HIGH POWER CO-AXIAL SRF COUPLER*

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Abstract

There are over 35 coupler designs for SRF cavities ranging in frequency from 325 to 1500 MHz. Two-thirds of these designs are coaxial couplers using disk or cylindrical ceramics in various combinations and configurations. While it is well known that dielectric losses go down by several orders of magnitude at cryogenic temperatures, it not well known that the thermal conductivity also goes down, and it is the ratio of thermal conductivity to loss tangent (SRF ceramic Quality Factor) and ceramic volume which will determine the heat load of any given design. We describe a novel robust co-axial SRF coupler design which uses compressed window technology. This technology will allow the use of highly thermally conductive materials for cryogenic windows. The mechanical designs will fit into standard-sized ConFlat® flanges for ease of assembly. Two windows will be used in a coaxial line. The distance between the windows is adjusted to cancel their reflections so that the same window can be used in many different applications at various frequencies.

INTRODUCTION

Every SRF cavity needs an RF coupler. There are over 35 coupler designs for SRF cavities ranging in frequency from 325 to 1500 MHz [1, 2]. Two-thirds of these designs are coaxial couplers using disk or cylindrical ceramics in various combinations and configurations. While it is well known that dielectric losses go down by orders of magnitude at cryogenic temperatures [3], it not well known that the thermal conductivity also goes down, yet peaks at values far below room temperature [4] and it is the ratio of thermal conductivity to loss tangent (Merit Factor) and window volume which will determine the heat load of any given design.

CONCEPT

We propose a novel robust co-axial SRF coupler design which uses compressed window technology. This technology will allow for the use of high thermal conductivity materials for 70K windows. Using compressed window techniques on disk co-axial windows in general will make significant improvements in the power handling of SRF couplers.

For example, BeO has been used in microwave windows [5, 6, 7, 8] with mixed results. Most issues have centered around the metalizing and the strength of the braze. BeO is mechanically weaker than alumina, it has 60% of the strength in both compressive and tensile, while the ratio of compressive to tensile is 10:1, the same as alumina. Because of the soft material, tensile strength of braze joints tend to be weaker, by a factor of 2, with respect to alumina. This makes BeO an ideal candidate for compression window techniques. There have been safety concerns about the use of BeO, but those concerns are in the manufacturing end where unfired powder is being used. BeO use is not restricted anywhere in the world [9]. As shown in Table I, the advantages of using BeO over alumina is quite significant at low temperatures. Also many new materials based on compounds of Aluminum Nitride and additives such as Y2O3 are being experimented with to achive low loss high thermal conductivity alternatives to BeO [10].

Table 1: Comparison of Alumina and BeO properties at 75K. The Merit Factor is the ratio of thermal conductivity to ceramic loss tangent at operating temperature.

approx 75K Data (approx 1 GHz)			
Material	Loss Tangent tan δ	Thermal Conductivity W/m/K	Quality Factor x10^6
AL_2O_3	4.4E-05	95	**2.159**
BeO	1.0E-04	600	**6.000**

Another important concept is that with compressed window construction techniques, it is possible to utilize various materials that would not otherwise be used because the assembly processes put significantly different stresses on the window assembly. Pre-stressed window assemblies have the potential of withstanding five times the power as an unstressed window [4]. The caveat in this argument, is that for very soft materials, such as Boron Nitride, which has a compressive strength about an order of magnitude less than alumina, it cannot be used in the compressed window design because, the material cannot withstand the internal stresses created by the compressed window technique.

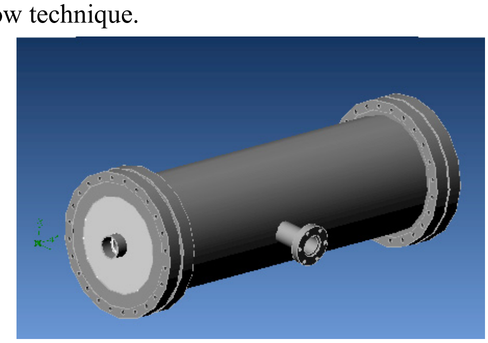

Figure 1: Two windows in the SRF coupler creating a near perfect match at the wavelength where they are separated in length by odd multiples of a quarter-wavelength..

The microwave design of the coupler will incorporate two windows separated in distance by odd multiples of a quarter wavelength of the operating frequency, so that their respective reflections cancel. This concept is not

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new for coaxial lines [11], but has yet to be introduced in SRF couplers. Figure 1 shows the conceptual layout of two windows for which there is a match frequency determined by the distance between them.

TECHNICAL APPROACHES

Designed for a Conflat Flange

Figure 2 shows the components of the novel compressed coaxial window. The elements are the same as those used for disk waveguide windows [13] except for the critical inner backing ceramic. The inner backing ceramic and inner conductor may be made into a sub assembly that is brazed prior to brazing to the co-axial window. The purpose of this novel sub-assembly is to minimize the stresses on the ceramic-to-metal joint on the ID of the co-axial window during cool down from room temperature to operating temperature. The ANSYS modeling of this assembly and process controls established during the SBIR Phase I work plan will be critical to the success of this program.

