COMPLETED ASSEMBLY OF THE DARESBURY INTERNATIONAL ERL CRYOMODULE AND ITS IMPLEMENTATION ON ALICE

P A McIntosh#, M Cordwell, P Corlett, P Davies, E Frangleton, P Goudket, T Jones, K Middleman, S Pattalwar, J Strachan and A Wheelhouse, STFC Daresbury Laboratory, Warrington, UK.
G Hoffstaetter, M. Liepe, H. Padamsee, P. Quigley, J. Sears, V. Shemelin and V. Veshcherevich, Cornell University, Ithaca, USA.
S. Belomesnykh, Brookhaven National Laboratory, New York, USA.
D. Proch and J. Sekutowicz, DESY, Hamburg, Germany.
A. Buechner, F. Gabriel and P. Michel, HZD Rossendorf, Dresden, Germany.
J. Corlett, D. Li and S.M. Lidia, LBNL, Berkeley, USA.
T. Smith, Stanford University, Stanford, USA.
R. Laxdal, TRIUMF, Vancouver, Canada.

Abstract

The completion of the integration of an optimised SRF cryomodule for application on ERL accelerators has now culminated with its successful assembly, following an intensive 5 years of development evolution. The cryomodule, which incorporates 2 x 7-cell 1.3 GHz accelerating structures, 3 separate layers of magnetic shielding, fully adjustable and high power input couplers with fast piezo tuners, is nearing its installation readiness on the ALICE ERL facility at Daresbury Laboratory. It is intended that its implementation will permit operational optimisation for maximised efficiency demonstration, through increased Q_{ext} adjustment, whilst retaining both effective energy recovery and IR-FEL lasing. The collaborative design processes employed in completing this new cryomodule development are explained, along with the assembly and implementation procedures used to facilitate its proposed installation on the ALICE ERL facility at Daresbury.

INTRODUCTION

The engineering and technology development of a new type of SRF cryomdoule, explicitly designed for CW application on high current ERL facilities, is nearing its critical stage of hardware completion. The preferred technology solutions for this cryomodule which include; 7-cell 1.3 GHz cavities, ferrite beam-pipe HOM absorbers, high power adjustable input couplers and 3 independent layers of magnetic shielding, are all intended to achieve an overall performance level of >20 MV/m at a Q_o of $>10^{10}$, in what has been a truly collaborative development programme. The design attributes for which have been reported elsewhere [1], with appropriate technical solutions proposed to match the overall boundary constraint, for ensuring the new cryomodule maintains plug compatibility with the existing ALICE ERL cryomodule and its associated support services.

CAVITY STRING ASSEMBLY

Sub-component testing and qualification of all cryomodule elements has been completed [2] and preparation for the cavity string and cryomodule assembly has also been performed. The critical QA controls and cleanroom provisions, governing the cavity string assembly have been pre-determined and implemented in the Engineering Technology Centre (ETC) at Daresbury Laboratory. The magnitude and criticality of this assembly, is the first of this type of process that the RF and technician personnel have undertaken at Daresbury and so utilising the specialist SRF team at Cornell University, they have been advising and consulting throughout every stage of the assembly activity. Even in the ISO-4 (Class 10) cleanroom environment, the assembly personnel at Daresbury have been able to communicate and transmit real-time video and audio to the remote Cornell team, which has considerably expedited and safeguarded the assembly progression and has provided an additional level of administrative control, thereby significantly benefitting the overall assembly process.

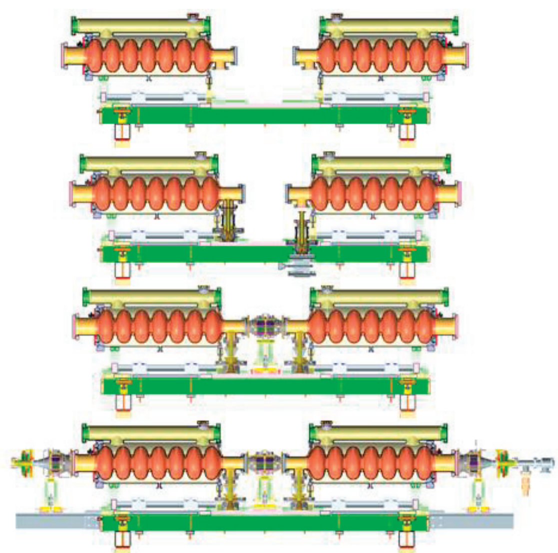

Figure 1: Cryomodule cavity-string assembly process.

The critical cleanroom assembly stages have required the two 1.3 GHz, 7-cell cavities to be pre-aligned and positioned on the assembly fixture support frame, prior to implementation of the cold-coupler sections. Once

#peter.mcintosh@stfc.ac.uk

attached, the HOM absorbers are then positioned and attached to each of the cavities, starting with the central HOM absorber which connects both cavities together. The two half-HOM absorbers are then attached at the end of each cavity and the process is concluded by adding the bellows and cryomodule end-cap interfaces. A leak check versification is then performed to confirm the cleanroom assembly process. Figure 1 highlights the cavity string assembly stages which have been completed.

