A THIN BERYLLIUM INJECTION WINDOW FOR CESR-C*

Yulin Li†, Laboratory for Elementary-Particle Physics, Cornell University, Ithaca, NY 14853, USA

Abstract

The e^+e^- collider CESR is expanding its beam energy range to below 2 GeV for the planned Charm Physics Program. The original 5 GeV injection beam lines consisted of two 0.025-mm thick titanium windows, separated by a helium line at atmospheric pressure. The beam injection efficiency at low energies is reduced dramatically due to excessive emittance growth from multiple scattering in the Ti windows. The Ti windows were replaced with 0.075-mm thick beryllium windows to restore injection efficiency at low beam energies. This paper describes the design and construction of the Be windows. Finite-element analysis was used to determine the minimum Be window thickness able to support atmospheric pressure across 24-mm diameter aperture. The Be window housing is a cylinder consisting of two stainless steel tubes (SST) vacuum brazed to each end of a copper ring. The Be window is subsequently vacuum brazed to the copper ring at a lower braze temperature. The SST ends of the window assembly provide mechanical strength and protection to the fragile window, and facilitate welding of the window assembly to the injection vacuum chambers. Injection efficiency close to 70% was achieved with the beryllium injection windows in CESR.

INTRODUCTION*

At CESR, the injected electron or positron beam from the boost ring, the Synchrotron, are merged into the stored beam in CESR via a pulsed electro-magnet, the septum, as shown in Figure 1. The beam passage channel in the septum is filled with pure helium at atmospheric pressure. Two thin metallic windows at each ends of the septum provide vacuum separation between the helium space and the CESR and the Synchrotron vacuum systems.

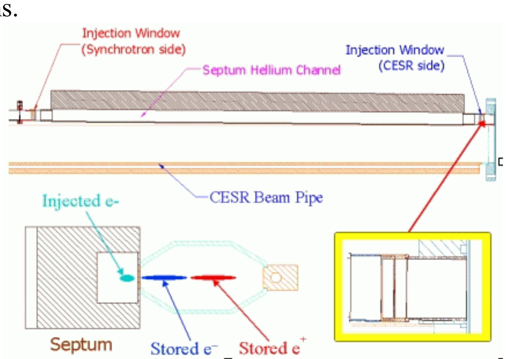

Figure 1. CESR Injection (vacuum) layout

The windows made of 0.025mm thick titanium were used when CESR was running at beam energy ~5 GeV. As a part of CESR-c conversion program [1] in optimizing luminosity performance in beam energy range of 1.5 to 2.5 GeV, the titanium windows are replaced with thin beryllium ones, to reduce excessive emittance growth due to multiple scattering [2]. This paper describes the construction of the thin beryllium windows.

WINDOW DESIGN

The beryllium window assembly is designed with the following requirements. First, it must provide reliable mechanical performance to handle both a static differential pressure between the atmospheric helium and the vacuum, and occasional pressure cycling when either the CESR or the Synchrotron vacuum system is vented for maintenance. Secondly, it needs to provide a required 24-mm beam aperture. Furthermore, the window housing need to be thin enough so that to allow the injecting beam to be brought close to the stored beam in CESR.

Deflection and stress across a 24-mm diameter beryllium foil are calculated under atmospheric pressure using finite element analysis (FEA) for two commercially available thicknesses, namely 0.050 mm and 0.075 mm. A beryllium thickness of 0.075-mm was chosen based on the FEA results.

WINDOW CONSTRUTION

The beryllium window assemblies are made through a two-step vacuum furnace braze.

The first step produces the window housing, as shown in Figure 2. The window housing consists of a copper ring sandwiched between two stainless steel (SST) tubes. The SST tubes at the ends provide mechanical strength and protection to the fragile window, and make it much easier to weld to the stainless flange on the CESR injection vacuum chamber. The parts are vacuum brazed at 955°C with BAu-4 (82%Au-18%Ni, or Nioro®) alloy wires. Two grooves in the base SST tube and the copper ring serve as brazing alloy retaining "wells" to ensure reliable joints among the parts. The housing is completed by machining away the grooves after the vacuum braze and a successful leak checking.

The 0.075 mm (0.003") thick beryllium disk (Brush-Wellman, Electrofusion Grade IF-1) is vacuum brazed onto the copper ring of the window housing using Bag-18 (60%Ag30%Cu10%Sn) alloy at 718°C, with the braze joint arrangement shown in Figure 3. The beryllium disk is brazed on both sides to enforce the very narrow joint.

Due to brittleness of the thin beryllium disk and the braze joint, extreme care must be taken to avoid sudden pressure changes cross the window aperture, either during pumping down or venting to atmospheric pressure. This is specially the case for the first pumping down of the window assembly after the second vacuum braze.

* Work supported by the National Science Foundation
† yl67@cornell.edu

Because the beryllium disk is flat at this state, quick evacuation from one side of the window induces sudden deflection across the beryllium disk that may result in failure of the beryllium disk or/and the braze joint. To avoid the failure, the brazed window assembly was evacuated very controlled fashion, using a setup as illustrated in Figure 4, to slowly form a stable curved state. The beryllium disk experiences much less mechanical stress from the atmospheric pressure at this curved form.

