INTEGRATION, COMMISSIONING AND CRYOGENICS PERFORMANCE OF THE ERL CRYOMODULE INSTALLED ON ALICE-ERL FACILITY AT STFC DARESBURY LABORATORY, UK

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Abstract

On successful completion of the assembly and preliminary testing of an optimised SRF cryomodule, being developed under international collaboration, for application on ERL accelerators, the cryomodule has now been installed on the 35 MeV ALICE (Accelerators and Lasers in Combined Experiments) Energy Recovery Linac (ERL) facility at STFC Daresbury Laboratory. Existing cryogenic infrastructure has a capacity to deliver approximately 120 W cooling power at 2 K, but the HOM (Higher Order Mode) absorbers, the thermal intercepts for the high power RF couplers and the radiation shields inside the cryomodule are designed to be cooled with gaseous helium instead of liquid nitrogen. As a result, the cryogenic infrastructure for ALICE has been modified to meet these additional requirements. This paper, presents our experience with the integration and cryogenic commissioning with some initial results.

INTRODUCTION

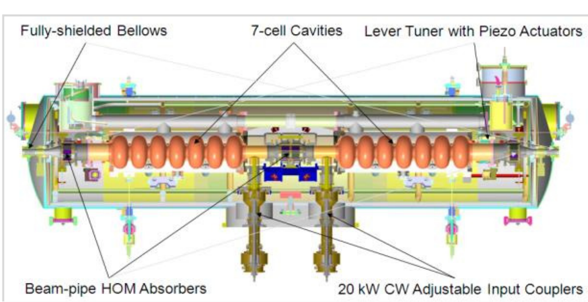

Figure 1: CW-ERL cryomodule under development.

On successful completion of the assembly of the optimised SRF cryomodule (Fig. 1) for CW ERL applications [1], extensive tests were conducted in 2012 to evaluate the cryogenic performance, first with liquid nitrogen and then with liquid helium at 4.2K with the assembled cryomodule (Fig. 2). The main purpose of these offline cold tests were to identify any unforeseen issues that may occur during the installation and commissioning on ALICE Several issues were identified and resolved during the tests, for example - large temperature gradient between the two cavities during cool-down and the lowest temperature reached was only ~8K. Most of these observations could be explained by considering the limitations on the non-ideal test conditions and attributed to the absence of the cooling power at intermediate temperatures for cooling the thermal intercepts on the RF couplers and the HOM absorbers.

Figure 2: Fully assembled cryomodule undergoing Qualification tests.

The cryomodule subsequently passed the offline acceptance tests [2] and was installed on ALICE as shown in Fig. 3 in February 2013. The existing cryogenic infrastructure [3] has a capacity to deliver approximately 120W cooling power at 2K and liquid nitrogen is used as a source for cooling to 80K.

However, for the new CW-ERL cryomodule the HOM absorbers, the thermal intercepts for the high power RF couplers and the radiation shields are designed to be cooled with gaseous helium instead of liquid nitrogen.

This alternative solution was chosen to allow for investigation of microphonics susceptibility and so a special system called COOL-IT [4] was developed to provide COOling power at Intermediate Temperatures and has been integrated with the main cryogenic system for ALICE (Fig. 4). Subsequent sections describe the first experience with the process of integration and cryogenics performance observed during the initial cool-down.

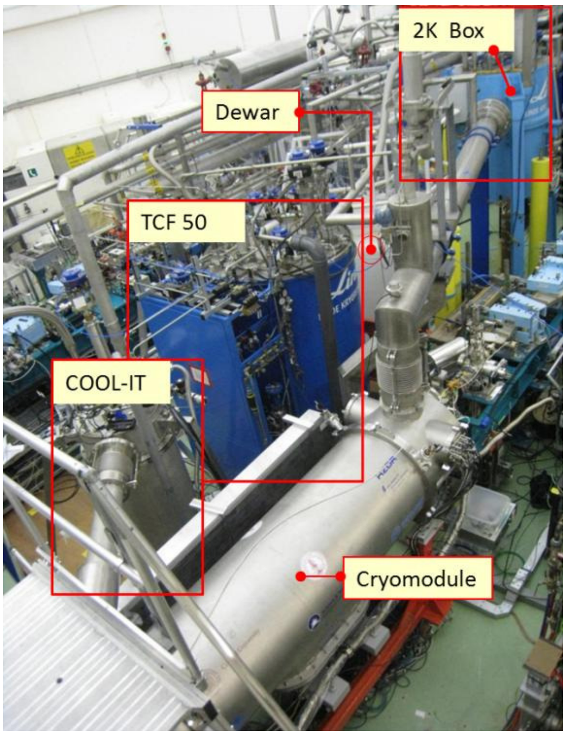

Figure 3: Cryomodule installed on ALICE- 25 MeV ERL facility at STFC Daresbury Laboratory.

