FIRST COOL DOWN OF THE JUELICH ACCELERATOR MODULE BASED ON SUPERCONDUCTING HALF-WAVE RESONATORS

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Abstract

In the context of upgrading the existing proton and deuteron accelerator facility COSY at the Forschungszentrum Juelich [1], an accelerator module based on superconducting half wave resonators is prototyped. Due to beam dynamics, the requirements of cavity operation and a top-loading design for mounting, the cryostat had to be designed very compact and with a separate vacuum system for beam and insulation vacuum. These restricted requirements lead to very short cold-warm transitions in beam port region and to an unconventional design regarding to the shape of the cryostat vessel [5]. This paper will review the design constraints, gives an overview of the ancillary parts of the module (cavities, tuner etc.) and will present the results of the first cool-down experiments. Furthermore the future work will be presented.

CRYOSTAT DESIGN

The development of the accelerator module was defined by the beam dynamics and by the requirements of cavity operation. In order to reach a high accelerating gradient a separated vacuum system (between beam and insulating vacuum) was needed. Due to the beam dynamics calculations the cryostat layout had to be very compact.

This restricted space together with the need for separated vacuum systems lead to an unconventional design in the beam port region, where the outer vacuum vessel has a round shape, while the diameter changes to an angled surface in the region of the beam tube. Like other accelerator modules a top-loading design approach was chosen to allow for easy and clean mounting. All inner parts (cavities, RF coupler and tuner, helium system, shield cooling as well as magnetic shielding and support structure) are attached to the cryostat top (torispherical head). The separate beam vacuum allows the use of standard cryogenic techniques such as multilayer insulation (MLI) to reduce the heat transfer due to radiation. 30 Layers of MLI are located between the copper sheets of the shield cooling and the magnetic shielding. In the same way the valves at beam axis are mounted together with the other parts at the cryostat top but finally will stay outside the cryostat at room temperature.

The cooling of the cavities is done by liquid helium at 4.2 K. Therefore, a reservoir with approx. 34 l volume is located above the resonators (housed inside individual helium vessels), feeding them via an open-cycle thermosiphon. To keep the system as simple as possible and to allow a stand alone operation, the cooling of the radiation shield and the thermal intercepts is done by using gaseous helium evaporated from the liquid helium reservoir. The temperature of the gas leaving the cryostat is expected to be 50 K during normal operation. Figure 1 gives an impression of the whole cryostat, for a more detailed description see [2] - [5].

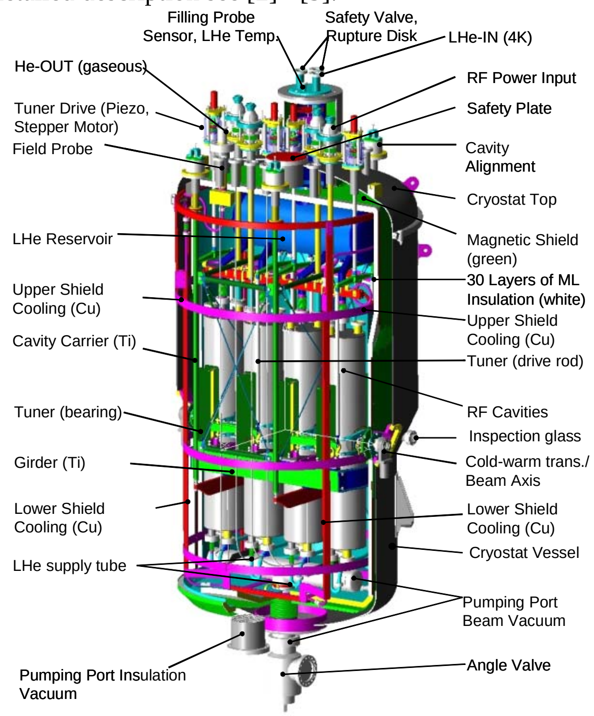

Figure 1: Cryostat Design (Cu sheets of the shield cooling system are partly removed).

To be conform with space requirements and at the same time keep thermal losses low the total length of the cold-warm transition at the beam tube was designed to be less than 70mm but by using two welded bellows on both sides.

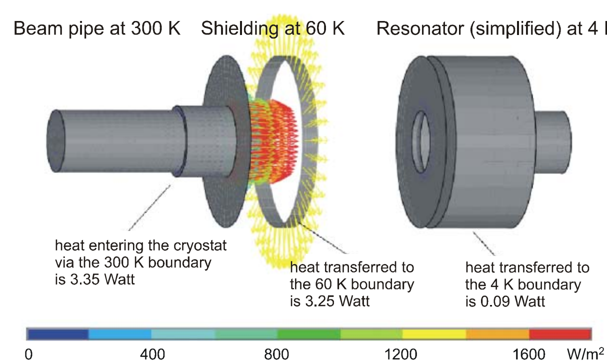

Figure 2: Numerical calculation of the heat transfer for the cold–warm transition at the beam tubes [6].

