IMPLEMENTATION AND OPERATION OF ELECTRON CLOUD DIAGNOSTICS FOR CESRTA*

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Abstract

The vacuum system of Cornell Electron Storage Ring (CESR) was successfully reconfigured to support CesrTA physics programs, including electron cloud (EC) build-up and suppression studies. One of key features of the reconfigured CESR vacuum system is the flexibility for exchange of various vacuum chambers with minimized impact to the accelerator operations. This is achieved by creation of three short gate-valve isolated vacuum sections. Over the last three years, many vacuum chambers with various EC diagnostics (such as RFAs, shielded pickups, etc) were rotated through these short experimental sections. With these instrumented test chambers, EC build-up was studied in many magnetic field types, including dipoles, quadrupoles, wigglers and field-free drifts. EC suppression techniques by coating (TiN, NEG and amorphous-C), surface textures (grooves) and clearing electrode are incorporated in these test chambers to evaluate their vacuum performance and EC suppression effectiveness. We present the implementation and operations of EC diagnostics.

INTRODUCTION

The Cornell Electron Storage Ring (CESR) has been successfully reconfigured [1] and CesrTA now utilizes two long straight experimental sections and two short experimental sections to study electron cloud (EC) growth and mitigation, ultra-low emittance lattice development and tuning, and beam instrumentation R&D. These experiments are critical for the global design efforts of the International Linear Collider Damping Rings. The two long and two short experimental sections are able to be isolated with gate valves so that test chambers can be interchanged without significantly impacting accelerator operations. Many new vacuum chambers have been installed with various EC diagnostic such as retarding field analyzers (RFAs) used to measure steady state EC build-up [2], RF shielded pickups [3] for studying EC growth, and TE wave transducer/receiver beam buttons [4]. Many EC mitigation techniques can be evaluated using the diagnostic chambers. The details of these evaluations are described in the referenced papers. This paper focuses on the vacuum aspects of the implementation and operation of the diagnostic hardware and test chambers.

SOUTH IR EXPERIMENTAL SECTION

The South interaction region (IR) experimental section (~17.6m long) houses six superconducting wigglers (SCWs). Four SCWs were constructed with thin-film RFAs [5] and are rotated through the 3 west SCW locations. The four RFA SCWs have different beam pipe interior features being tested for their EC mitigation characteristics. The four feature types are (1) bare copper, (2) copper with TiN coating, (3) grooved copper bottom plate (which was later coated with TiN), and (4) copper with an EC clearing electrode along the bottom.

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RFA SCW with Grooved Bottom Plate

Simulations [6] showed that in order to suppress secondary electron yield (SEY), the tips and valleys of the triangular grooves must be very sharp. A special milling technique was developed to make the radius of the tips and valleys less than 0.1mm (Fig. 1). The grooved SCW was installed in the South IR section between July 2009 and March 2010 for CesrTA experimental runs and CHESS high current running. After the wiggler was removed in March 2010, a close-up optical inspection of the grooves was done, and then a TiN coating was applied to the interior surfaces of the grooved beampipe via a DC sputtering technique. Careful arrangement of multiple titanium electrodes resulted in a uniform ~0.5μm TiN coating. The grooved SCW was then reinstalled in the South IR experimental section for further testing.

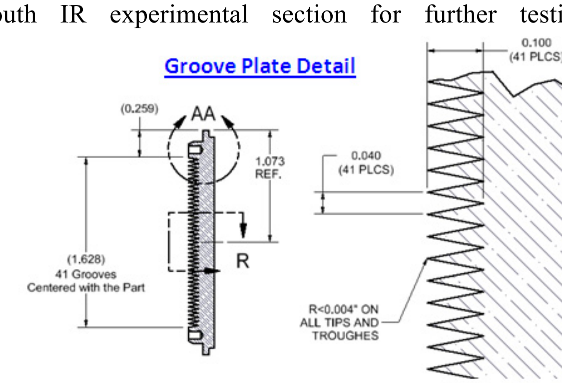

Figure 1: Detail of grooved plate welded into SCW beampipe. The plate is copper with 41, 1mm spaced triangular grooves.

RFA SCW with Clearing Electrode

One SCW RFA contains an EC clearing electrode based on the KEK design [7]. DC voltage up to 1.5 kV can be applied to the clearing electrode. This RFA SCW was installed in the South IR region in March 2010 and has operated during two CesrTA and the CHESS x-ray runs. No measurable beam-induced heating has been detected up to stored total beam current of 430 mA. An inspection in January 2011 found the electrode and button in excellent condition, as seen in Figure 2.