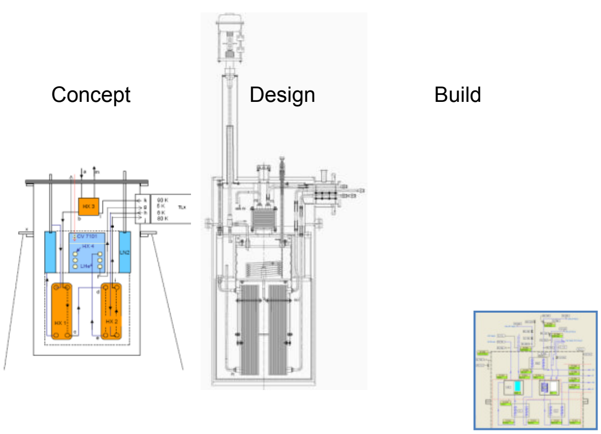

Figure 4: COOL-IT a system to provide cooling power at intermediate temperatures

CRYOGENIC PERFORMANCE

Cool-down to Base Temperature

The cryomodule was successfully cooled to 2K at the first instance and then thermally cycled between room temperature and 2K several times. Cool-down to 130K was very slow and was achieved only by radiation and conduction through the supports as shown in Fig. 5. A large temperature gradient between the two cavities below 100K can be attributed to the floating temperatures of various components, inside the cryomodule.

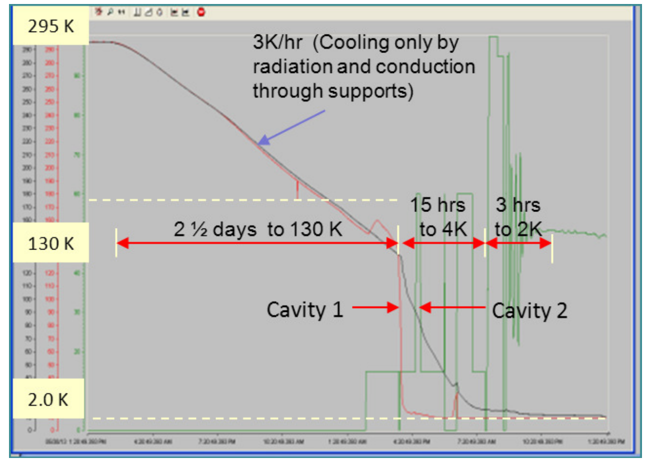

Figure 5: Cool-down to 2K. The red and black curves indicate the temperatures of the two cavities and the green curve shows position of the liquid helium feed valve.

Below 130K the cavities are cooled at a maximum possible rate by fully opening the liquid helium feed valves. Fig. 6 shows the control obtained over liquid helium levels and excellent pressure stability achieved of ±0.05 mbar around an absolute pressure of 30 mbar (Fig. 7) in the helium vessels surrounding the cavities after thermal equilibrium at 2K is attained.

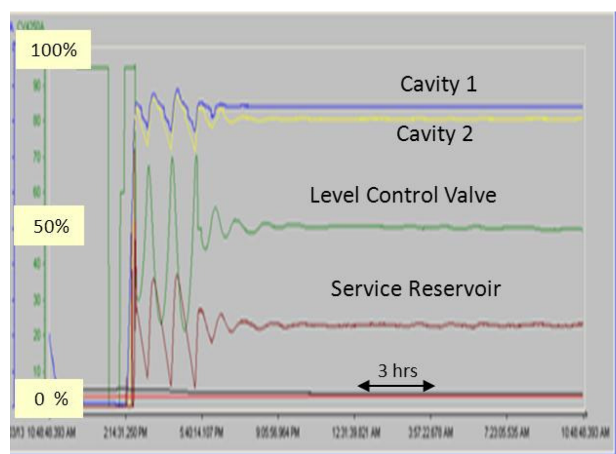

Figure 6: Liquid helium level control after reaching thermal equilibrium at 2K.

Temperature Measurements

In spite of achieving excellent temperature stability repeatedly, actual temperature readings of the cavities as measured using the Cernox temperature sensors appeared to be erroneous. This is likely to be due to the errors in the calibration curves while configuring the measuring instruments. Investigations are underway to confirm this reasoning.