Figure 2 depicts the results of the calculated thermal energy flow for such a cold-warm junction. The calculated total heat transfer via the beam ports is projected to be less than 0.1 W (due to radiation and heat conductance over the bellows). As the duty-cycle of the accelerator was expected to be only 0.1 %, particularly the static losses of the cryogenic system were minimized, leading to the values listed in table 1.

Table 1: Expected heat losses at 4 K for the cryostat

RF losses	3 W
Input coupler	2 W
Vacuum cold-warm transitions	0.45 W
Tuner	0.9 W
Cavity support	0.95 W
Thermal radiation	0.7 W
Total heat load	8 W

The total heat load to the radiation shield (60K) including all intercept cooling connections amounts to approx. 75W.

EXPERIMENTAL SETUP

All cold tests and measurements were performed beside the former COSY test facility [2], so that the same equipment could be used. That includes the data logging system for 16 temperature sensors, a liquid helium level sensor as well as measurement of pressure (He-system) and vacuum (insulation and beam area). The LHe supply was done by an 800 liter dewar whereas the exhaust helium gas goes back to the central liquefier at the campus of FZJ. The consumption of helium was measured by a gas meter. Figure 3 gives an idea of the experimental setup and figure 4 shows all connections for instrumentation and equipment on the top of the cryostat.

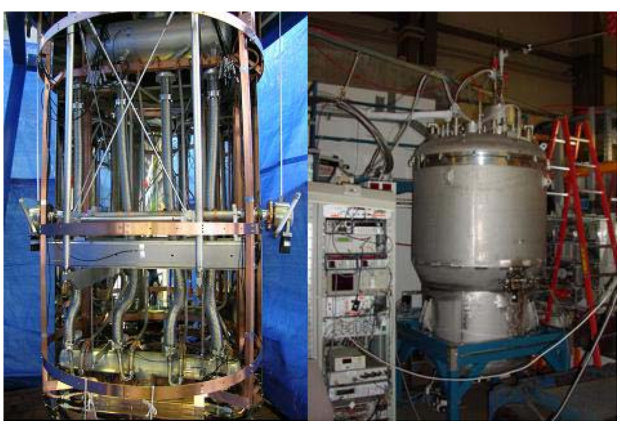

Figure 3: Experimental setup inside the cryostat (without shielding) and at a glance at the facility.

The main intention of the first cold test was to test the functionality of the helium system so that it was possible to substitute four corrugated tubes for the cavities and a simple tube for the beam pipe (see fig. 3). As well the tuning system and the power coupler were not integrated. To simulate the head load of the cavities four thermal resistors (4 W each) were installed.

Inside the cryostat we find 15 thermocouples uniformly distributed between helium system and shielding.

Two vacuum pumps were installed for the two separated vacuum systems.

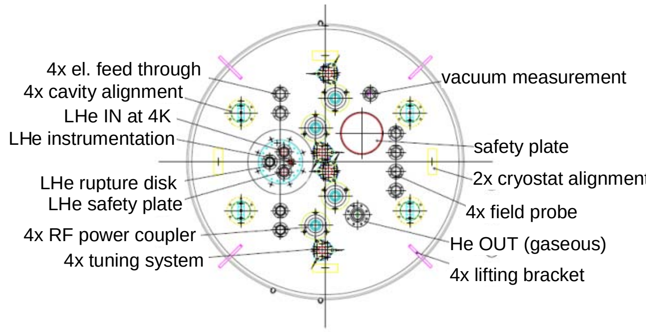

Figure 4: Instrumentation and Measurement Equipment on the top of the cryostat.

FIRST TESTS AND RESULTS

Up to now two tests were done with some important results both for the design of the cryostat and for the way of commissioning. After the first assembly, leakage testing and transport of the cryostat to the test facility some problems were mentioned. First the leakage testing, which was done through the inspection glass beside the beam axis (see fig. 1), causes some damages at the MLI. Second because of the agitation during the transport some of the thermocouples lose contact. The worst problem was that one of the electric feed through becomes leaky when it was plugged in. Therefore only five thermocouples were functional. Together with the lack of LHe supply that first cooling down test was not very effective. The only important result was that the thermal connection of the LHe supply tubes (see fig. 1 and fig. 3) with the vacuum tube was a fault. For this reason no effective cooling of the corrugated tube (as substitute for the cavities) was possible.

After the disassembling of the cryostat the temperature sensors were fixed again and the thermal connection (vacuum tube vs. supply tubes) was removed. Table 2 shows the temperature measuring points for that second test phase.