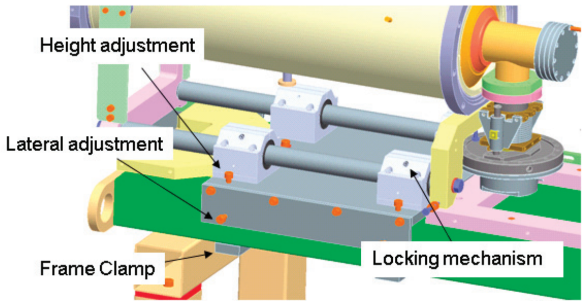

Figure 2: Cavity alignment and rail fixtures.

Once brought into the cleanroom, the two cavity vessels are loaded onto the cavity string assembly frame and installed on a rail fixture which has provision for both height and lateral adjustment (see Figure 2). This then allows for re-positioning of each of the cavities with provision maintained for beamline concentricity as each of the additional cavity string components are included.

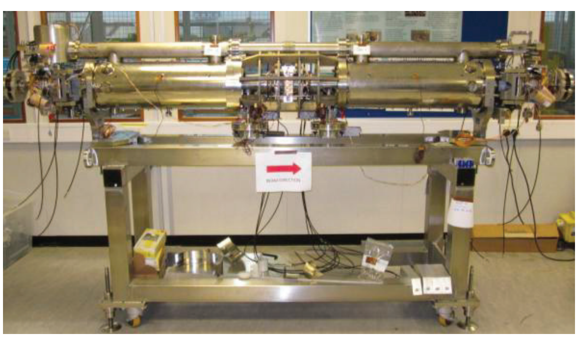

Figure 3: Cavity string integrated assembly.

To minimise the time correcting alignment when the cavity flanges are open, fixtures have been included which allow the HOM absorbers to be accurately positioned prior to physically removing the connecting flanges from both vessels. With the cavity string fully assembled and a leak check verification performed, the assembly frame was removed from the cleanroom and installation of the instrumentation, cryogenic pipework (incl. 2-phase line), cavity tuners and permanent HOM support fixtures were all completed, ready for loading into the outer cryomodule vessel (see Figure 3).

WARM COUPLER ASSEMBLY

The warm couplers have been installed with the module rotated by 90 degrees, using a specially designed rotation fixture. The coupler and warm window installation was then carried out under an ISO-5 (Class 100) portable laminar flow (see Figure 4). The main difficulty encountered during this process was retaining the RF gaskets in the location grooves whilst preserving the alignment and cleanliness of all of the warm coupler components.

Figure 4: Warm coupler installation.

CRYOMDODULE COLD TESTING

In order to facilitate CW mode of operation, the cryomodule has received several modifications in terms of its integrated cryogenics instrumentation [3] and it has been necessary to validate such diagnostics and qualify the cryomodule prior to its installation on ALICE. A major change in the cryogenic operation is using cold helium gas (single phase flow) instead of the liquid nitrogen (two phase flow), to cool the thermal shields, couplers, HOMs and associated thermal intercepts to minimise microphonics instabilities.

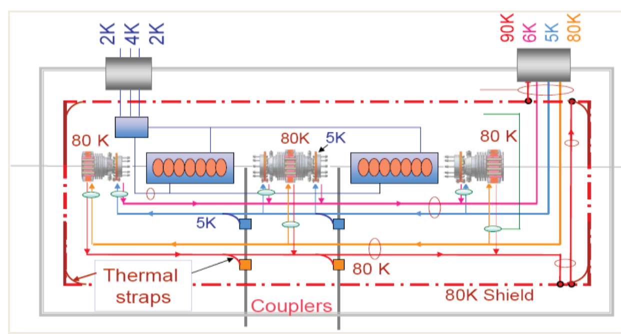

Figure 5: Schematic of the gas cooled cooling circuits inside the cryomodule.

The existing cryogenic system on ALICE has been modified to provide additional cooling power at intermediate temperatures [4]. However, this change has made the cryogenic process more complicated, as the cavity string assembly inside the cryomodule experiences several temperature transitions: 300K - 80K - 5K - 2K - 5K - 80K as shown in Figure 5. About 30 additional thermometers have been installed to map the thermal performance of the cryomodule, encompassing the two cooling circuits 5K - 6K and 80K - 90K, which are connected in series to cool the various components.

Several quality control tests [5] have been undertaken during the intermediate stages of the assembly process, in

ISBN 978-3-95450-115-1

order to gain confidence in the reliable operation after commissioning. It is planned to test the performance of the fully assembled cryomodule in two stages – first at 80 K and then at 4 K. The cryomodule has successfully passed the first cryogenic performance tests at 80 K and Table 1 shows some of the preliminary results.

Table 1: Preliminary results of the first cold test to 80 K.