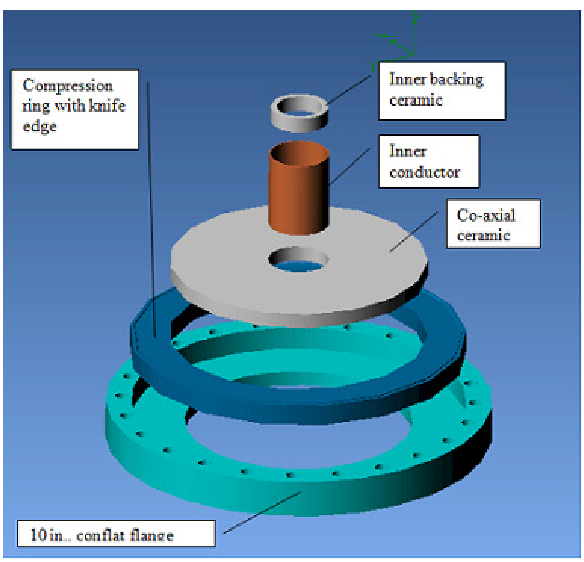

Figure 2: The components of the compressed coaxial window designed fit within a 10in Conflat flange..

The concept of a backing ceramic is not new and is used in many ceramic to metal seals to prevent non-uniform sheer stresses from building up during the cool down from braze temperatures. With the backing ceramic, the sheer stresses are applied evenly to the ID and OD of the inner conductor. Under the conditions of the compressed coaxial window, the purpose of the backing ceramic is two-fold; along with minimizing sheer stresses, it also prevents the copper inner conductor from creating tensile stresses on the braze joint as it shrinks away from the ceramic.

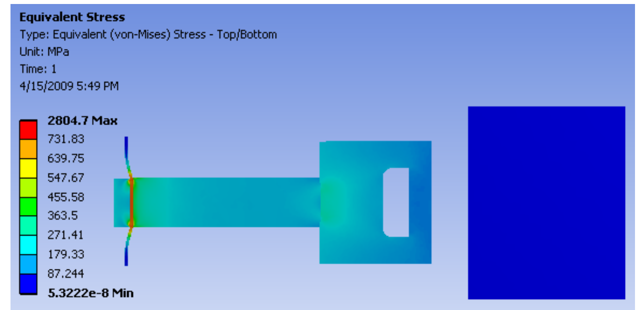

Figure 3: Axi-symmetric ANSYS calculations with the inner backing ceramic restricting the copper inner conductor from pulling away from the ceramic braze joint. During cool down from brazing, a stress-relieving is performed at 400C to relieve the stress in the copper. (not modeled in this analysis.)

Controls for Multipactor

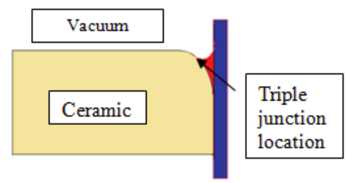

Figure 4: Triple junction beneath the plane of the ceramic..

Recent advances in multipactor codes and experiments in coating ceramics and biasing center conductors have shown great promise in terms of designing out multipactor issues for high power couplers. However, the easiest method for control of the triple junction (metal-ceramic-vacuum) is to bury the junction below the plane of the ceramic as shown in Figure 4, and implemented in reference [12]. The addition of chokes surrounding the inner and outer conductor as is done in most co-axial couplers of the "Tristan" design, may shield the triple junction, but add other fields to the multipactor problem as discussed in reference [13].

Fabricating the Windows

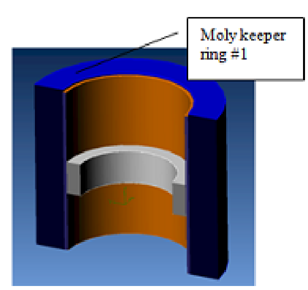

Figure 5: Cutaway view of the inner conductor sub-assembly braze. The moly keeper ring is removed for the next assembly.\..

