JLAB UPGRADE AND HIGH CURENT CAVITY DEVELOPMENTS*

J. Preble, J. Hogan, F. Marhauser, R. A. Rimmer, H. Wang,
Jefferson Lab, Newport News, VA 23606 U.S.A.

Abstract

We present the status and recent results from the development of new SRF cavities for the CEBAF 12 GeV upgrade and for future light source applications. The JLab 12 GeV upgrade requires ten new high-performance CW cryomodules. These will each contain eight seven-cell cavities of a "low-loss" design with HOM damping sufficient for ~1mA of continuous current. Jlab has fabricated and tested a number of such cavities and demonstrated compliance with all 12 GeV project requirements with conventional BCP cavity processing. Recently we have also electro-polished several cavities of this type and shown significantly better performance than the standard BCP. This processing method could provide improved operational margin and lower cryogenic loads at the CEBAF working point. For future light source applications such as FELs or ERLs, cavities with higher beam current capability are desirable. Jlab has developed a high-current cavity for such applications with a cell shape optimized to optimize HOM power extraction and maximize the BBU threshold. We report on the latest tests of this design and on plans to assemble a two-cavity cryomodule for testing with beam in the recirculation loop of the JLab FEL.

CEBAF 12 GEV UPGRADE

The CEBAF accelerator [1] will require several significant upgrades to support the 12 GeV program. This includes the installation of 10 cryomodules, 5 in each linac, providing an additional 1 GeV of energy gain per pass. Each cryomodule contains 8 SRF cavities, RF power couplers, cryogenic end caps, and thermal transition beampipes providing 108 MV of voltage which includes operational overhead for nominal operations at 100 MV. These cryomodules will be placed in the empty slots already existing at the high energy ends of the two linacs.

SRF Cavities

The cavity assembly, C100 cavity designation, includes a low-loss geometry 7 cell structure with a waveguide fundamental power coupler on one end and 2 HOM couplers on the opposite end [2].

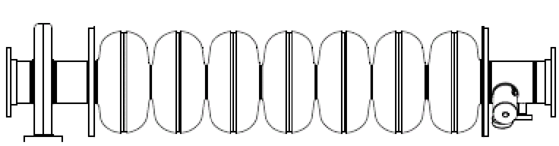

Figure 1: Cavity Assembly.

Cavity and cryomodule parameters are listed in Table 1. These include a revised HOM damping specification [3] which provides additional margin for operations 400 µA of injected current.

Table 1: Upgrade Cavity and Cryomodule Parameters

Cavity	
Frequency	1497 MHz
Cavity active length	0.7 m
Geometry Factor	280 Ω
Ep/Eacc	2.17
Hp/Eacc	3.74 mT/(MV/m)
Gradient	19.2 MV/m
Qext fundamental pwr coupler (FPC)	$3.2 * 10^7$
FPC power rating	13 kW
Higher order mode damping	$<1 *10^{10}$ Ω/m
Cryomodule	
Total active length	5.6 m
Voltage	108 MV
2 K heat load	≤300 W
50 K heat load	≤300 W
Cryomodule length	~8.5 m

Cavity Performance

Required cavity performance has been demonstrated in an integrated performance test conducted using a horizontal test cryostat, HTB, including the final configuration RF couplers, cavity frequency tuners, and thermal strapping.

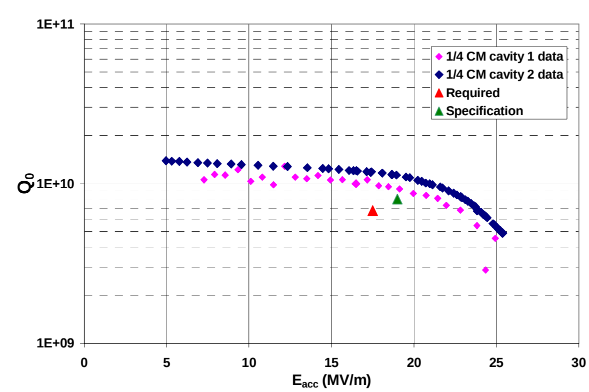

Figure 2: Cavity Performance in the HTB Test.