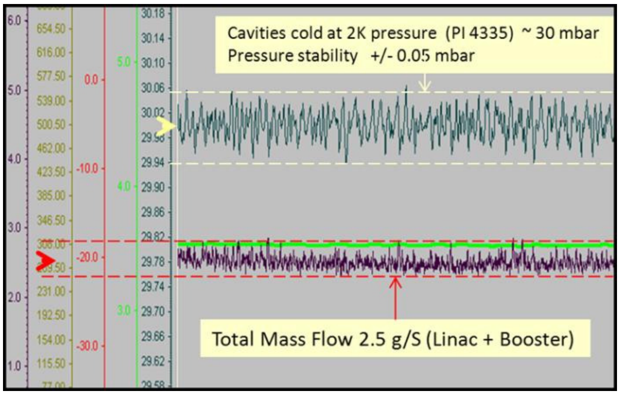

Figure 7: Excellent pressure stability of +/- 0.05 mbar around an absolute pressure of 30 mbar corresponding to a temperature of 2 K.

The thermal shield and the HOM absorbers were cooled to temperatures between 89K and 99K using cold helium gas provided by COOL-IT. The thermal intercepts could be cooled to temperatures between 13.5K and 15.5K instead of a target of 10K, but this is not anticipated to be a major issue, as the static heat load measurements at 2K have been found to be within specifications . The dynamic heat loads have not been measured but the cryo-system has sufficient overhead to handle additional heat leak in the presence of RF power, as along as power dissipation and Q_o for the cavities is within acceptable limits. The primary RF interlocks for the couplers have been set by the vacuum level (1.0E-07 mbar) and the secondary interlocks corresponding to temperatures will be set to 5K higher than those measured at thermal equilibrium.

Heat Load Measurements

Table 1: Cryogenic performance measurements under static conditions

Parameter	**Units**	**Value**	**Spec**
Base Temperature	K	2.0	2.0
Static Heat Load	W	6.2	15
Absolute Pressure	mbar	30	30
Pressure Stability	mbar	+/- 0.05	+/- 1.0
Base Mass flow[#]	g/S	2.5	2.5
Dynamic Heat Load	Not yet measured		
Shield temperature	K	89 < T< 99	~ 90
Intercepts (80K)	K	89 < T < 99	~ 90
Intercepts (10K)	K	13.5 < T < 15.5	~10
Cavity Frequency	GHz	1.3	1.3
Tuning Range	MHz	+/- 350	+/- 350

This is a minimum mass flow equivalent to static heat leak for the entire cryogenic system for ALICE including a second (booster) cryomodule.

A summary of heat load measurements [5] is given in the Table 1, showing that all of the basic cooling parameters are within the specification and similar to the SRF LINAC previously operating with ALICE as reported in the reference 3. The temperatures of the thermal intercepts are higher than expected, but should not pose a major problem for the reasons mentioned in the previous section. This situation will certainly improve after optimising operation of COOL-IT. Currently the helium gas pressure is set to a fixed value of 2 barA, but in future it will be controlled automatically via a feedback loop based on the temperature of the thermal intercept on the HOM absorbers.

Initial RF Performance

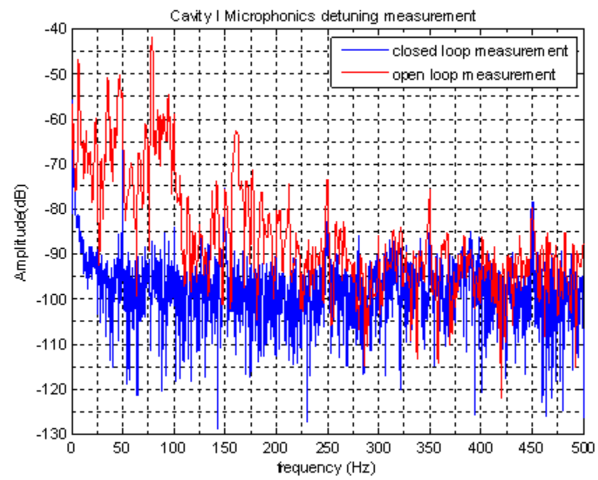

Figure 8: Microphonics tests on cavity 1

The operation of the modified Saclay II tuners was verified by tuning both the cavities to 1.3 GHz at 2K with a tuning range of ± 350 MHz. A digital low level RF (DLLRF) control system has been developed and initial testing with the cryomodule has been successfully carried out. Microphonic behaviour of both the cavities in the cryomodule was also studied, with various low frequency (mechanical) detuning peaks measured, and the DLLRF system has been demonstrated to overcome these disturbances [6]. These were adequately damped by use of a digital phase locked loop as shown in Fig. 8 for cavity 1, with Cavity 2 showing similar behaviour.

SUMMARY AND FUTURE PLANS

The CW-ERL cryomodule was successfully cooled to 2K after installation on ALICE. Initial cryogenic performance, particularly under static conditions is within the specifications. A newly developed digital low level RF system has been provisionally validated successfully by undertaking microphonic measurements. Evaluation of the cryomodule with high power RF initially through conditioning of the cavities and then in the presence the electron beams will resume after optimising the operation of the cryogenic system including COOL-IT over the next few weeks.

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