THE CONCEPTUAL DESIGN OF A VACUUM SYSTEM FOR THE ILC DAMPING RINGS INCORPORATING ELECTRON CLOUD MITIGATION TECHNIQUES *

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Abstract

We describe the conceptual design of the vacuum system for the damping rings of the International Linear Collider. The design incorporates a range of techniques to suppress the development of the electron cloud (EC) in the positron ring. These techniques include coatings with low secondary electron yield (SEY), grooved chambers, clearing electrodes and antechambers for photoelectron control. The EC mitigation choices are based on the ILC Electron Cloud R&D program, which has been conducted at the Cornell Electron-Positron Storage Ring Test Accelerator (CESRTA) and at other collaborating institutions [1]. The conceptual designs for vacuum chambers in drifts, dipoles, wigglers and quadrupoles are presented.

INTRODUCTION

A conceptual design for the vacuum system of the ILC damping rings (DR), incorporating the electron cloud mitigation techniques specified by the ILC Electron Cloud Working Group [2] for the positron damping ring, has been prepared and costed for the ILC Technical Design Report (TDR). The mitigation techniques for each region of the machine are enumerated in Table 1. The present conceptual design draws on previous design work [3, 4, 5] and incorporates inputs from the lattice designers, magnet engineers, and electron cloud dynamics simulation group working on the current version of the DR lattice.

Table 1: EC Mitigations Specified for the Positron DR

Magnetic Region	Primary Mitigation	Secondary Mitigation
Drift	TiN Coating	Solenoid Windings
Dipole	Grooves wtih TiN Coating	Antechamber
Wiggler	Clearing Electrodes	Antechamber
Quadrupole	TiN Coating	—

VACUUM CHAMBER DESIGN

Arc Vacuum Chambers

Dipole Chambers in the DR (Fig. 1) will implement three electron cloud mitigation techniques. Antechambers with sloped radially outside walls are used to minimize scattered photons entering the main beam aperture, a titanium nitride (TiN) coating is applied to the inside surface of the chamber to reduce secondary electron yield (SEY), and grooves on the top and bottom of the vacuum chamber will further reduce the number of secondary electrons that enter the central region of the vacuum chamber near the beam [6]. The radially inside antechamber will contain non-evaporable getter (NEG) strips to provide distributed pumping. Explosion bonded transition pieces will be used on the ends of the cambers to allow the use of stainless steel flanges.

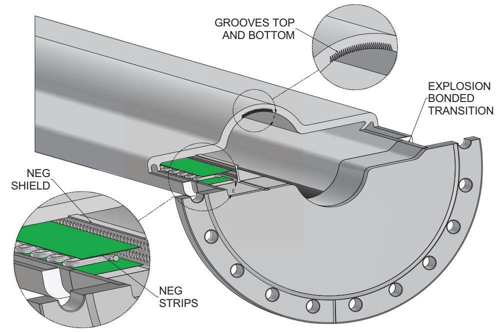

Figure 1: Dipole Chamber with grooved top and bottom surfaces, radially inside antechamber with NEG strips, and radially outside antechamber with sloped wall.

The remainder of an arc cell consists of two short drift chambers on either side of the dipole, and one chamber extending through three quadrupoles, four sextupoles, and three corrector magnets. These chambers will have the same profiles and TiN coating as the dipole chamber, but without the grooves on top and bottom (Fig. 3(b)). In addition, solenoid windings will cover the accessible drift sections to further reduce the number of secondary electrons approaching the beam axis.

Wiggler Region

The wiggler region vacuum chambers (Fig. 2) will be made from copper to provide good thermal conductivity in this high power region. The copper will also minimize the rate of scattered photons that escape the vacuum chamber to deposit energy into the cold mass and coils of the superconducting wigglers. It should be noted that most synchrotron radiation (SR) should pass through the wiggler antechambers to be trapped in the photon stops located at the end of each cell. The wigglers are grouped in pairs and a single vacuum chamber will run through two wigglers as well as the quadrupole magnet between them. The long vacuum chamber traversing each wiggler pair will have a 46 mm beam aperture and 20 mm tall antechambers. A