Work continues on improvements in cavity processing to extend the performance margin. The present baseline plan includes Buffered Chemical Polishing, BCP, processing and was used in the HTB test. Preliminary work has been completed on developing an electro-

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polishing, EP, process for the C100 cavities [4]. Initial results using two High Gradient, HG, cavities have been very promising. In one case, HG006, prior to EP processing the cavity had experienced significant performance degradation after extensive BCP processing that removed more than 400 µm from the surface. After EP processing and low temperature baking this cavity performed extremely well, Fig. 3, reaching a gradient of 35 MV/m with a good Q, 1×10^{10}. The second cavity, HG007, had received "standard" BCP processing only and met the upgrade project specification. After EP processing significant improvements in gradient and Q also resulted in this cavity up to a quench limit at 25 MV/m. The increased Q, reducing the cryogenic heat load at 2 Kelvin, enables higher gradient operations of the cavities up to the RF power limit, 13 kW, at the budgeted heat load or spare watts for the remainder of the linacs.

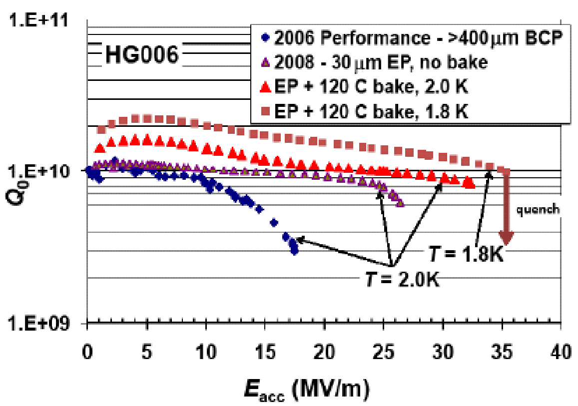

Figure 3: HG006 Performance with EP Processing.

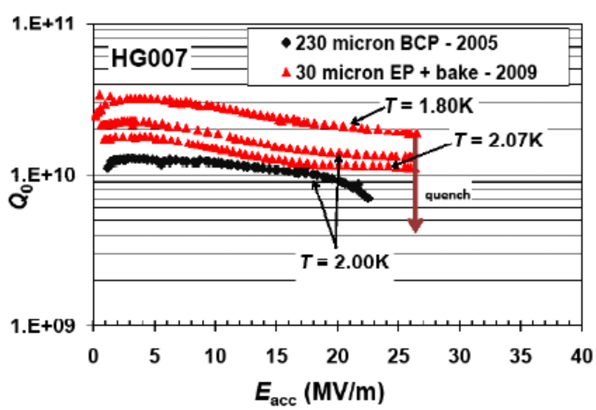

Figure 4: HG007 Quench Limited After EP Processing.

Future Activities

The 12 GeV project has placed a cavity order for 86 cavities with Research Instruments. The start of cavity delivery is planned for the spring of 2010. Jlab will finalize processing plans and procedures before that time.

HIGH CURENT CAVITIES

Jefferson Lab has been engaged in the development and use of CW SRF cavities for high current, HC, applications starting with the Jlab FEL. Since that time there has been significant interest in using CW SRF cavities in light source applications. Past requirements have been for ~10 mA of beam current while future plans increase this to 100-1000 mA. This increase in current requires new cryomodule designs, most notably for cavities and RF couplers, both Fundamental power and HOM.

Cavity Design

Work on cavity design has focused on managing RF power and fields, both fundamental and HOM, present in high current applications. Cavity cell shape designs are developed and evaluated using CST MAFIA time-domain wakefield simulations for broadband HOM impedances and Microwave Studio for external Q of the fundamental power coupler (FPC) and R/Qs of the HOMs [5]. Multipacting simulations have been preformed as well. The design of an Ampere class cavity using a 5 cell structure with six waveguide HOM couplers has been completed.

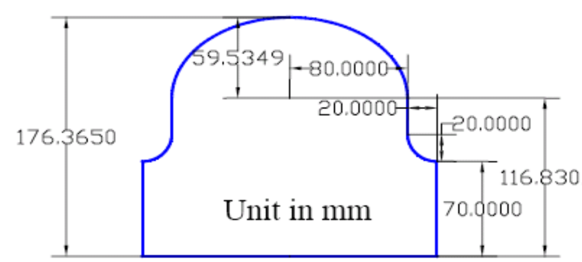

Figure 5: Center Cell Shape for the 748.5 MHz HC Cavity.

