TESTS OF SRF DEFLECTING CAVITIES AT 2 K*

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Abstract

The Advanced Photon Source (APS) at Argonne National Laboratory (ANL) is developing 2.8-GHz deflecting-mode superconducting rf (SRF) cavities in collaboration with Jefferson Lab (JLab) as part of a major facility upgrade. On-site testing of these cavities requires a new cryostat capable of operation at 2.0 K or less. The APS has leveraged facilities and expertise within ANL's Physics Division to upgrade an existing test stand for continuous operation at temperatures as low as 1.7 K. A new cryogenic feedbox was fabricated and mated to an existing liquid helium "bucket" dewar with 0.6-m inside diameter and 1-m working depth. The configuration allows continuous sub-lambda operation using warm vacuum pumping and helium make-up from the Physics Division's existing cryoplant at heat loads up to 50 W dynamic, plus 15 W measured static load at 2.0 K. A 2.8-GHz TWT-based rf station has been installed and commissioned, providing up to 275 W of rf power. We describe the cryogenic and rf performance of the system and provide examples of cavity test results.

INTRODUCTION

Short-pulse x-ray (SPX) capability is planned as a major element of the proposed APS Upgrade [1]. Deflecting-mode SRF structures at 2.8 GHz are being designed, fabricated, and tested in collaboration with JLab in order to provide a 2-MV deflecting "chirp" to the APS electron beam. Photons produced by the chirped beam will be sliced down to short (~2 ps) x-ray pulses for facility users. Four single-cell 0.5-MV SRF cavities [2] housed in a single cryostat provide the initial deflecting kick. The chirp is completely canceled by a second cryostat with four more 0.5-MV cavities located two sectors downstream.

This paper describes ANL's contribution to the single-cavity R&D effort. In addition to relieving JLab of some of the testing burden, this activity provides APS personnel with the opportunity to gain experience with SRF cavity testing, including hands-on experience developing and operating the cryogenic, vacuum, and low- and high-level rf systems involved.

CRYOGENIC SYSTEM

Substantial SRF facilities exist at ANL in support of the low-beta cavites that comprise the ATLAS heavy ion linac [3]. These resources have been made available to the APS and include shared use of a helium refrigeration system and several test cryostats. APS has upgraded the existing hardware where necessary to provide enhanced sub-lambda testing capability (over 50 W at 2.0 K).

Figure 1 shows a section view of a refurbished test dewar used for immersion tests of bare (unjacketed) SPX cavities. In order to further cool the nominal 4.3-K LHe produced by the ATLAS refrigerator, a special feedbox was designed, built, and installed to cool the incoming LHe stream via heat exchange with the boiloff gas, which is pumped on by a room-temperature vacuum system capable of pumping 2.5 g/s of helium gas at 3-kPa inlet pressure. A plate heat exchanger fabricated by DATE, La Motte d'Aveillans (France), is used between supply and return streams. This exchanger is designed for a nominal 2.5 g/s flow rate and is based on the LHC heat exchangers supplied to CERN [4]. System performance is shown in Figures 2 and 3.

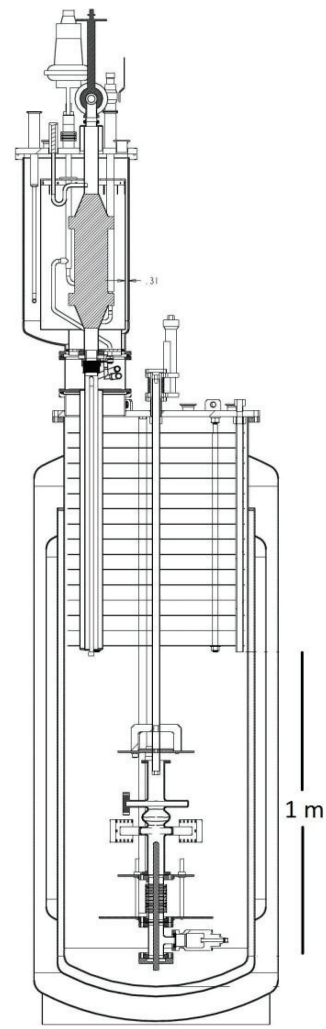

Figure 1: Test cryostat layout.