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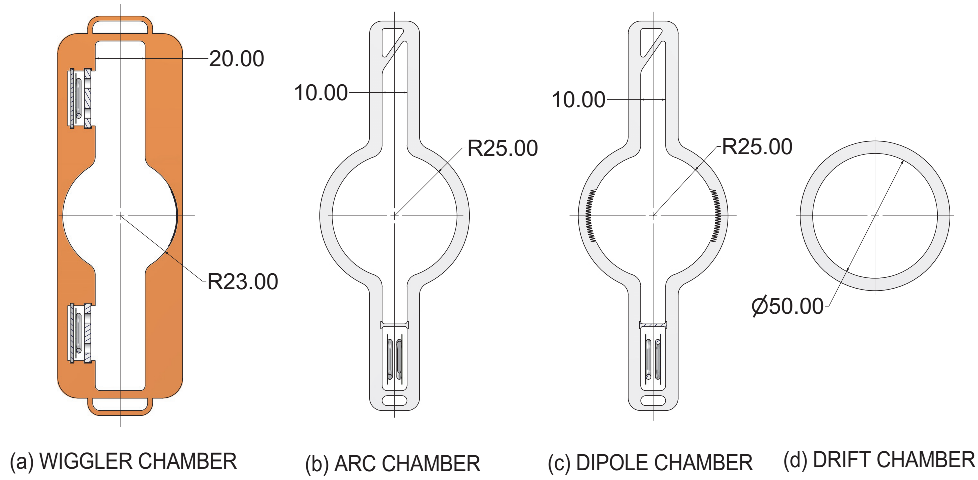

Figure 3: Side-by-side comparison of ILC DR vacuum chamber profiles. Dimensions are in millimeters.

tungsten clearing electrode will be deposited via thermal spray on the bottom of the chamber as the primary EC mitigation technique [7]. The choice of 20 mm tall antechambers was based on photon tracking simulation results in Synrad3D [6]. NEG Strips are recessed into the upper wall of the antechambers to act as distributed pumping and are shielded from beam induced heating by means of a perforated aluminum strip. The other drift and quadrupole

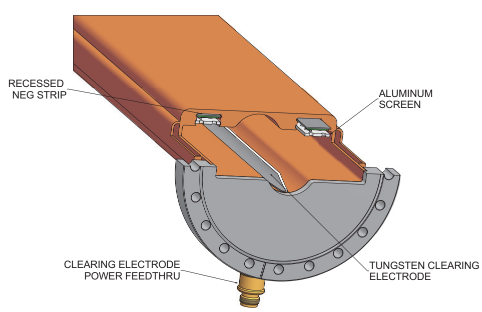

Figure 2: Wiggler Vacuum chamber with clearing electrode and 20mm tall antechambers with recessed NEG strips.

chambers in the wiggler section will be copper chambers with TiN coating. They will also have a 46 mm aperture and incorporate 20 mm tall antechambers to match the wiggler chambers and avoid impedance issues. Solenoid windings will cover the accessible drift sections.

Drift Region

The straights of the ILC DR will employ simple round aluminum beampipe with a 50 mm aperture and TiN coating (Fig. 3(d)). These chambers will have aluminum to stainless steel explosion bonded transitions on the ends to allow welding to stainless steel flanges. At the ends of the straight drift sections, chambers that slowly taper (over $\sim$ 0.5 m, based on impedance calculations) to antechamber profiles will be installed. Again, the accessible drift

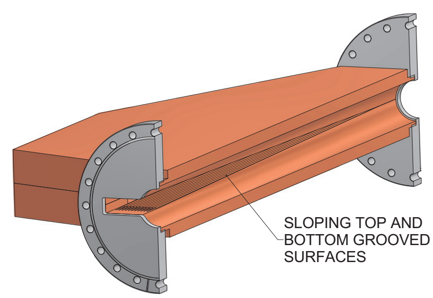

Figure 4: ILC DR Wiggler Section Photon Stop section showing sloping and grooved photon-absorbing walls.

sections will be wound with solenoids.

