ASSEMBLY OF THE INTERNATIONAL ERL CRYOMODULE AT DARESBURY LABORATORY

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Abstract

The collaborative development of an optimised cavity/cryomodule solution for application on ERL facilities is nearing completion. This paper outlines the progress of the cryomodule assembly and details the processes used for final cavity string integration. The preparation and installation of the various subcomponents of the cryomodule are also detailed in this paper.

INTRODUCTION

The assembly at Daresbury Laboratory of the Superconducting RF (SRF) cryomodule developed for high current ERL applications, with intrinsic capability for operating at high Q_{ext} and CW operation is nearing its final stages of completion.

Table 1: Cryomodule Design Parameters

Parameter	Value
Frequency (GHz)	1.3
Number of Cavities	2
Number of Cells/Cavity	7
Cryomodule Length (m)	3.6
R/Q (Ω)	762
E_{acc} (MV/m)	>20
E_{pk}/E_{acc}	2.23
H_{pk}/E_{acc} (Oe/MV/m)	46.9
Cryomodule Energy Gain (MeV)	>32
Q_0	$>1 \times 10^{10}$
Q_{ext}	$4 \times 10^6 – 10^8$
Maximum Beam Current (mA)	100
Max. Cavity Forward Power (kW)	25 SW

The international partners who have participated in this collaborative development (Cornell and Stanford universities, STFC Daresbury Laboratory, DESY, FZD-Rossendorf, Lawrence Berkeley Laboratory and TRIUMF) have identified appropriate subsystem solutions to achieve the fundamental requirements for this new cryomodule, which have been reported previously [1,2]. Table 1 highlights the primary design parameters of this optimised cryomodule, which is due to be installed on the ALICE ERL accelerator at Daresbury Laboratory and validated with beam later this year.

CAVITY QUALIFICATION

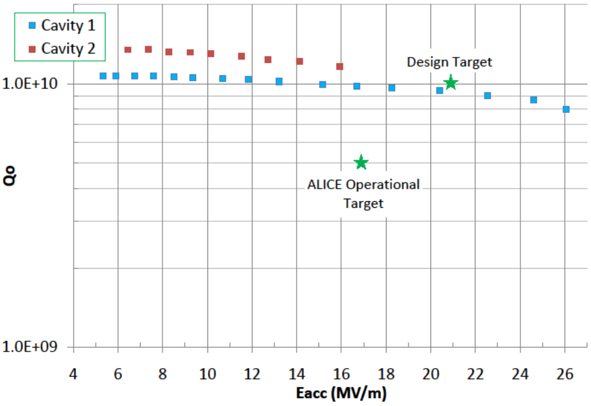


Figure 1: Vertical test results.

After heavy etching (400-500 μm) and a 48h 115°C bake, the vertical tests carried out at Cornell on the two highly modified DESY superstructure cavities showed very good performance and met the ALICE operational specification. The FE limitations observed were ascribed to the difficulty in cleaning the He jacketed cavities. Further improved cleaning, particularly of the central cells, was carried out before shipping to Daresbury, and final performance is expected to be better than the test results shown in Figure 1.

INPUT COUPLER TESTING

As previously reported, the input couplers were high power tested (see Figure 2) to 5 kW CW and 10 kW pulsed with no notable vacuum activity throughout the process [3]. Further tests were carried out following improvements to the coupler test stand HV power supply and RF systems. Temperature rises on the coupler ceramics were detected when attempting to raise the CW power, therefore it was decided to run pulsed power tests.

Ultimately, 30 kW pulsed power could be reached. No activity was detected on any of the vacuum gauges and thermocouple temperatures stayed below 30°C (see Figure 3).

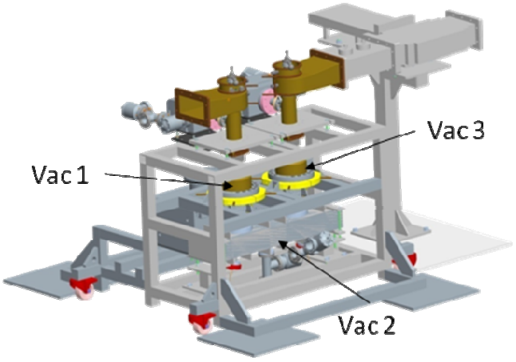


Figure 2: Layout of the coupler test stand showing the couplers and vacuum gauge positions.