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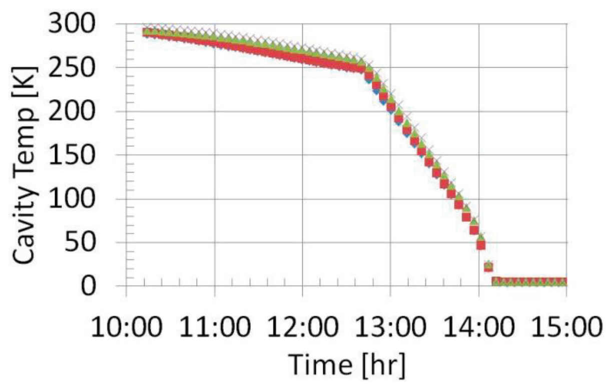

Figure 2: Cavity cooldown in the test cryostat.

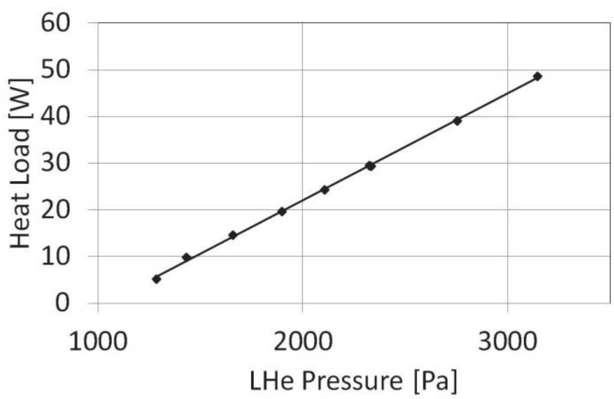

Figure 3: Cryostat vacuum system performance.

RF SYSTEM

Test Stands

Two rf test stands have been constructed. The first is used for high-power testing of mode damper materials and designs while the other is used for cavity tests under superconducting conditions. A 2.815-GHz, 4-kW cw rf system and associated test stand apparatus have been designed and built (Figure 4). This test stand is being used to provide rf power for thermal cycling tests on HOM damper material bonding techniques and includes a clean room, instrumentation to provide particulate count data on various damper materials mounted in WR284 waveguide structures, and infrared monitoring of damper material temperatures under rf power conditions.

A vertical cavity test stand (see Figure 5) was assembled at the ANL ATLAS SRF Cavity Test Facility and was used to confirm rf performance measurements on the first-article SRF cavity produced by JLab for the SPX R&D program. The test stand uses a 275-watt TWT amplifier to drive the cavity. Plans are underway to modify the SPX cavity test system at the ATLAS Test Facility to use a 5-kW cw amplifier to drive SRF cavities and input couplers to full-field performance.

Figure 4: SPX rf test stand area showing clean room fo waveguide and damper particulate testing on the left an 4-kW rf system on the right.

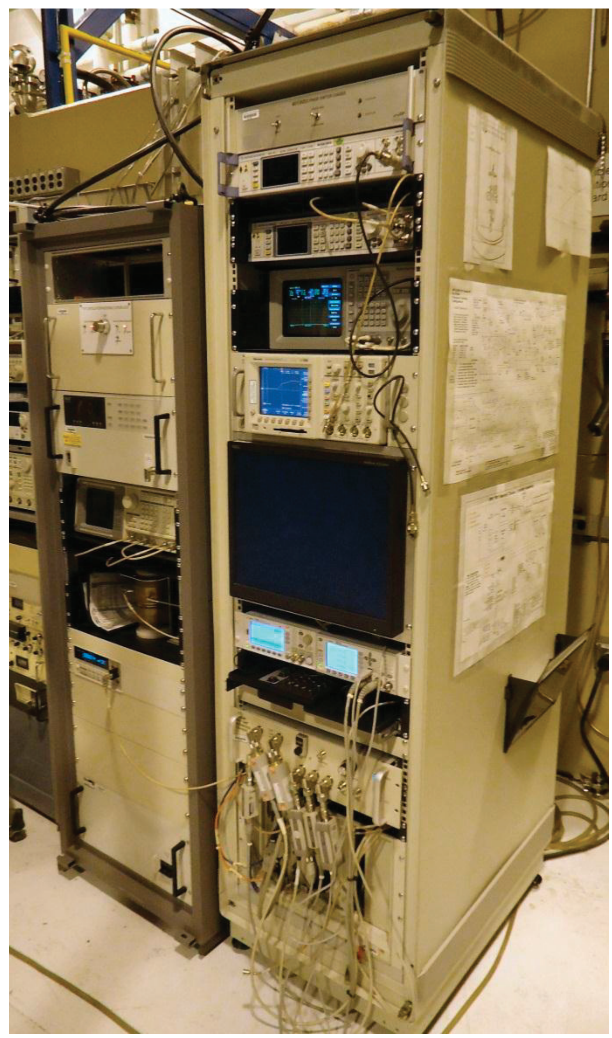

Figure 5: SPX rf test stand for vertical cavity testing at the ATLAS SRF Cavity Test Facility.