Along with the cavity layout conceptual designs for the HOM dampers and FPC have been completed [6]. One of the 6 HOM waveguides performs double duty as the FPC and utilizes a round pre-stressed RF window for cavity vacuum isolation.

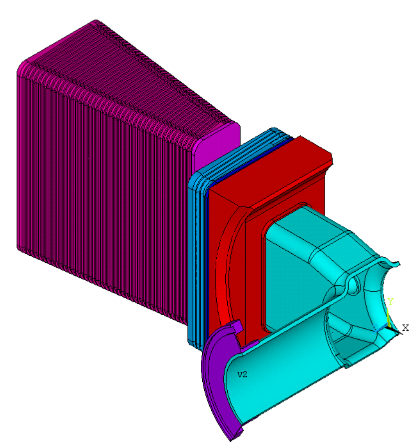

Figure 6: Waveguide for Fundamental and HOM Power Coupling for the 1497 MHz cavity.

HOM damper designs have been developed for high and low power applications, Fig. 7. Testing of absorber materials to cryogenic temperatures [7]is included in this design effort. High power applications include water cooling.

Figure 7: Round Pre-stressed RF Window.

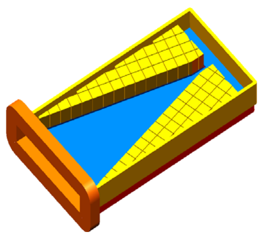

Figure 8: High-power HOM Absorber.

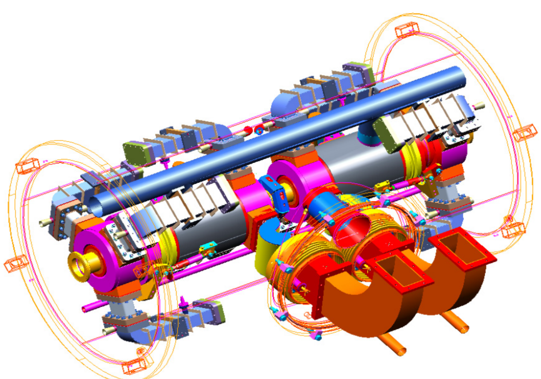

Figure 9: Concept for HC Cryomodule.

Fabrication and Performance

Two 5 cell niobium 1497 MHz cavities and one 5 cell 748.5 MHz cavities have been fabricated along with single cells and copper multi-cell cavities. Warm bench testing as well as cold performance testing has been completed [8].

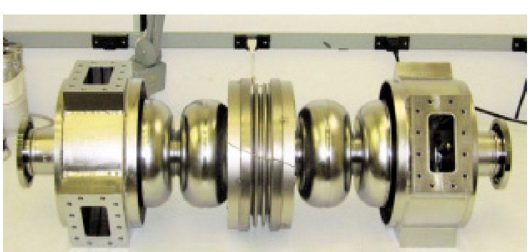

Figure 10: 1497 MHz HC Cavity.

High power RF window prototyping is already well along for the 1497 MHz waveguide coupler. Several windows have been completed and tested to over 60 kW CW.

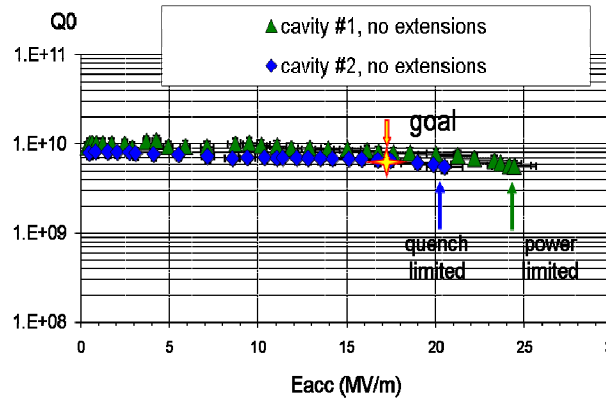

Figure 11: HC 1497 MHz Multi-Cell Cavity Performance.

Future Plans

Presently Jlab is continuing the design of a two cavity cryomodule based on the existing 1497 MHz HC cavities previously built and tested. Final designs and fabrication of FPC and HOM components will be completed as required. Many existing components will be used to complete the cryomodule. These include the cryostat, cryogenic end caps, cavity tuners. Present plans include installing the completed cryomodule into the FEL accelerator for beam test in 2010.

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