Parameters	Measured*	Specification
Static Heat Load at 80 K (HOMs, Thermal shield and intercepts.)	~ 7 W	20 W
Static heat losses for the cavities at 80 K	~ 3.5 W	15 W at 4 K
Delta T across thermal shield at equilibrium	< 5 K	<10 K
Delta T across the 2 cavities during cooldown	< 5 K	<5 K

**The value should be considered only qualitative as it is difficult to measure the heat losses with continuous two phase flow of LN_2. Improved results will be available after the cold tests at 4K*

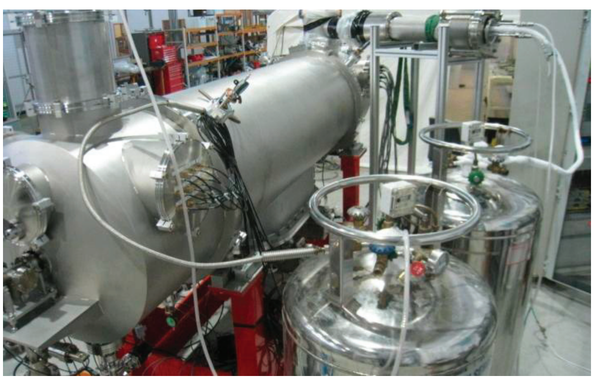

Figure 6: Cryomodule undergoing final cold testing prior to installation on ALICE.

During this cold testing process (see Figure 6), the cavity 2 tuner mechanism was found to stop functioning at 240 K. Freezing of moisture at critical locations on the tuner motor and/or mechanism was considered to be the primary cause of the problem. In order to remove any residual moisture in the isolation vacuum region of the cryomodule where the tuners are located, extensive pump and purge operations were undertaken with the outer cryomodule vessel being baked up to 70°C. This operation has improved the base vacuum pressure by about an order of magnitude, achieving 2 x 10^{-5} mbar. Detailed investigations are ongoing to understand and resolve this recent problem. The performance tests will be extended to 4 K using liquid helium upon resolution of the tuner problem.

ALICE INTEGRATION

To provide the required 5 K and 80 K gaseous helium (GHe) supply for the new cryomodule on ALICE, a secondary heat exchanger system (designated COOL-IT; COOLing to Intermediate Temperatures) has been developed which taps off available 300 K, high pressure GHe from the main compressor, plus an additional LHe feed from the 4 K reservoir dewar. The high pressure GHe circuits at 80 K and 5 K are then generated via the heat exchanger box, which is located close to the ALICE ERL cryomodule as shown in Figure 7.

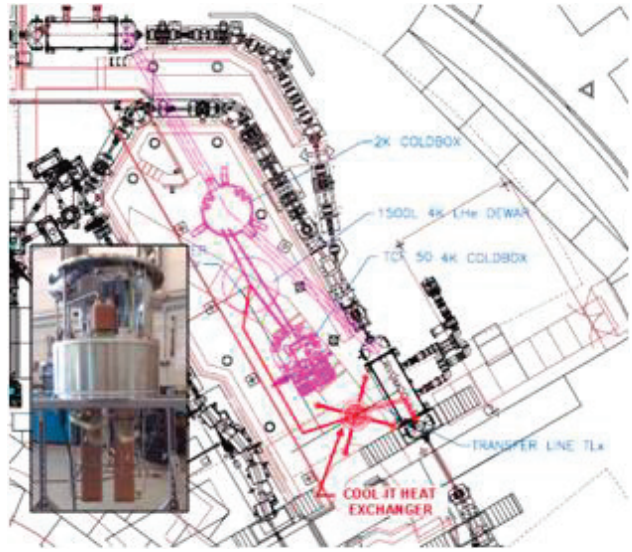

Figure 7: ALICE cryoplant modifications, (inset) COOL-IT heat exchanger.

CONCLUSIONS

Assembly of the new international collaboration cryomodule has been successfully completed at Daresbury Laboratory and preliminary cold testing at 80 K performed. Thermal management characterisation has demonstrated improved performance compared to the original specification. Problems with a stuck cavity tuner at cryogenic temperature are currently being investigated, following which 4 K verification tests will be conducted. Installation of the cryomodule on the ALICE ERL facility will occur later this year, including integration to the new COOL-IT heat exchanger system.

REFERENCES

[1] P. A. McIntosh et al., "Development of a prototype superconducting CW cavity and cryomodule for Energy Recovery," EPAC06, Edinburgh, pp 436-438, (2006).
[2] P Goudket et al, "Assembly Preparations for the International ERL Cryomodule at Daresbury Laboratory", SRF11, Chicago, (2011).
[3] S. Pattalwar et al, "Instrumentation and Control system for the international ERL Cryomodule", SRF2009, Berlin, pp 710-712, (2009).
[4] S. Pattalwar and R. Bate, "COOL-IT A heat exchanger system to provide gaseous helium at intermediate temperatures for SRF LINAC", Advances in Cryogenic Engineering, 55A, pp 595-600, (2010).
[5] S. Pattalwar et al, "Intermediate Quality Control tests in the development of a Superconducting RF Cryomodule for CW operation", Proceeding of CEC 2009, Tucson (2011).