Table 2: Measuring points for temperature

Thermocouple	Position
T1	cooling shield He-Tank top (cupper)
T3, T13, T15	helium gas tube (exhaust gas)
T4, T10, T14	cooling shield (cupper)
T5	girder (titanium)
T6, T7, T16	Beam tube. cold-warm transition
T8	pumping tube
T9	He-Tank vessel (LHe)
T11, T12	LHe supply tubes cavities

To accelerate the cooling down a pre-cooling with LN2 was provided. Unfortunately the result was worse. The LN2 stays in the supply tubes and the corrugated tubes, which should work like a thermosiphon. That leads to a constant temperature level of 77K (see T11 in fig. 5). Figure 5 shows the change of temperature for four measurement points. After 200 minutes the LHe reservoir was empty so that the cold-warm transition (T7) and the exhaust gas (T13) warms-up whereas the beam tube (T6) gets colder because of the heat conduction. The LHe supply tube (T11) stays at LN2 temperature instead.

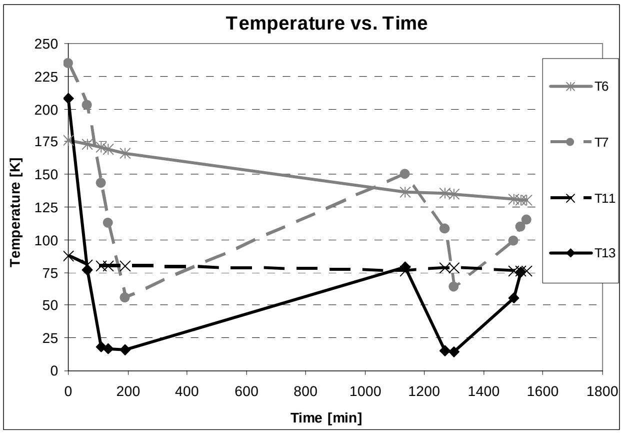

Figure 5: Results after pre-cooling with LN2 (T6: beam tube; T7: c/w-transition; T11: LHe supply tube; T13: exhaust gas).

After that experience the cryostat had to warm-up and the next cooling down starts with the pre-pumping of the helium system. That's makes sure that all the nitrogen and as well all the humidity leaves the system. The new results are shown in Figure 6. All temperatures decrease and within 200 minutes the expected liquid helium level is reached (see T11, T13). After one night without refilling (see T7, T13), LHe still remains in the helium dewar.

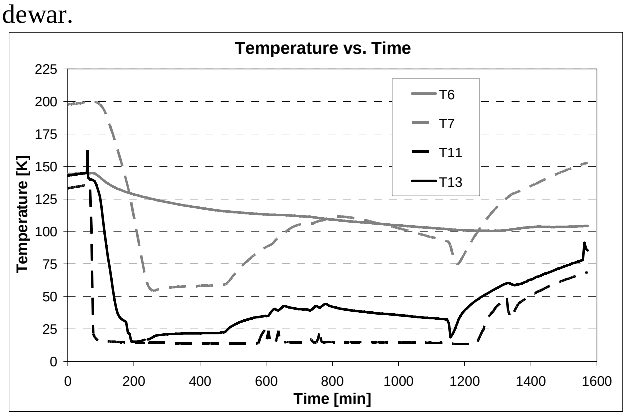

Figure 6: Results after pre-pumping (T6: beam tube; T7: c/w-transition; T11: LHe supply tube; T13: exhaust gas).

During the following tests it was possible to identify the heat loss of the cryostat without RF power to approx. 1 W. Therefore the LHe supply was stopped and the evaporation of helium was measured by a gas meter. In comparison with the expected heat losses (see table 1) the value is about a factor of two lower (only considered the cold-warm transition, the cavity support and the radiation losses).

The simulation of the RF power was done by two thermal resistors after 1150 minutes. In figure 6 the influence on the temperatures are evident. First the temperature of the exhaust gas rises and about 100 minutes later the temperature of the LHe supply tube rises. That indicates the evaporation of the helium inside the tubes. After that a decreasing of the temperatures again was possible, but unfortunately after a couple of minutes the helium Dewar was empty and the system had to warm up.

ACKNOWLEDGEMENTS

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OUTLOOK

The next steps will be another cooling down experiment without cavities but some additional measuring instrumentation (esp. temperature in helium bath and at the shielding) and some changes in the concept of insulation, e.g. additional 10 layers of MLI covering the helium system and the thermal disconnection of the corrugated tubes, which simulate the cavities. Furthermore the cold test with one prototype cavity is designed to be in fall. Then it is possible to test the whole system which means the cavity, the RF power coupler and the tuning system (for more details see [2], [3], [4], [5]).

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