PROGRESS ON EUCLID SRF CONICAL HALF-WAVE RESONATOR PROJECT*

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Abstract

Project X is a high-intensity proton accelerator complex proposed at Fermi National Accelerator Laboratory. Euclid TechLabs is involved through the design of a conical Half-Wave Resonator (cHWR) with a frequency of 162.5 MHz optimized for protons at β=v/c=0.11. The novel design considers both the superconducting resonator and helium vessel together to minimize the dependence of the resonant frequency on external loads. A unique cavity side-tuning option is also under development.

Niowave, Inc. builds and operates commercial superconducting accelerators for electrons, and as such, was able to propose a complete cavity production procedure including preparation of technical drawings, processing steps and resonator high gradient tests.

Here we present the procedure of the cavity and helium vessel fabrication, cavity preparation and initial experimental results.

INTRODUCTION

The very first investigations of the conical Half-Wave Resonator were made in the frame of the COSY Linac project [1]. The recent cavity developments [2-3] integrated the conceptual design of the cHWR with its liquid helium vessel, minimizing the sensitivity of the resonant frequency to fluctuations in helium pressure.

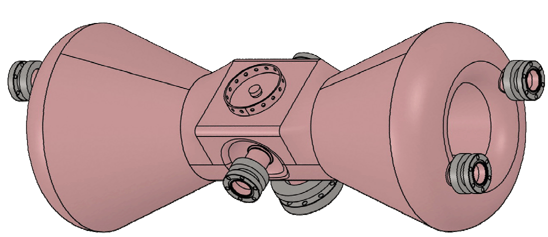

Figure 1: cHWR modified design.

To use the outer conductor walls for cavity tuning deformations effectively, the central part of cHWR is made asymmetric with a planar surface on one side. This planar surface is used for tuning by deformation (Fig. 1). This optimization of the central resonator section was made without compromising the cavity performance. The cavity RF parameters are shown in Table 1.

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The side tuning procedure results in tune sensitivity up to 80 kHz/mm with acceptable stresses 350 MPa/mm. There is nearly no dependence on the resonator frequency slow tuning.

Table 1: Conical HWR Parameters

frequency	MHz	162.5
β = v/c		0.11
R_aperture	mm	18
βλ	mm	202.94
R_cavity **)	mm	90
G	Ohm	36.36
R/Q	Ohm	119
E_{pk} / E_{acc} *)		5.1
B_{pk} / E_{acc} *)	mT/MV/m	7.1
B_{pk} / E_{pk}	mT/MV/m	1.39
tune	kHz/mm	-87
*) $L_{eff} = N_{gaps} * \beta\lambda/2$, where N_{gaps}=2 – number of gaps		
**) Cavity radius in center		

CAVITY FABRICATION

Niowave, Inc. proposed a series of cavity and helium vessel modifications to simplify their manufacturing without affecting the main resonator mechanical stability parameters [3]. The modified cold mass design calculations (cavity and helium vessel) confirmed that the total effect of external pressure on all cavity and liquid helium vessel walls results in nearly complete compensation of the frequency shifts caused by cavity and vessel wall deformations (df/dp is close to zero).

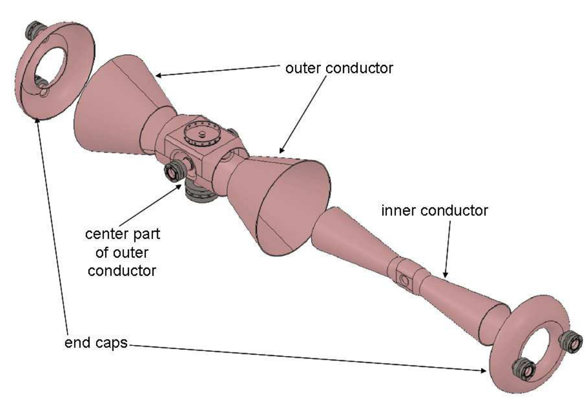

Figure 2: Cavity assembly.

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Niowave, Inc. performed the cavity fabrication and installation into the stainless steel helium vessel. The niobium walls of inner and outer conductors are formed of 2.8 mm thick niobium sheets. (Fig. 2). Significant efforts were made for precise manufacturing of the beam ports and the central part of the cavity (Fig. 3).

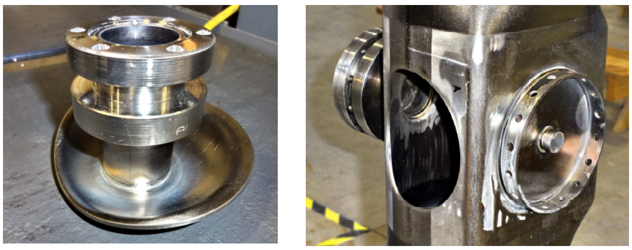

Figure 3: Cavity beam port with flanges (left) and central part (right).

The central electrode was formed in halves and seam welded together (Fig. 4). The outer conductor conical walls also have been manufactured from two halves and longitudinally welded. All niobium-niobium joints in the cavity body were joined by electron-beam (EB) welding.

Figure 4: cHWR central electrode.

After the final EB closure welds and leak checks, a bead pull measurement was performed, indicated field flatness between the two accelerating cells less than 2%. The cavity was then fitted with its stainless steel liquid helium vessel. The vessel is pieced together around the niobium cavity and TIG welded (Fig. 5).

