DESIGN OF THE PEP-II LOW-ENERGY RING

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The PEP-II Project, a collaboration of SLAC, LBL, and LLNL, began construction in January 1994. Since the Conceptual Design Report (CDR) [1] was issued in June 1993, considerable progress has been made at refining and optimizing the Low-Energy Ring. Lattice design has progressed considerably, with solutions obtained for the chromatic correction of the IR and new, more relaxed, parameters for the required wigglers. Based on the latter change, the number of RF stations was reduced from 5 to 4. A new concept for the arc vacuum system has been adopted, based on an antechamber configuration with discrete photon stops pumped by titanium sublimation pumps. Designs for the arc dipoles and quadrupoles have been developed in collaboration with IHEP (Beijing) and these magnets are now being fabricated there. A new configuration for the high-power wiggler photon dumps has been developed and is in the detailed design phase.

I. INTRODUCTION

The PEP-II asymmetric *B* factory collider comprises two storage rings, a High-Energy Ring (HER) with 9 GeV electrons and a Low-Energy Ring (LER) with 3.1 GeV positrons. Main parameters for the LER are summarized in Table I. The requirements of the LER for a large circumference, a low energy, a large emittance, and a short bunch length make the lattice difficult, and substantial effort has been spent on its design. The high beam current requirement is also challenging.

Because the LER is an entirely new ring, all of its technical components must be newly designed and fabricated. LBL is responsible for the arc magnets and supports, the arc vacuum system, and the transverse feedback system, LLNL for the interaction region (IR), the wigglers, and the vacuum system in the straight sections, and SLAC for both the RF and the longitudinal feedback systems. All three labs play a role in the areas of power supplies and diagnostics.

Table I
PEP-II LER main parameters.

Energy [GeV]	3.1
Circumference [m]	2200
Emittance, *y/x* [nm-rad]	2.6/64
Beta function at IP, *y/x* [cm]	1.5/37.5
Beam-beam tune shift	0.03
RF frequency [MHz]	476
RF voltage [MV]	5.1
Bunch length, rms [cm]	1
No. of bunches	1658
Total current [A]	2.1
Energy loss per turn [MeV]	0.8

II. LATTICE DESIGN

To fit in the PEP tunnel, the LER lattice (see Fig. 1) is hexagonal, with six FODO arc sections joined by six long straight sections. The collision straight section is IR-2 (at the 2 o'clock position), with injection on the opposite side of the ring in IR-8. The lattice is mirror symmetric about the axis from the injection point to the interaction point. To simplify the installation and alignment, all magnets in each FODO half-cell are clustered together on a single raft. To keep the overall geometry of the two rings similar in the arc sections, the LER dipoles are centered above the much longer HER dipoles. Emittance control is handled with wigglers located in two straight sections.

The challenges in designing the lattice arise mainly from the low vertical beta function (1.5 cm) at the interaction point (IP) along with the need to produce the relatively large emittance (64 nm-rad) required by the beam-beam interaction. Chromaticity correction is done by means of a "semi-local" scheme [2], with a pair of horizontal sextupoles located in the IR straight section on each side of the interaction point. (Because the two beams collide head on with magnetic separation close to the IP, and because the LER beam must be raised above the plane

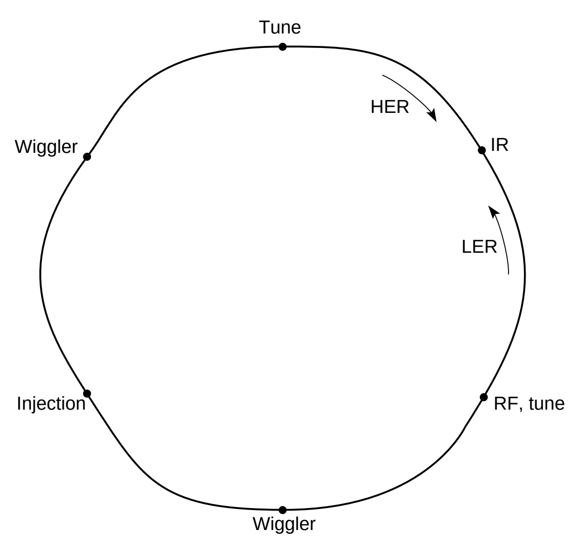

Fig. 1. Functional layout of the LER.

