BNL 56 MHz HOM DAMPER PROTOTYPE FABRICATION AT JLAB

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Abstract

A prototype Higher-Order Mode (HOM) Damper was fabricated at JLab for the Relativistic Heavy-Ion Collider's (RHIC) 56 MHz cavity at Brookhaven National Laboratory (BNL). Primarily constructed from high RRR Niobium and Sapphire, the coaxial damper presented significant challenges in electron-beam welding (EBW), brazing and machining via acid etching. The results of the prototype operation brought about changes in the damper design, due to overheating braze alloys and possible multi-pacting. Five production HOM dampers are currently being fabricated at JLab. This paper outlines the challenges faced in the fabrication process, and the solutions put in place.

INTRODUCTION

Work on the prototype 56 MHz HOM Damper was started at JLab in July, 2013[1]. The agreement between BNL and JLab called for the following to be completed at JLab:

- Determine an assembly and fabrication sequence and plan
- Fabricate required components
- Conduct required welding, chemistry, brazing and inspection
- Tune fabricated damper
- Perform pressure and leak checks as required

The prototype was delivered to BNL in December, 2013.

DESIGN

A cut-away view of the prototype damper is shown in Fig. 1. The two main subsections of the damper are the Main Inductor and Filter Assembly.

Main Inductor

The Main Inductor connects to the Loop at the cavity end of the damper, and supports the Filter Assembly at the other end. The Inductor acts as the primary cooling mechanism for the damper. Essentially, it is a Niobium tube, through which a copper rod runs. The rod is connected via an interference fit at the Loop (the area of highest heat generation) and is immersed in flowing liquid helium at the Cooling Turret.

Filter Assembly

The Filter Assembly is a capacitor consisting of three Niobium and three Sapphire rings. The Niobium rings are connected to the outer shell of the damper via three inductor rods, and to the N-Type connected via another inductor rod. In the prototype, the rings were joined together by means of Stycast™. The final tuning of the damper was achieved by moving the entire Filter Assembly in an axial direction along the Main Inductor. The response frequency was measured by a network analyser coupling to the Loop. Figure 2 shows the tuning response. Once in the proper position, it was fixed in place using more Stycast™.

