Nonmagnetic UHV Optical Viewports

S. Crane and C. Ekstrom
United States Naval Observatory
Washington, DC 20392
http://tycho.usno.navy.mil/clockdev/CDpapers.html

Abstract

There are many atomic physics and frequency metrology applications that require nonmagnetic optical viewports for vacuum chambers. We have refined two techniques for producing these viewports. The first is a weld-in window cell made by brazing an optical blank into a thin weld collar. The second is a demountable sealing method that relies on crushing a series of thin copper knife edges.

Weld-in Windows

The design of the weld-in cell consists of a thin titanium collar that is brazed (or soldered) to an optical window. The thin lip on the collar minimizes heat and stress transfer to the optical window during welding.

Cutaway of the weld-in window design.

High Temperature Braze

High temperature braze allows high vacuum bake-out temperatures (up to 400 C) and easier application of the optical coatings after the window has been attached to the weld collar.

Materials required for high temperature braze design lead us to use sapphire windows. The windows are cut normal to the C-axis and show no optical birefringence.

Sapphire optical window with a titanium collar welded into a titanium 2.75" CF flange. Also shown is an unwelded window cell on the right.

Low Temperature Braze

In parallel, we investigated a low temperature braze design modeled after the work of JPL and their PARCS ground testbed [1]. By using a lower temperature solder, fused silica can be attached to a titanium weld collar. However, this design allows less latitude in bake-out temperature (<180 C). Optical coatings are applied before brazing.

Fused silica optical window with a titanium collar welded into a titanium 2.75" CF flange. Also shown is an unwelded window cell.

1. W. Klipstein, R. Thompson, D. Seidel, L. Maleki, "Development of Flight Technology for Future Laser-Cooled Space Clocks," Proc. IEEE Freq. Control Symp. (2000)

Welding

Welding tests were performed using various nonmagnetic material combinations. Titanium proved by far the easiest material to work with.

CNC laser welding is best for joining the thin lip of the window collar to the vacuum chamber as it minimizes the heat and stress which can cause window failure. It also allows for better control than e-beam welding.

High temperature braze window laser welded to the USNO Rb fountain detection region. Weld-in windows allow for a compact design and excellent optical access.

Lessons Learned

We tried several combinations of nonmagnetic materials that we would not recommend.

Copper Collars

We were able to produce windows with copper collars using a high temperature braze. These windows were leaktight before welding.

The welding temperatures required to make good joints to either copper or steel were too high. Welding produced small fractures in the windows or the braze material near the window edge.

Stainless Steel

We tried but were unable to produce windows with stainless steel collars and high temperature braze.

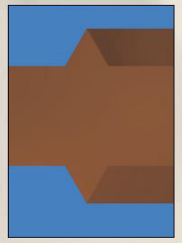
Demountable windows

We have also developed a nonmagnetic demountable window system that is inspired by the work of Kasevich [2]. Our sealing design provides low, symmetric stresses to both sides of an optical flat and is essentially as easy as sealing any conventional conflat blank.

We have successfully built windows with BK7, fused silica, sapphire, and silicon. We have also baked these windows to 250 C. We have produced seals with both stainless steel and titanium vacuum fittings. These windows show no leaks at the 6×10^{-10} Torr-liter/sec level.

Gasket Design

The key element in this design is a copper gasket with identical, 0.015" high knife edges with a 60 degree included angle protruding from the top and bottom of the gasket. The gasket is compressed between flat surfaces so as to crush each knife edge by 0.005".



Cutaway of a copper gasket. The two machined knife edges are each crushed by 0.005" from an original height of 0.015".

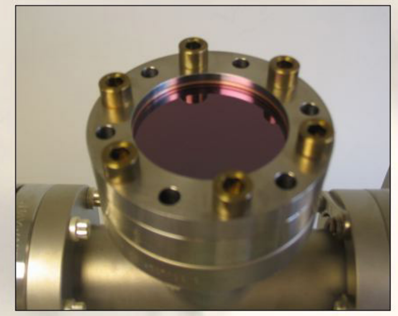
All force to crush a knife edge is transmitted through another identical knife edge producing low and very symmetric stresses on the window. Using this method, no windows were broken in our sealing tests.

Large Clear Aperture, Low Profile Design

An aggressive design gives a lower profile (0.335" height window cap) with a 1.75" clear aperture when using thin (0.125") windows. The recess in the window cap provides the needed 0.020" crush to the gaskets when bolted to the seat.

Cutaway of a the thin window design. The window cap is bolted firmly to the transition piece.

Thin sapphire window with large clear aperture knife edge gaskets.



Thin silicon window under test.

2. A Noble and M. Kasevich," UHV optical window seal to conflat knife edge," Rev. Sci. Instr. 65, pp 3042-3043 (1994)