooling is still required throughout the straights.

C. Rf System

The RF system for the high energy ring consists of 5 RF stations providing a RF acceleration voltage of 14 MV with a resultant bunch length of 1.15 cm. Each RF station consists of four single-cell cavities, one 1.2 MW klystron and the necessary power splitting waveguide network and an isolating circulator.[8] A low-level RF system provides control of amplitude, phase and tuning of the cavity and includes an elaborate fast feedback system to stabilize the interaction of the cavity with the beam to dampen multi-bunch oscillations.[9] The cavities are normal conducting, reentrant copper cavities with three waveguides for higher order mode damping attached. The HOM loading waveguides are located to achieve optimal damping of longitudinal and transverse resonant modes in the cavity without loading the fundamental accelerating mode. A prototype cavity[10] is 90% complete and will be tested to 150 kW wall dissipation in summer this year. A 10 inch Alumina disk window in a waveguide[11] serves as vacuum barrier to the rf and is designed to transmit up to 500 kW of rf power to cavity and beam. Two prototype windows are under test and show promising results. A prototype klystron with 3 MHz bandwidth and < 150 nsec delay required by the fast feedback loops was constructed at SLAC and is awaiting test to 1.2 MW power.[12]

D. Feedback Systems

The HER relies on bunch-by-bunch feedback systems for both longitudinal and transverse stability. State-of-the-art digital signal processing is used to accomplish the filtering required for loop stability.

D.1 Longitudinal feedback

The longitudinal feedback system uses a dedicated BPM to pick up the beam phase information, which is processed at the sixth harmonic. Down sampled and digitized it is distributed to a farm of 128 DSP modules for signal processing, delay and filtering at a 238 MHz combined rate. The DSP output streams are read into a holding buffer and delivered to an 8-bit DAC. Commercial power amps (2 kW) and modulators will be used to drive the longitudinal kicker at 1.012 GHz. For low-frequency modes the kicker will not have sufficient amplitude and the correction signal is being fed to the low-level rf system, for the main rf cavity to act as longitudinal kicker.

Prototypes of most components of the system have been built and have been successfully tested at the ALS at LBL.

D.2 Transverse feedback

The transverse feedback system is similar in concept, although somewhat more straightforward in implementation. The system is implemented as a one-turn delay system with digital delay

buffer. Two dedicated BPM buttons will provide signals with roughly $90°$ betatron-phase difference that are processed again at the sixth harmonic. After low-pass filtering and phase adjustment the signal is converted to digital form and delivered to a dual-bank hold buffer. The delayed signal drives base-band kickers.

E. Beam Injection

Vertical injection into the HER takes advantage of the small emittance of the damped SLAC beam ($\epsilon < 10^{-4}\pi$nm-rad). Four slow orbit bump magnets steer the HER orbit to within $8\ \sigma$ towards the edge of the septum. Two fast kickers, $180°$ apart in betatron phase, kick the closed orbit such that the injecting beam enters the ring at about $8.5\ \sigma$ of the fully coupled beam. In this way, the circulating beam can be topped off without significant scraping-off of the circulating beam. 60 Hz operation is foreseen with the possibility of upgrading to 120 Hz. Every bucket in the HER is accessible by suitable programming of the system; allowing to equalize the charges of different bunches. The HER beam has a 5% ion clearing gap; this gap will also be used for "training pulses" to tune up the injection before an attempt to top-off the circulating bunches is made. The system is capable of supporting on-axis injection, which will be an important commissioning tool and also allow for beam-based alignment of the ring.

F. Beam Diagnostics

Several diagnostic systems are being prepared for commissioning the PEP-II HER in 1997. An extensive network of beam-position monitors, one set of four 15-mm-diameter buttons at each quadrupole, will track the beam centroid; the button signals will be combined to provide x or y readout at each focusing or defocusing quadrupole, respectively. Memory in the front-end processors will maintain a 1000-turn history.

Tunes will be measured by driving the beam with a swept-frequency sinusoid while monitoring the beam's spectrum; a phase-locked loop will be added later. This drive signal will be added to the low-level signal for transverse feedback, to share the amplifiers and strip lines.

A DC current transformer will precisely measure the time-average current. The relative charge in each of the 3492 individual buckets (of which typically 1658 will be filled to a charge of 3×10^{10} electrons) will be determined from the sum signal of a set of four buttons.

Visible and near-UV synchrotron radiation will be imaged to profile the beam at two points in the lattice, with low and high dispersion. At each of these locations, the transverse profile will be recorded in the tunnel using CCD cameras; the light from one location will also be transported to a surface building for detailed streak-camera measurements. To study the beam's transverse tails, movable collimators will be used as scrapers.

Beam losses will be monitored by a linear distributed ion chamber ("PLIC Cable") around the tunnel for both HER and LER together. In addition, PIN-diode beam-loss monitors will be distributed around the ring to be able to localize losses.

IV. CONCLUSION

Construction of the HER is on track for a first commissioning run beginning March 1997. At that time, two rf stations (8 cavities) will be available and we expect to be able to commission the ring injection system, store and accumulate beam and perform first tests of the feedback systems.

ACKNOWLEDGMENTS

References

[1]   J.T. Seeman, "PEP II Status and Plans", these proceedings.
[2]   M.H.R. Donald *et al.*, "Lattice Design for the High Energy Ring of the SLAC B Factory (PEP II)", these proceedings.
[3]   S.A. Heifets *et al.*, "Impedance Budget of the PEP II B-Factory", these proceedings.
[4]   C. Perkins *et al.*, "Vacuum System of the PEP-II High Energy Ring", Proc. EPAC, London, UK, 1994.
[5]   M. Nordby *et al.*, "Bellows Module Design for the PEP II B-Factory", these proceedings.
[6]   F.R. Holdener *et al.*, "Test Results of Prototype Distributed Ion Pump Design for the PEP II B-factory", these proceedings.
[7]   U. Wienands *et al.*, "The Vacuum System of the Straight Sections for the PEP II High Energy Ring", these proceedings.
[8]   H. Schwarz *et al.*, "RF System Design for the PEP-II B Factory", Proc. EPAC, London, UK, 1994, pp.1882-1884.
[9]   P. Corredoura *et al.*, "Low Level RF System Design for the PEP-II B Factory", these proceedings.
[10] R. Rimmer *et al.*, "Development of a High-Power RF Cavity for the PEP-II B Factory", these proceedings.
[11] M. Neubauer et al, "High-Power RF Window and Coupler Development for the PEP-II B Factor", these proceedings.
[12] R. Fowkes *et al.*, "1.2 MW Klystron for Asymmetric Storage Ring B Factory", these proceedings.