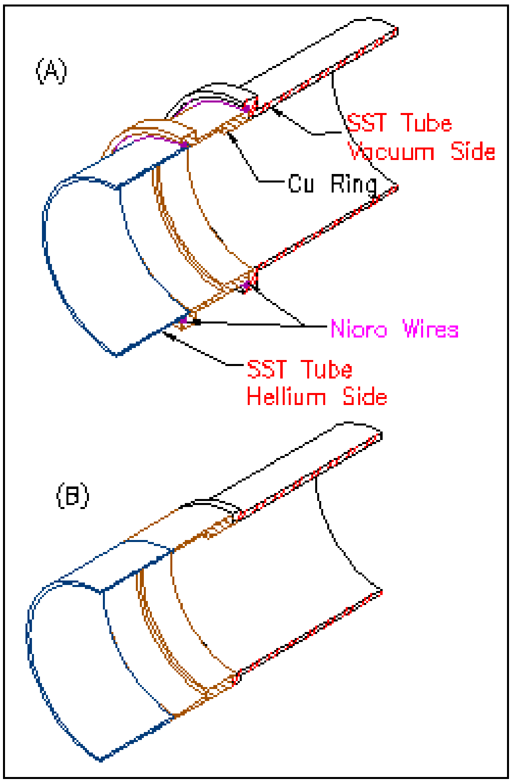

Figure 2: Vacuum braze of the beryllium window housing (a)Braze arrangement, (b)Finished housing.

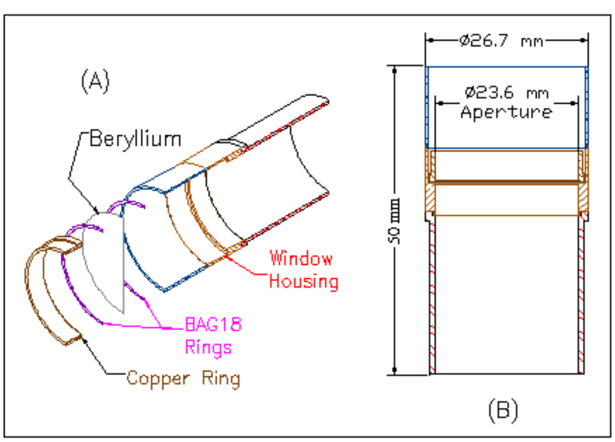

Figure 3: Vacuum braze of the beryllium window (a)Braze arrangement, (b)Finished window assembly

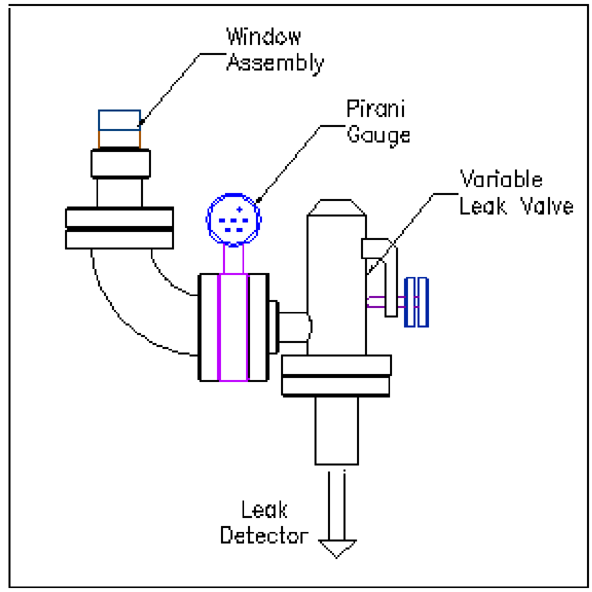

Figure 4: Setup for forming the beryllium window and leak checking. The pumping down rate (<1 torr/sec) is controlled by the opening of the variable leak valve, and monitored by a Pirani vacuum gauge.

CONCLUSION REMARKS

During a short accelerator shutdown in September 2002 (when a prototype CESR-c super-conducting wiggler magnet was installed in CESR), the titanium injection windows for the electron beam were replaced with the new beryllium windows. This led to an estimated a factor of 2.6 reduction [2] in the electron beam emittance growth from multiple scattering in the injection windows. Machine studies before and after the injection window replacement showed expected improvement in the electron beam injection efficiency, as listed in Table 1. During a 4-month long shutdown starting in March 2003, the titanium injection windows for the positron beam will also be replaced with the 0.075mm thick beryllium windows. Similar improvement in the CESR positron injection efficiency is expected for the CESR-c operations.

Table 1. Comparison of the Measured Electron Beam Injection Efficiencies between Ti- and Be- Windows [3]

0.025mm Ti Windows		0.075mm Be Windows	
η_{max}	η_{τ}	η_{max}	η_{τ}
38%	13%	69%	56%

Notes: η_{max} is maximum injection efficiency disregarding beam lifetime; η_{τ} is injection efficiency with reasonable beam lifetime

ACKNOWLEDGEMENT

The author would like to thank Neil Sherwood for his very helpful suggestion in the braze joint design, and for carrying out the vacuum furnace braze of the beryllium windows described in this paper.

REFERENCES

[1] D. Rice, "CESR-C – A Frontier Machine for QCD and Weak Decay Physics in the Charm Region," Proc. of EPAC 2002, p. 428

[2] D. Rubin, "Multiple Scattering in Injection Channel", CON 02-01, LEPP, Cornell University, Ithaca, NY 14853, USA

[3] A.Temnykh, private communication