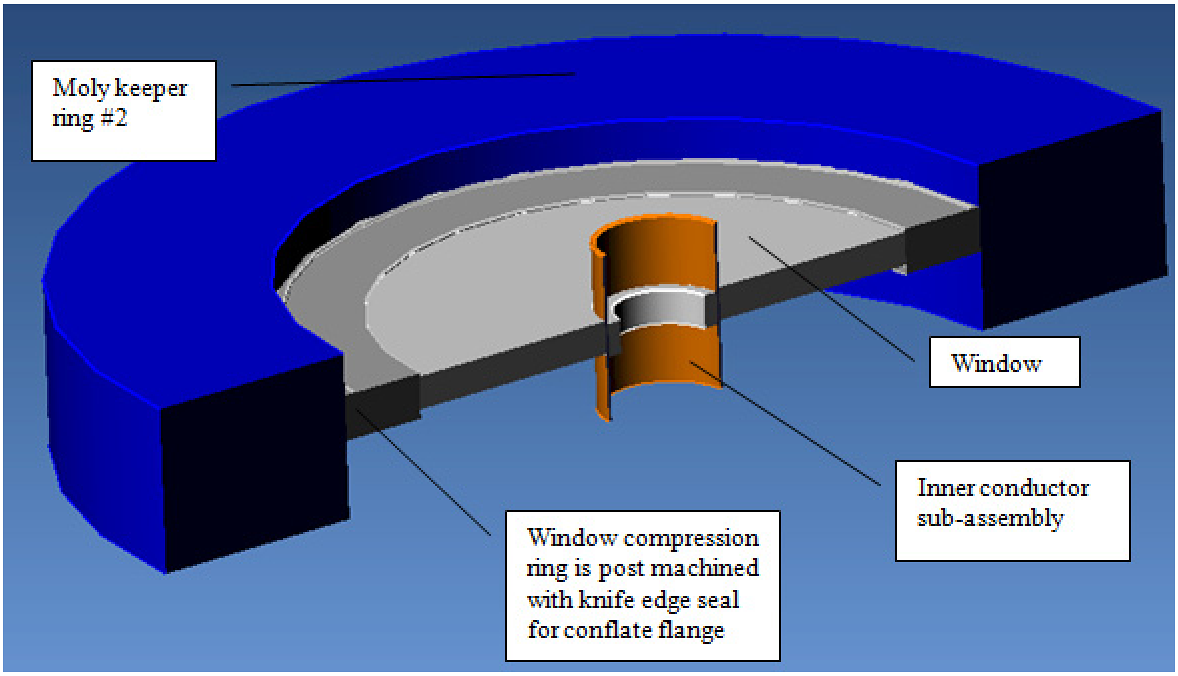

Figure 6: The final assembly of the window braze with the Moly keeper ring which will be removed after brazing.

Brazing the windows with appropriate fixtures is a complex endeavor that involves well controlled processes. There may be two steps to the assembly process as shown in Figure 5 and 6 or a single step as modeled in Figure 3.

After brazing, the compression ring is machined with a knife edge seal so that the final vacuum assembly utilizes the bolting of the Conflat flange to make the final seal. The copper gasket used to make the vacuum seal is also designed to make perfect RF contact with a “serf” type gasket, a common technique developed to force the metal-to-metal contact on the ID of the copper so that RF currents do not flow past the ID.

REFERENCES

[1] S. Belomestnykh, et.al.; “High average power fundamental input couplers for the Cornell University ERL: requirements, design challenges and first ideas”; ERL 02-8; 8 September 2008.

[2] Carl Beard; Review of Fundamental Power Couplers; Cockcroft Institute, STFC Daresbury Laboratory; 41st Advanced ICFA Beam Dynamics Workshop on Energy Recovery Linacs, "ERL07" May 21-25, 2007, Daresbury Laboratory

[3] B. Dwersteg, Z. Yu; Measuring complex Dielectricity constant of Aluminum Oxide window ceramics for TTF-power couplers at DESY.

[4] Neubauer, M. et.al., “Rugged Ceramic Window for RF Applications” This proceedings.

[5] T. Schultheiss, et.al.; “A High Thermal Conductivity Waveguide Window For Use In A Free Electron Laser”; Proceedings of the 1999 Particle Accelerator Conference, New York, 1999

[6] Pisharody, P. et.al.; “High Power Window Tests on a 500 MHzPlanar Waveguide Window for the CESR Upgrade”; IEEE Proceedings from PAC ‘95

[7] R. W. Bierce, et.al.; “Window Materiais Design And Properties For Use In High Power Klystrons”; The first National Particle Accelerator Conference, Washington D.C., March 10-12, 1965; SLAC-PUB-0092

[8] P. F. Becher, et.al.; Mechanical Reliability of Ceramics for Microwave Window Applications; ORNL/TM-7811; July 1981

[9] Brush Ceramics Products, safety brochure: http://www.brushceramics.com/docs/BeO%20EH&S%20Cust%20Presentation2008.pdf

[10] Shoichi Kumea, et.al.; “Dielectric and thermal properties of AlN ceramics”; Journal of the European Ceramic Society Volume 27, Issues 8-9, 2007, Pages 2967-2971

[11] George L. Ragan; “Microwave Transmission Circuits”, MIT Radiation Laboratory Series 9, 1948

[12] Neubauer, M., et.al.; (1994). “High-power RF window design for the PEP-II B-factory.” SLAC-PUB-6553, EPAC94

[13] Y. Kang†, S. et.al.: “Electromagnetic Simulations And Properties Of The Fundamental Power Couplers For The Sns Superconducting Cavities”; Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, June, 2001

[14] P. Lepercq, L. et.al.; “Design And Low Power Tests Of An Input Coupler”; Workshop on High-Power Couplers for Superconducting AcceleratorsJefferson Lab, Newport News, Virginia October 30 - November 1, 2002