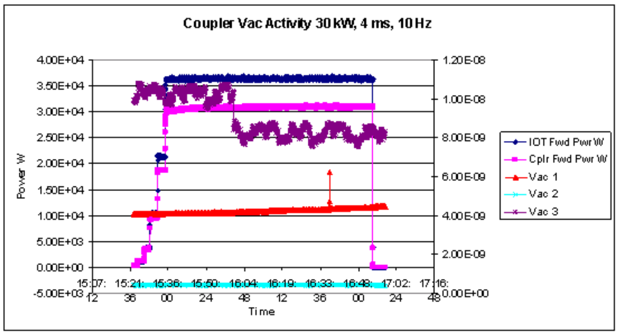


Figure 3: Coupler vacuum activity over extended period of testing at 30 kW pulsed, 10 Hz repetition rate, 4 ms pulses.

COLD COUPLER INTEGRATION

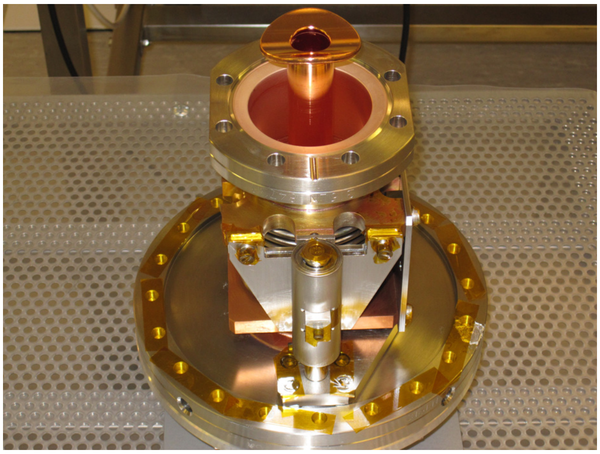


Figure 4: Cold coupler just before integration onto the cavity flange.

The cold couplers were installed on the cavity string after a stringent preparation process. In order to minimise the risk of particulate contamination of the SRF cavities, all components including the cold coupler assembly fixtures were cleaned and particle counted to less than fifty 0.5 µm particles per cubic foot per minute (ISO 3) when blown with pulsed 6.5 bar high purity compressed nitrogen gas.

The assembly procedure was the subject of significant refinement and was tuned to minimise the number of steps and risk of particulate generation during operations while the component flanges are open. All steps of the process were carefully rehearsed and particle counted in order to verify that the levels remained acceptable. Despite a number of setbacks regarding background particle levels in the cleanroom, both cold couplers were successfully installed onto the cavity string after a thorough cleaning procedure (See Figure 5).

Figure 5: Cold coupler insertion into the cavity port in the ISO4 cleanroom.

HOM ABSORBER TESTING AND INTEGRATION

The cavity string design incorporates three sections of higher order mode (HOM) absorbers. These are composed of Co_2Z and Ceralloy tiles configured radially around the beam axis [4] as shown in Figure 7. The absorbers are located at either end of the cavity string (½ HOM sections) and between the two cavities (full HOM section), as shown in Figure 6.

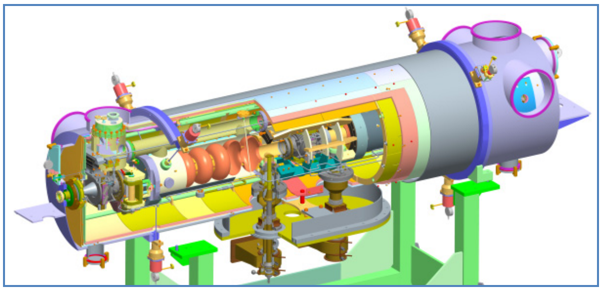


Figure 6: Overall layout of the cryomodule showing HOM absorber and input coupler locations.

