TEST RESULTS FOR A HEAT-TREATED 4-CELL 805-MHZ SUPERCONDUCTING CAVITY*

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Abstract

Assessing superconducting technology for potential upgrades to existing proton accelerators as well as applications to future high-current machines necessitates developing expertise in the processing and handling of multicell cavities at useful frequencies. In order to address some of these technological issues, Los Alamos has purchased a 4-cell 805-MHz superconducting cavity from Siemens AG. The individual cavity cells were double-sided titanium heat-treated after equatorial welding, then the irises were welded to complete the cavity assembly. The resulting high RRR (550-730) in the cells enables stable operation at higher cavity field levels than are possible with lower RRR material. Additionally, the high thermal conductivity of the material is conducive to rf and high peak power processing. The cavity was also cleaned at Los Alamos with high-pressure water rinsing. Results from the initial cavity tests, utilizing various processing techniques, are presented.

Introduction

The 4-cell 805-MHz niobium cavity was originally purchased from Siemens AG as a prototype test piece for a proposed pion accelerator [1]. As such, it was fabricated using state-of-the-art techniques for maximum accelerating fields. Most notable was the double-sided titanification and preliminary etching of the niobium cells (with equator welds) before the irises were welded. This gave a residual resistance ratio (RRR) of greater than 550 in the cavity-equator welds, and bulk-material RRR values around 730. These values were obtained by parallel-fired samples. The cavity was designed for a β=0.92, with a beam-pipe radius of 2.6 inches.

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In the interest of obtaining high accelerating fields, the cavity manufacturing processes of inspection, forming, machining, welding, firing, and etching were stringently specified [2]. Additional processing refinements were also added, based on LANL research in field emission in single cell cavities. Augmentations to the standard cavity processing used by the manufacturer included a 0.5-μm filter and heat exchanger for the recirculating etch chemistry, a long (90 hours) spray rinse with ultrapure water, and High Purity Liquid Chromatography grade (HPLC) methanol rinsing.

The original manufacturer cleaning was supplemented by additional cleaning at Los Alamos that included high-pressure ultrapure-water cleaning of the cavity and components and microscopic inspection of ancillary components and flanges.

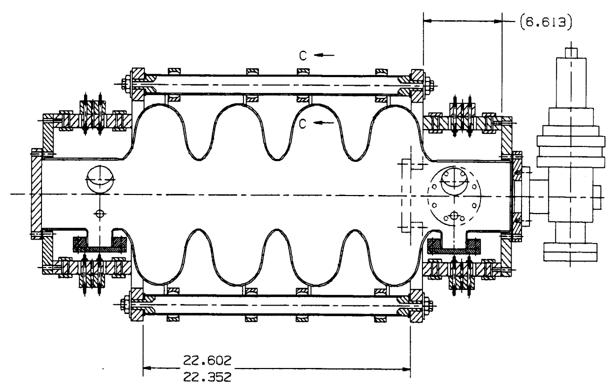

Figure 1. Sectional engineering drawing of the 4-cell 805-MHz cavity.

Mechanically, the cavity was stiffened with 6 titanium tubes connected to the cavity with welded tabs and anchored to two titanium bulkhead rings on each end, as shown in figure 1. The end half-cells are deformed using a titanium tuner that has no backlash. The cavity was designed to be sealed with silver plated Helicoflex Delta seals on niobium-hafnium alloy flanges. The Helicoflex seals remained leak-tight throughout the test and the stiffening scheme produced no adverse effect. Overall, the mechanical aspects of the cavity performed as expected.

Analysis was done in the cavity design to specify the room-temperature frequency value such that 805-MHz was obtained upon cooldown to 4 K. The targeted room-temperature π-mode resonant value of 803.450-MHz gave a 4 K value of 805.077-MHz, in close agreement with calculations [3]. The ability to reliably predict the final frequency from room temperature values is useful for manufacturing purposes.

RF system

As this was a vertical cavity test in the lab and extensive conditioning was envisioned, an adjustable coupler was designed for delivering power to the cavity. The coupler was based on 3-1/8" coax, and used a choke joint to reduce the current on the rf seals [4,5]. In measurements, the coupler covered an external Q range of $2x10^6$ to $1x10^{11}$, as designed [6]. Cold and warm windows were used to isolate the cavity vacuum near the cavity, so a long section of the coax line was under vacuum. Quarter-wave stubs were used to support the center conductor without unduly stressing the coaxial windows.

RF power for high-power conditioning was supplied by two klystrons that, combined, provided CW power up to 18-kW and pulsed power up to 180-kW at 10-Hz and with 10-msec pulse lengths.

Test results

Two tests were carried out on the cavity, both at 2 and 4 K. In the first test, cavity characterization and performance evaluation tests were done, which provided initial Q values, coupler range, and the π–mode frequency. RF conditioning with up to 1-kW forward power was also done, usually in conjunction with the performance testing. The cavity responded very well to this rf conditioning, and it took approximately an hour to realize the gains shown in figure 2. Field emission was observed as the limiting mechanism of the cavity at 2 K. The amount of field emission decreased with increased conditioning time, as noted by x-ray levels. At 4 K, the field level was limited by the rf power available.

Higher power processing was attempted using the klystrons, but the test was limited by an arcing problem in the coaxial high-power switch. The arcing required keeping the power level below 100-kW with a pulse length less than 0.5-msec. With this pulse profile, and an external Q of $2x10^6$, the cavity fields only achieved the values obtained during CW conditioning, and thus, further conditioning was not realized.

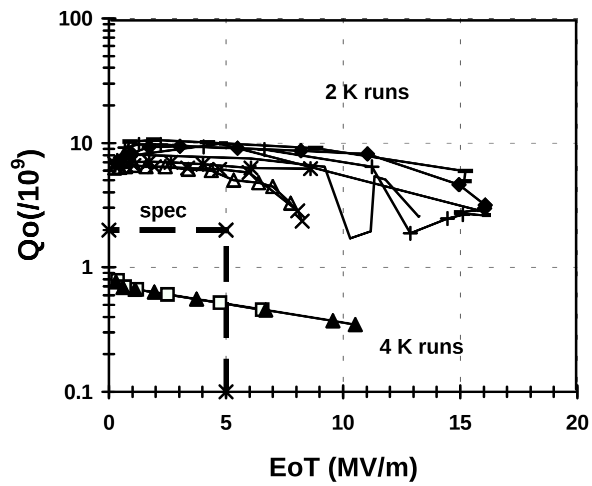

Figure 2. Unloaded Q related to accelerating field in the cavity. The original specification at 2 K is shown as a dashed box in the left corner. The maximum field obtained was field emission limited. The different lines represent different power sweeps.

Conditioning with CW power up to 1.5-kW was also tried, but was limited by center conductor heating leading to breakdown in the driveline.

Conclusion

The cavity performed very well. The fabrication and cleaning techniques used yielded a cavity with high RRR that sustained high field levels. At 2 K, the cavity obtained a maximum E_oT of 16.3 MV/m with field emission at a Q_o of $3x10^9$, and ran at 8-10 MV/m with minimal field emission.

Acknowledgments

As with any experimental endeavor, the test is the final culmination of a great deal of work by many people. The authors would like to acknowledge the work of J.N. DiMarco, E. Gray, and G. Spalek in the design and specification of the cavity tested, and the fabrication efforts of the personnel of Siemens AG.

References

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