OTHER VACUUM SYSTEM ELEMENTS

Photon Stops

Photon Stops are designed to intercept all SR power generated by the wigglers. The proposed design is based on the ones previously implemented for the DC04 lattice [3, 4]. These chambers employ gradually sloping, grooved antechambers (Fig. 4) to dilute power density striking the photon stop. The gap between the sloping surfaces opens to antechambers pumped with an ion pump and Titanium sublimation pumps through ducts (Fig. 5). An additional photon stop is required at the first bending magnet of the arc after the wiggler straight to intercept the forward SR component.

BPMs and Sliding Joints

Beam Position Monitors (BPMs) are located near the majority of quadrupoles in the DR. There are no BPMs near the quadrupole trapped between the wiggler pairs due to lack of space, nor is there a BPM near the center quadrupole in each arc cell. The BPM near the center quad in the arc cell is omitted because, with the support

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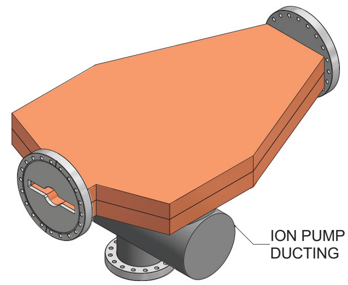

Figure 5: ILC DR Wiggler Section Photon Stop.

and alignment scheme of the arc cell magnets, simulations indicate that one BPM at the beginning and end of the magnet beam will be sufficient [8]. The BPM blocks are paired with a sliding joint on one side (Fig. 6) to allow them and the chamber they are connected to through the quadrupole to float, and for the absolute position of the BPM to be kept as steady as possible and so that movement of the BPM can be monitored. The sliding joint also allows for expansion and contraction of the surrounding vacuum chambers during use and is used during installation of vacuum chambers.

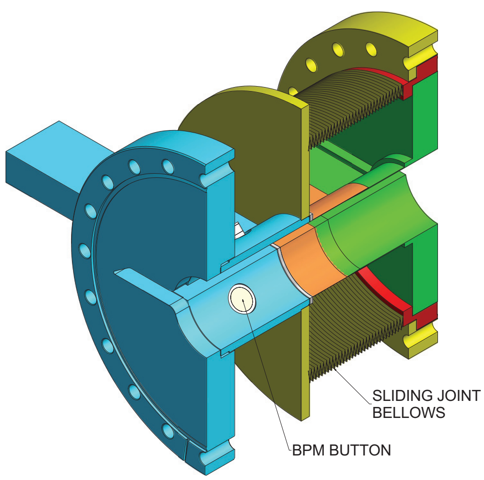

Figure 6: ILC DR BPM and Sliding Joint Assembly.

VACUUM PUMPING AND INSTRUMENTATION

A sufficient number of ultra-high vacuum pumps, both localized (lumped) and distributed, will be installed in the vacuum system to maintain the required average gas pressure ($\sim 10^{-9}$ torr) at the design beam current. The installed pumping system must have enough pumping speed and capacity to allow vacuum system conditioning of reasonably short duration during the initial accelerator commissioning, and after installation of new vacuum components for upgrades and/or repairs. Typical pumps are sputter-ion pumps (noble-diode style), non-evaporable getters (NEGs) and titanium sublimation pumps (TiSPs).

As illustrated for the dipole and wiggler chambers, NEG strips are inserted into the ante-chambers to provide distributed pumping. Adequate pumping speed and capacity will be accounted for in a final design to handle the SR-induced gas load. Lumped ion pumps will be periodically installed, with a typical spacing of 5 m. These ion pumps will assist initial pumping down and beam conditioning of the DR vacuum chambers during the commissioning stage, and handle any non-getterable gases (such as CH4 and trace of Ar) in the vacuum system.

The vacuum system will be divided into sectors by RF-shielded gate valves to facilitate staged vacuum system installations, vacuum system upgrades, maintenance, and repairs. A typical length for each vacuum sector is 50 m.

Cold-cathode ion gauges (CCGs) will be installed periodically throughout the vacuum system to monitor vacuum system performance and for vacuum system trouble shooting. Each vacuum sector will be equipped with at least one residual gas analyzer (RGA). Numerous thermocouples will monitor local temperatures of vacuum components. Monitoring and interlock functions will be integrated into the central control system.

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