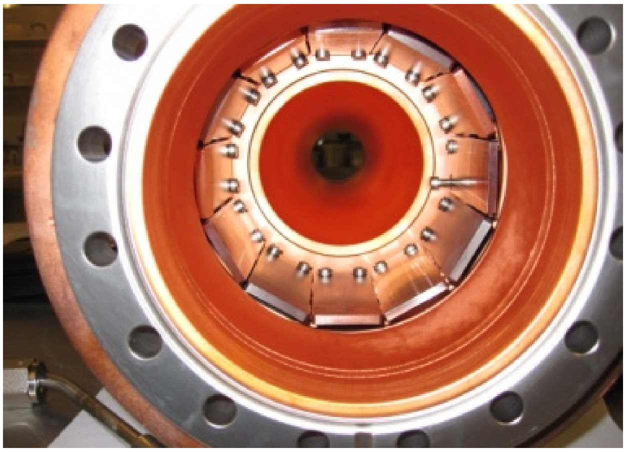


Figure 7: View into a ½ HOM section showing the RF absorber tiles.

The HOM tiles were carefully checked for homogeneity and thermal performance, then cleaned and mounted into the sections, which were then leak checked and thermally cycled to 80K [5,6] and thoroughly cleaned in the cleanroom prior to assembly onto the cavity string.

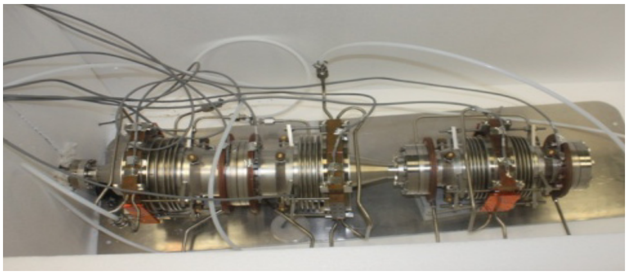
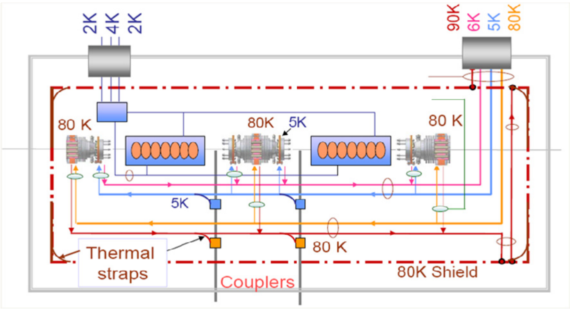


Figure 8: Full HOM and ½ HOM sections assembled for cold test and leak-check.

The assembly of the HOM absorber sections was completed with the same attention to particle levels as that of the cold couplers. As of writing, the full HOM absorber and a first ½ HOM section has been successfully installed and the remaining ½ HOM section is due to be assembled imminently.

CRYOGENICS



HOMs and Couplers in parallel.
Radiation shield in series.

Figure 9: Internal flow schematics of the cryomodule.

During operation the temperature of the structure each HOM will be maintained close to 80K using high pressure cold helium gas [7,8]. Necessary thermal intercepts at 5K have been added to minimise the heat in-leak from the HOM structures to and the cavities (see Figure 9). A special instrumentation scheme using 40 thermometers mounted at various key locations inside the cryostat has been developed (Figure 10).

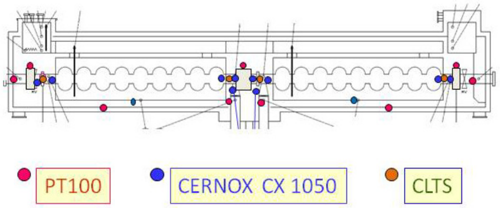


Figure 10: Location of various thermometers mounted inside the cryomodule.

CONCLUSION

Following the lengthy process of ensuring the cleanliness of all components, the cryomodule assembly is due to be complete in several months with the integration of the cavity string into the outer cryostat and magnetic shields. This should allow its installation and validation on ALICE this year.

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