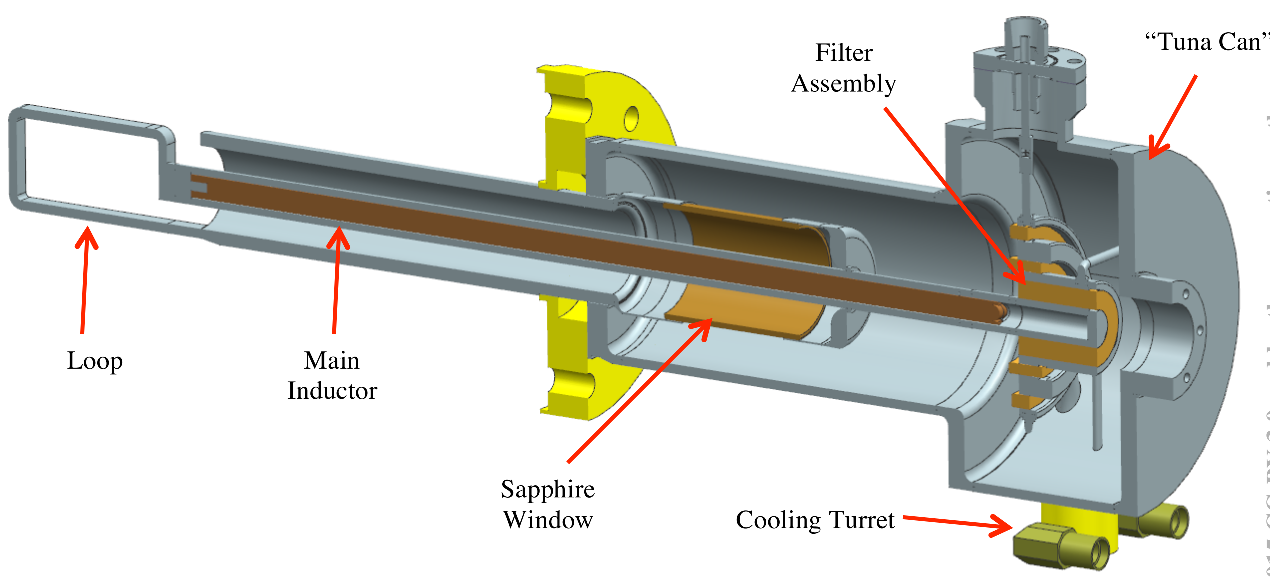

Figure 1. Cut-away view of the prototype damper, showing main components

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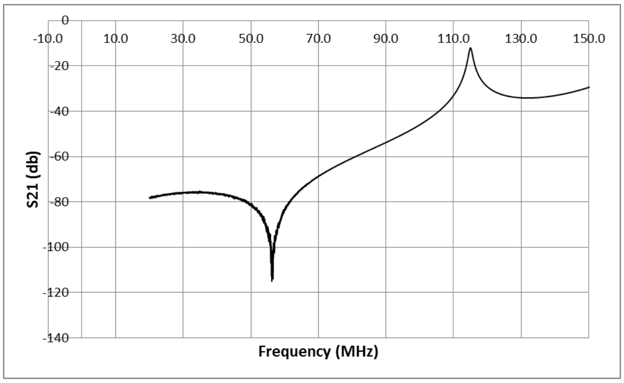

Figure 2: Network analyser output from tuning process. Target is first notch being set to 56.3 MHz.

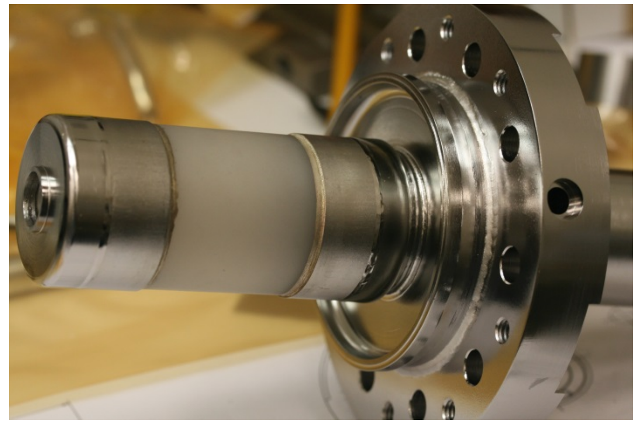

Figure 4: Sapphire Window brazed on to Niobium cuffs.

PROTOTYPE

The completed prototype damper was installed in the RHIC cavity in April, 2014 (Fig. 3). It was found to quench at approximately 1/36 of full power. Through numerical analysis conducted at BNL, it was surmised that there had been extra heat generation from the braze alloy (InCuSil ABA) used in joining the Sapphire Window to the Niobium cuffs (Fig. 4). Another possible factor was thought to be arcing at a sharp edge on the inside of the Tuna Can. Evidence of the arcing from the disassembled prototype can be seem in Fig. 5.

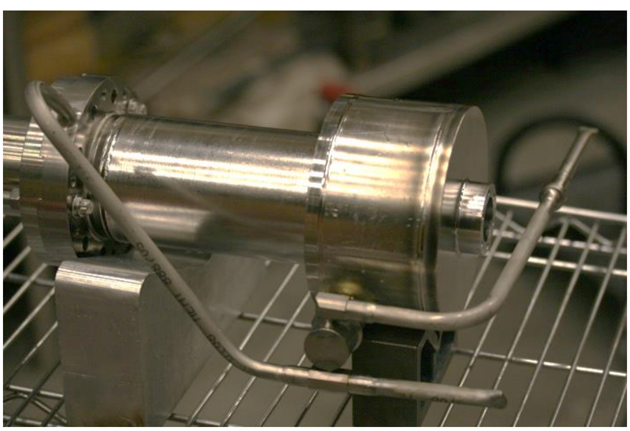

Figure 3: Completed prototype damper with Ti cooling tubes attached.

PRODUCTION DESIGN MODIFICATIONS

Sapphire Window Removal

It was decided to completely remove the sapphire window assemblies from the production dampers. At this stage, the assemblies had already been fabricated beyond the installation of the sapphire window by an industry vendor. The sapphire windows were removed via Wire EDM at Jlab.

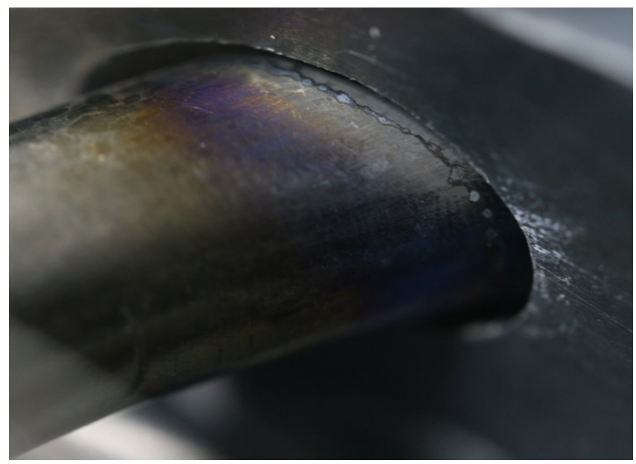

Figure 5: Evidence of possible arcing in the prototype.