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of the HER in the rest of the collider, dispersion is present in much of IR-2.) Families of sextupoles in the two arcs adjacent to the IR serve to correct the vertical chromaticity. Compared with the CDR design, the resulting simplified layout eliminates 24 magnets in the IR, with substantial cost savings. As part of the optimization, we have also adopted a non-interleaved sextupole scheme in the four arcs remote from the IR. Although this has the disadvantage of constraining the phase advance in the arcs to certain values (90° or 60°) it saves considerably on the number of sextupoles, requiring 80 fewer magnets.

III. MAGNETS AND SUPPORTS

Both the arc dipoles and arc quadrupoles are being fabricated at the Institute for High Energy Physics (IHEP) in Beijing under Attachments to the Interlaboratory Collaborative Agreement between SLAC and IHEP. Both magnets were designed collaboratively by LBL and IHEP engineers [3] and work on prototypes is under way. LER magnets will operate at beam energies up to 3.5 GeV.

The LER quadrupole is a two-piece design (see Fig. 2), modeled on the successful ALS booster quadrupole. Most quadrupoles will be 43 cm in length; a few special needs will be met with 65 cm long magnets. To accommodate the very different operating ranges of quadrupoles in the LER lattice, a number of different coils and cooling topologies are used. Most of the coils use aluminum conductor to match the (existing) magnets of the HER. In cases where the gradient requirements are very high, such as in the IR, a few magnets will use copper coils. The two long arc quadrupole strings are configured with 15-turn coils. The magnets designated for the short magnet strings have 58-turn coils to better match power supply needs. A few magnets in the wiggler straights require a modified version of the 58-turn coil to accommodate the very wide vacuum chamber used in that region. The prototype arc quadrupole will be available this summer.

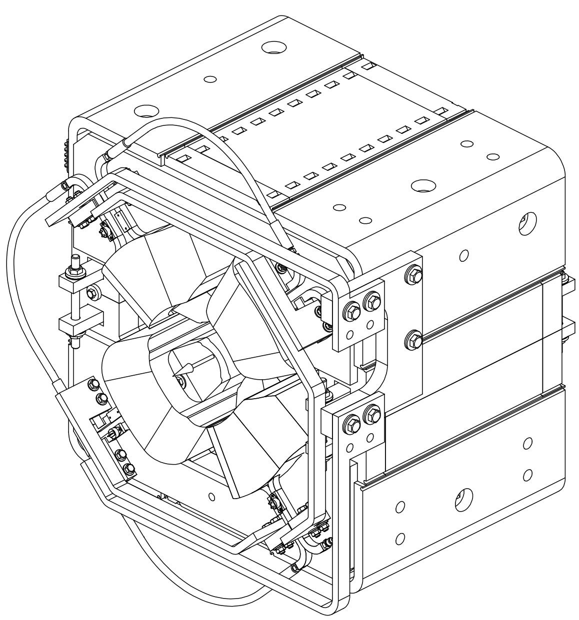

Fig. 2. LER arc quadrupole.

Dipoles are standard H-magnets with a gap of 63.5 mm and an effective length of 45 cm; the operating field at 3.1 GeV is 0.75 T. The aluminum coils of the dipole have a pancake configuration with a large cross section to minimize power consumption. A prototype dipole magnet will be available in the fall.

Designs for the sextupoles are just beginning. We plan to use the same laminations as the original PEP sextupoles. Existing "long" PEP sextupoles will be split into shorter magnets (with new coils that accommodate the larger LER vacuum chamber profile, see below) to meet LER needs.

IV. VACUUM SYSTEM

The LER arc vacuum system is based on an extruded aluminum antechamber, following that of the Advanced Photon Source. Synchrotron radiation exits the beam chamber through a 15-mm high slot. The "magnet chamber" is sized to fit in the magnet bores and has only a clearance slot. In the span between magnet rafts there is a much larger "pumping chamber" containing a photon stop, a titanium sublimation pump (TSP), and a sputter ion pump. The TSP has very high pumping speed and is situated immediately below the photon stop in each half-cell (see Fig. 3). More than 99% of the gas-producing photons are intercepted on the photon stops, which are designed to handle the 15 kW of power from the dipoles at 3.5 GeV and with a 3 A beam. Thermal analysis confirms that the chamber would not be damaged by a worst-case beam missteering event at full power.