High-Power RF System

The SPX high-power rf system consists of two groups of four 10-kW cw klystron-based rf power amplifier systems, each configured to drive a single SRF deflecting cavity. Each 10-kW amplifier system includes a WR284

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waveguide run that also provides two directional couplers for system monitoring, a four-post tuner to adjust cavity loaded Q, and a waveguide absorptive filter that dissipates any significant HOM power generated by the cavity that would propagate back towards the amplifier system. Each amplifier system also includes a 50-kW isolator to absorb rf power that the cavity develops due to being driven by the stored beam, two personnel safety interlock systems, and master slow and fast rf interlock systems for equipment protection of the amplifier and cryomodule components.

RESULTS

A single-cell deflecting cavity was shipped under vacuum from JLab to ANL for 2 K testing. The cavity was processed at JLab and tested before shipping [5]. The cavity was installed onto ANL's vertical test stand as a hermetically sealed assembly with no active pumping or monitoring of the cavity vacuum space available during testing. The main power coupler is an "L"-shaped copper rf antenna inserted into the beam pipe, which has an external Q about 9×10^9. The field probe is an off-center antenna installed on the opposite side of cavity beam pipe where its external Q is about 2.5×10^{10}. Cavity tests showed no field emission, no multipacting, and exceeded the specified gradient and Q required by SPX. The test data (Figure 6) are consistent with measurements made previously at JLab. Cavity quench occurred at a field level similar to the previous JLab data.

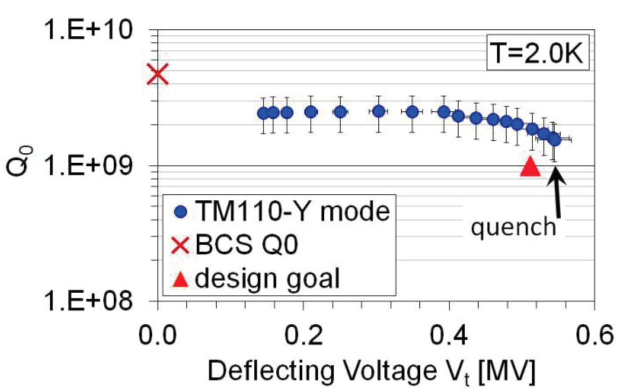

Figure 6: Cavity Q vs. deflecting voltage at 2.0 K

FUTURE TESTS

A horizontal cavity test of a dressed deflecting cavity (including fixed waveguide input coupler and mechanical slow tuner) is planned to be conducted in the same facility using a different cryostat where helium is present only within the helium vessel of the cavity. The dressed cavity will be powered through a waveguide power coupler with ceramic window attached as shown in Figure 7. The external Q will be set to a nominal value of 1×10^6. A 5-kW klystron rf source is available to power the cavity to nominal operating field gradient. A scissor-jack-style mechanical slow tuner will control cavity frequency during the horizontal test. Test results will be evaluated to guide further engineering optimization for SPX cryomodule development.

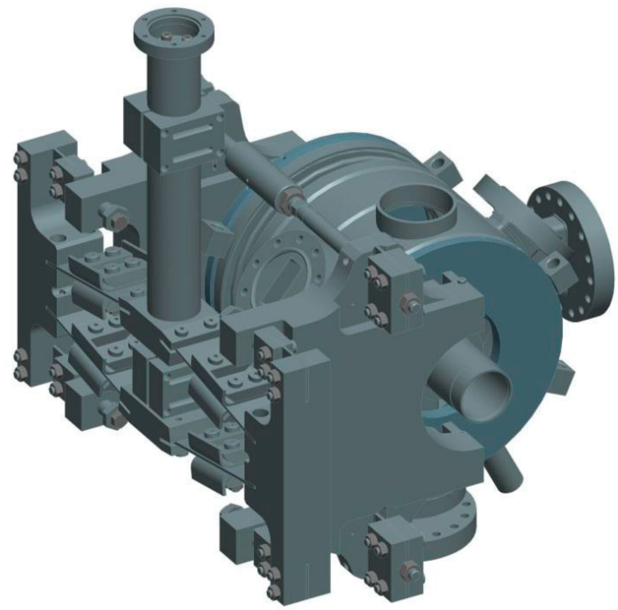

Figure 7: Dressed SPX cavity showing titanium helium tank, coupling ports, and mechanical slow tuner.

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