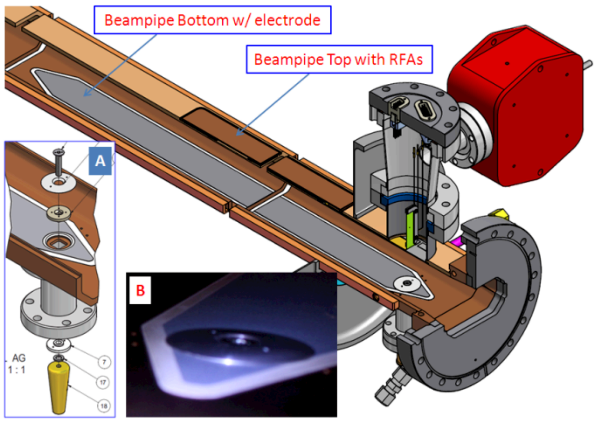

Figure 2: RFA SCW beampipe with a clearing electrode. The electrode was deposited onto the bottom half of the beampipe via thermal-spray technique. Insert A illustrates structure of low-profile electric contact, and insert B is an image of the contact button taken during post operation inspection in January 2011.

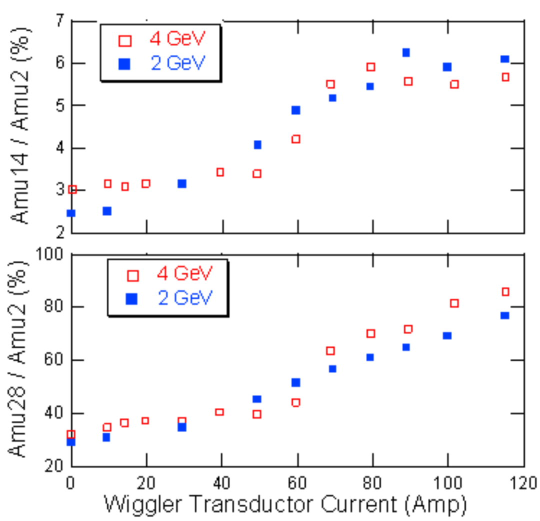

Figure 3: Increased desorption of N_2 from TiN coated surfaces with increasing magnetic field in the SCWs. The measurements were taken with a 35 mA positron beam at beam energies of 2 and 4 GeV.

Vacuum Performance

The South IR section is pumped primarily by six non-evaporable getter (NEG) pumps and by six small ion pumps for non-gettable gases. Vacuum performance is monitored by 6 evenly spaced cold cathode ion gauges (CCGs) and a residual gas analyzer (RGA) in the center.

Beam processing of the vacuum chambers during CHESS runs, where the beam condition is constant and stable, is monitored. During CHESS running, the east and west sides of the South IR receive comparable synchrotron radiation (SR) flux, however, the west side had much higher SR-induced outgassing. A possible source of higher outgassing in the west is the TiN coatings. Normal RGA spectra clearly indicate desorption of N_2, from the TiN coated surfaces. Significantly high N_2 desorption was related to high-energy photons generated in the SCWs in the area. Further, as seen in Figure 3, the ratio of N_2 to H_2 can be seen to increase as the SR fan strikes the TiN coated surfaces.

NORTH IR EXPERIMENTAL SECTION

The North experimental section (L3) is another long straight that hosts (1) SLAC Chicane dipole magnets with RFAs on grooved and TiN coated aluminium chambers; (2) RFA instrumented quad chamber; (3) NEG coating test chambers; (4) TE wave measurement; and (5) in-situ SEY measurement system.

NEG Coating Tests

A NEG coated stainless steel chamber equipped with 3 RFAs and an RF-shielded pickup (designed and fabricated by LBNL team) is used to measure the effectiveness of NEG coatings for EC suppression (Figure 4). To prevent influence of un-coated beampipes, the test chamber is "guarded" by two meter long NEG coated stainless steel beampipes (the beampipe string was coated by SAES Getters). The vacuum performance of the NEG coating was monitored by four CCGs and an RGA. After brief beam conditioning, the NEG coating was activated at 250ºC for 24 hours.

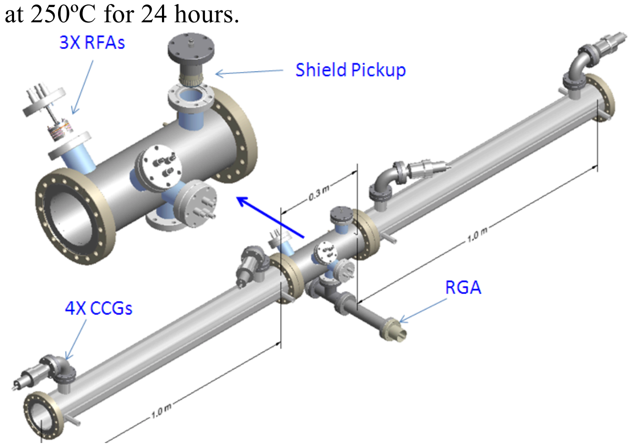

Figure 4: NEG test chamber.