Because of the very high beam current of positively charged particles, we must consider the pressure bump phenomenon and the possibility of multipactoring, both of which were originally seen at the ISR [4]. To avoid a pressure bump, we will use glow discharge cleaning (GDC). We expect the GDC to be "remembered" even

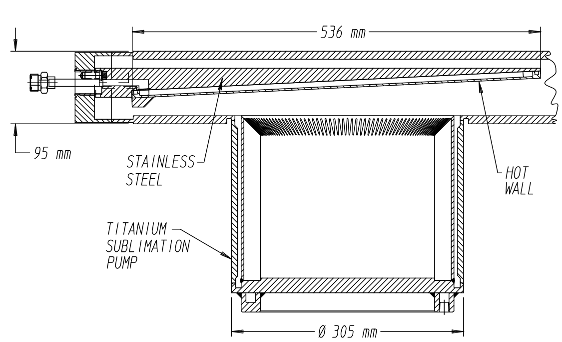

Fig. 3. Photon stop and TSP (elevation view).

after an accidental venting of the chamber, because only a monolayer of impurities is reabsorbed on the surface and this amount is easily removed by either photon or ion scrubbing. (Analysis of the photon distribution shows that some 10% of the emitted photons miss the slot and land within the beam chamber. These are very low energy and do not cause heating but they do serve to scrub the walls of the beam chamber, albeit with low efficiency, because of the high beam current in the ring.)

As concerns multipactoring, our evaluations show that we will be below threshold for nominal running, but we could temporarily reach threshold at some intermediate time during the filling process. The presence of a bunch gap and the ability to fill the bunches unevenly should give sufficient margin against problems. We also contemplate coating the chamber walls (with either TiN or a suitable metal) to reduce secondary electron emission.

V. WIGGLERS

The LER beam emittance is adjusted with wigglers. Although two straight sections are designated for wigglers, we will begin operation with only a single wiggler, located in IR-6. The linear optics in IR-10, where the second wiggler would eventually reside, are kept the same as those of IR-6 to maintain the ring symmetry. To obtain as much damping as possible, the single initial wiggler has five periods, compared with the baseline design of two three-period wigglers. It has been verified that the elimination of one wiggler period will not limit the required range of emittance adjustment and that it has minimal effects on the damping time and on beam-beam performance.

The wiggler is implemented [5] as individual dipoles, similar to the arc dipoles but optimized for higher magnetic field and sized to accommodate the wiggler vacuum chamber and photon dump. The dump comprises a copper chamber with longitudinal slots leading to water-cooled surfaces on both sides that intercept the synchrotron radiation. The dump is capable of dissipating the power from the full five-period wiggler at a 3 A beam current.

VI. RF AND FEEDBACK SYSTEMS

At the time of the CDR, the baseline design [6] called for five 476-MHz RF stations (five klystrons, each powering two single-cell cavities). With the present wiggler length and beam energy spread, it suffices to use only four RF stations. Indeed, an optimized operational scenario calls for running only three stations, with the fourth serving as a “hot spare.” At present, we intend to begin operation with a minimum set of three RF stations. We have estimated the bunch length increase and luminosity loss that would result from having a station fail in this circumstance and find these still to be acceptable.

The high beam current and large number of bunches in the LER demand broadband feedback systems. Both longitudinal and transverse feedback systems are employed for the LER. The design for the longitudinal system is based on a digital signal processing approach with downsampling. The transverse system makes use of two pickups with quadrature processing and a broadband kicker driven by a 120 W, 10 kHz–250 MHz, Class A commercial solid-state amplifier. Both systems were tested [7] at the ALS under operational conditions and found to work well.

VII. SUMMARY

The designs of all major LER systems are well along, and many components have now been ordered. The PEP-II commissioning plan calls for a phased approach, with the injection system beginning commissioning this year, the HER in 1997, and the LER in early 1998. An excellent team with members drawn from all three collaborating laboratories is in place and is making excellent progress.

VIII. ACKNOWLEDGMENTS

The professionalism and hard work of the members of the LER team are—and will remain—the key to a successful LER commissioning. We are grateful for their support and enthusiasm.

IX. REFERENCES

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