Filter Assembly Connections

With the sapphire window removed, the entire inner volume of the damper is now open to cavity vacuum. As such, the Stycast 2850 FT 24 LV which had been used in the filter assembly could no longer be used, as the outgassing rates were too high (0.66% TML, 0.02% CVCM) [2]. The epoxy was replaced by small Niobium "stoppers" which hold the sapphire rings in place within the Niobium rings. The stoppers are machined from 1mm thick Niobium stock. Figure 6 shows the original design and the new concept.

Sapphire Bridge

In the original prototype assembly sequence, the Filter Assembly was fixed at its final position using Stycast™. Due to the change in vacuum requirements, this was replaced by a "bridge" made of sapphire attached to the innermost Niobium ring, and fixed the position of the Filter Assembly on the Main Inductor via a jacking screw.

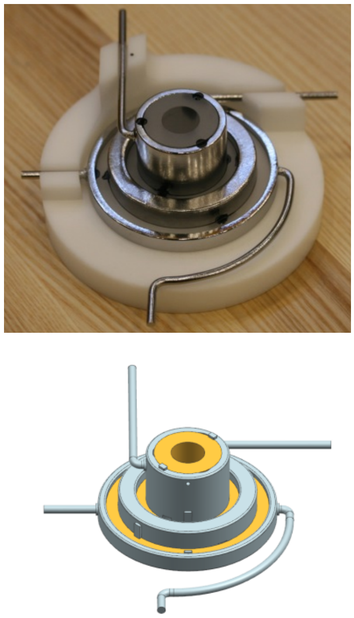

Figure 6: Original Filter Assembly attached with Stycast (above) and new concept (below)

LESSONS LEARNED FROM PROTOTYPE FABRICATION

Final Machining via BCP

The initial spec for the prototype damper called for 100 microns (0.004 inches) of material removal from all Niobium surfaces by means of Buffered Chemical Polishing (BCP). This large amount of material removal proved problematic for components which required a tight tolerance fit with the precisely-machined sapphire rings and window.

The Niobium rings in the filter required 0.002 – 0.004 inches diametric clearance, and the cuffs around the sapphire window required 0.001 – 0.002 inches diametric clearance. In practice, it was found that the etching was non-uniform, and the discrepancies in the diameters of the Niobium rings were as large as 0.010 inches.

The standard acid mixture of Nitric, Hydrofluoric and Phosphoric acid ratios were changed from 1:1:1 to 1:1:2. The extra Phosphoric acid acted as a buffer to the reaction, making it slower (~ 10 times slower) and generating less heat. The parts were etched to remove 5 microns at a time; between each run, they were neutralized, rinsed and measured, until the correct dimensions were obtained.

Due to the semi-random and non-repeatable nature of this process, removing an amount of material greater than the tolerance on the dimension is not recommended.

Final Tuning Process

After the prototype's Filter Assembly was fixed, there were means by which the damper's tuning could be altered. This meant that the effects of the final welds and cooling to 4K had to be estimated. The former was found to change the notch location by 2 MHz.

For the production dampers, the Sapphire Bridge is fitted with a jacking screw which can adjust the position of the Filter Assembly. The screw can be accessed by the port at the end of the tuna can. This would be done after all welds have been completed, and the notch location measured at 4 K.

PRODUCTION STATUS

Five production dampers are currently being fabricated at JLab. Four will be configured for different ports on the RHIC cavity, while the fifth will remain without its final configuration steps to act as a spare. Two dampers will be delivered initially in July, 2015 to be installed in the cavity. The remaining three dampers are set to be completed in October, 2015

FURTHER WORK

Filter Assembly

The use of welded components in the filter assembly has presented new difficulties in terms of cleaning. Due to spray caused by EBW, the Niobium and Sapphire require cleaning after the welds. Generally, this would be done using BCP, but in this case, there is a danger of acid remaining trapped between the rings.

Work is currently ongoing to develop a combination of clamps and shields which will allow the welds to be made without exposing the Niobium and sapphire to the EBW spray. Tests are also being done at JLab chemistry facilities to determine how effectively the acid can be removed and neutralized from the small gaps (~0.002 inches) between the rings.

Main Inductor Weld Bushing

The arcing caused by the sharp edge on the inside of the Tuna Can is to be avoided by means of a fillet weld. This is difficult due to the weld geometry (a curved tube containing a copper rod inside, welded onto the inside of a curved surface) and the inability of an EBW to add filler material.

A sacrificial bushing was developed to form a fillet weld around the outside of the bent tube. In addition to being leak tight, the bushing also needed to create a very smooth surface, due to the weld's location in a high-field area. The fittings are currently being fabricated and tested at JLab.

ACKNOWLEDGMENTS

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