RFA Quadrupole Chamber

A Cornell thin-style RFA was implemented in a bare aluminium quadrupole chamber (Figure 5). The RFA structure covers about 76º of the beampipe and consists of a gold-plated copper mesh as a retarding grid, and a flexible circuit detector with 12 segments. After CesrTA experimental runs from July 2009 to March 2010, the beampipe was coated with TiN at Cornell. It was then reinstalled in the same location in April 2010 for further experiments.

Secondary Emission Yield System

Two SEY systems were installed on a SLAC built beampipe. The system can test samples with different materials and different coatings in direct and scattered SR without interrupting CESR operations through the use of a load-lock system. SEY of bare aluminium (6061-T6) and TiN coated aluminium samples have been measured as a function of beam dosage [8].

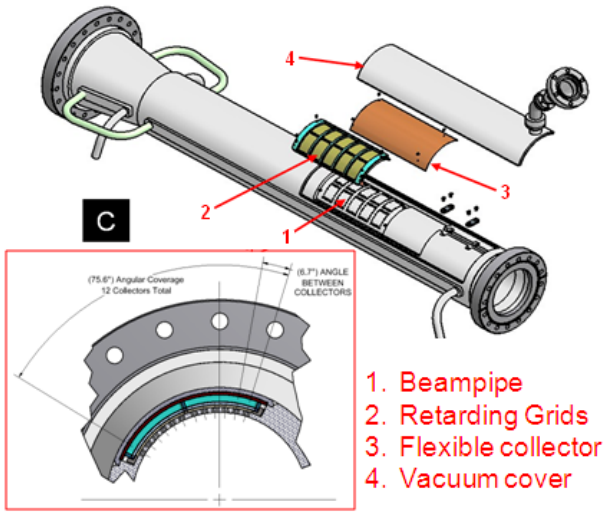

Figure 5: Implementation of thin RFA in a quadrupole vacuum chamber

SHORT EXPERIMENTAL SECTIONS

Two short experimental sections (Q15E and Q15W) were created in the arc of CESR with one bending magnet/chamber and a short straight. The sections are isolated by gate valves thus many chambers may be rotated through these sections without significant impact to CESR operations. Many EC-suppression coatings have been tested on aluminium beampipes. The aluminium beampipes are instrumented with a segmented RFA and two sets of RF-shielded pickups. Bare aluminium, TiN coated, and amorphous carbon coated chambers have been tested in these sections. Vacuum performance of these chambers has been very similar with similar beam conditioning.

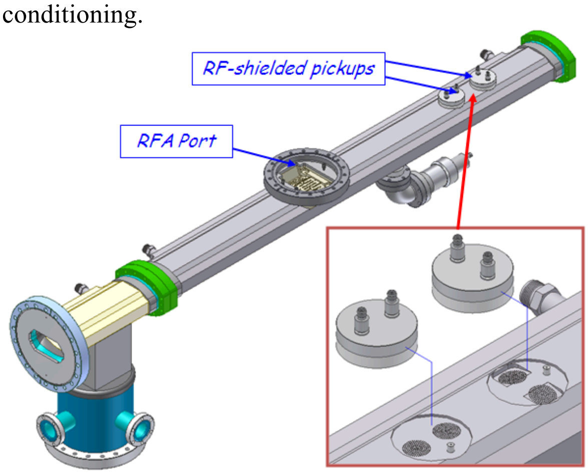

Figure 6. This design of aluminium chamber is used in the short experimental sections at Q15W and Q15E in CESR.

SUMMARY

The reconfigured CESR vacuum system has provided the flexibility needed to perform many EC studies for CesrTA. We have successfully implemented RFAs in all major types of magnets (dipoles, quadrupoles, and wigglers) as well as drift sections. Other EC diagnostics such as TE wave beam buttons and RF-shielded pickups were installed in many experimental areas. With these diagnostics, EC suppression techniques such as coatings (TiN, NEG, amorphous carbon, diamond-like carbon), grooved (triangular and rectangular) surfaces, and clearing electrodes, and their vacuum performance, have been evaluated.

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Ms. Dawn Munson of Lawrence Berkely National Laboratory (LBNL) and many technical staff members fabricated the RFA beampipes of the SCWs deployed in the South IR in this study. Their assistance is greatly appreciated.

Dr. Y Suetsugu of KEK introduced the technique of thermal sprayed EC clearing electrode, and arranged the thermal spray of EC clearing electrode for the CesrTA SCW beampipe.

Dr. S Calatroni and his colleagues at CERN provided assistance in amorphous carbon coating on two Q15 EC-study vacuum chambers.

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