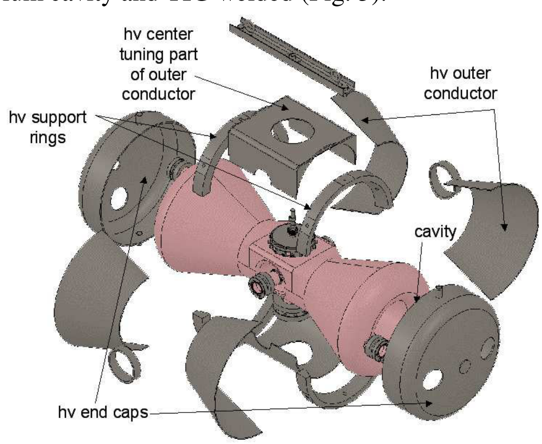

Figure 5: Helium vessel assembly.

The cavity helium vessel was manufactured from 3 mm thick stainless steel. A special technology has been used to join the cavity niobium port pipes with their stainless steel flanges using brazing via a copper layer. All cavity vacuum ports are sealed with Conflat flanges. The final modified geometry of the cavity with helium vessel with tuner bars and supporting rings is presented in cross-section as Fig. 6.

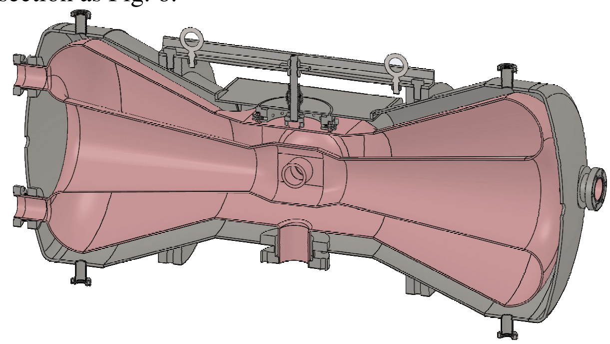

Figure 6: Final modified cHWR helium vessel design.

Following a final leak check, the cavity received a final chemical processing using ~150 micron of Buffered Chemical Polishing (BCP) and a High-Pressure water Rinse (HPR). Figures 7-8 show the BCP and HPR setups. During the leak check of the helium vessel (Fig. 9), measurements of the tuner displacement were made and the sensitivity of the cavity frequency with pressure was estimated at ~2 Hz/mbar with the tuner loose (maximum measured displacement of ~0.01 mm).

Figure 7: Buffered chemical polishing setup.

BCP was made with the cavity oriented in vertical position through vacuum ports with acid entering from

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the bottom and leaving through the top ports. The procedure was repeated twice rotating the cavity by 180 deg. A high-pressure rinse with ultra-pure water has also performed with the cavity in a vertical position using vacuum ports and beam pipes with the cavity flipped top to bottom during the rinse. A long wand with a nozzle at the end can reach the middle of the cavity using top-bottom vacuum ports. This allows spray on all interior cavity surfaces, including ports and beam pipes.

Figure 8: High-pressure water rinse setup.

INITIAL CRYOTEST RESULTS

An initial cryotest of the cHWR has been performed at Niowave in a vertical test dewar. The cavity was cooled down to the superconducting transition temperature in a little over two hours, with special care taken to cool more quickly in the intermediate temperature range of 50-150 K to prevent the formation of a lossy layer described as Q disease. The frequency of the cavity was 162.35 MHz at 4 K (shift of 220 kHz from the warm frequency).

Figure 9: Helium vessel leak check setup.

Table 2: cHWR Frequency Simulation and Test Results

mode	freq_calc.	freq_exp.
	MHz	MHz
1	162.014	162.33
2	340.833	348.614
3	512.778	514.992

The frequencies of two higher-order modes of the cavity were measured (Table 2). The measured Q was consistent with the expected low-field unloaded Q near 1.6×10^9. Several multipacting barriers were observed at low field levels, with some conditioning of these barriers accomplished. Further conditioning is required to reach the design field levels.

The helium vessel was also pressurized to test df/dp under cryogenic conditions. These df/dp measurements confirm the numerical simulations and are consistent with previous room temperature df/dp measurements. (Fig. 10).

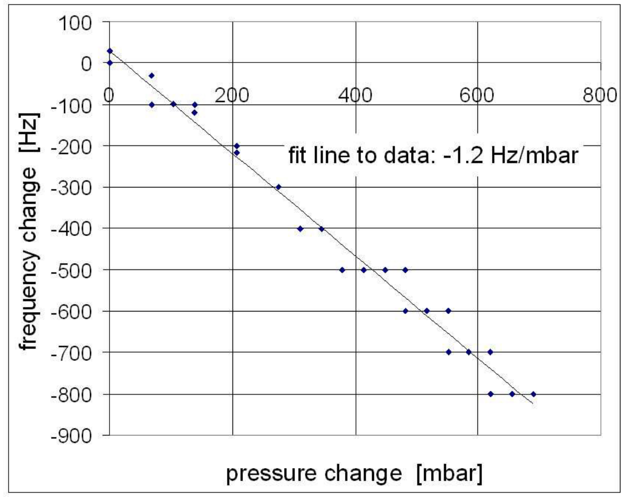

Figure 10: Frequency sensitivity to pressure measured at 4K.

CONCLUSIONS

An engineering design of the conical Half-Wave Resonator in the helium vessel with side tuning possibility was completely realized. The main project goal of the cavity and helium vessel structure designed to minimize microphonics caused by an external pressure has been confirmed by the structure cold test at 4K. The side option of the cavity tuner was effectively implemented providing the self-compensated frequency shift design.

The cavity with helium vessel has been fabricated at Niowave Inc. with supervision and quality control from Euclid Techlabs. After the bulk BCP and high pressure rinsing, the cavity with helium vessel was tested at Niowave vertical test cryostat. Further measurements of quality factor Q_0 and accelerating gradient for the dressed cavity are scheduled for fall of 2014.

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