

# CRYOGENIC SYSTEM FOR THE SLS THIRD HARMONIC RF CAVITY

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## Abstract

In order to improve the beam lifetime in the storage ring of the Swiss Light Source (SLS), it is planned to implement a third harmonic (1.5 GHz) idle superconducting RF system. The 2-cell cavity of the SOLEIL type will be operated at Liquid Helium temperature (4.5K). The cavity cryomodule and the associated cryogenic system are described here.

## 1 INTRODUCTION

Presently, the RF system of the SLS storage ring consists of four 500 MHz copper cavities that can generate a total RF voltage of 2.4 MV and deliver 240 kW to the beam. This system proved to be quite reliable in operation during the years 2001-2002 [1].

In order to further improve the beam lifetime, which is dominated by Touschek scattering, it is planned to implement a complementary 3rd harmonic RF system for lengthening the bunches and therefore reducing their charge density [2].

Since the boundary conditions at SLS and ELETTRA are similar, the two laboratories decided to search for a common approach. The chosen solution is the use of an idle superconducting system based on a "scaling to 1.5 GHz" of the 350 MHz two-cell-cavity developed at Saclay for the SOLEIL project [3].

In October 1999, PSI, Sincrotrone Trieste and CEA Saclay concluded a collaboration agreement, the so-called SUPER-3HC Project, with the objective of designing and producing two complete cryomodules, one for ELETTRA and one for SLS [4].

The cavity consists of two Nb/Cu cells, enclosed in their LHe reservoirs; on the tube between the two cells are located the couplers for the damping of the Higher Order Mode (HOM) impedances (Figure 1) [5].

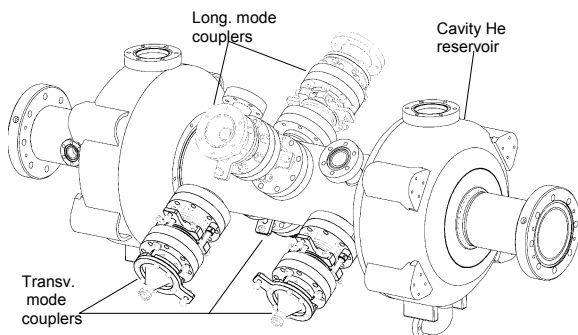


Figure 1: SUPER-3HC cavity with HOM couplers.

Each cell is equipped with its own frequency tuner, a mechanical system, driven by a stepping motor, which changes the cell length within the limits of the elastic

deformation ( $\pm 500$  kHz range, 10 Hz accuracy). In the idle cavity, the beam-induced voltage ( $V \propto \Delta f I_{\text{beam}}$ ) is directly controlled via the frequency tuners. With a cavity voltage of 800 kV (4 MV/m), one anticipates a bunch-lengthening factor of about 3 and that should result in 2 - 3 times longer beam lifetime.

## 2 CRYOGENIC SYSTEM

### 2.1 General Description

Figure 2 shows a scheme of the cryomodule cooling system. The LHe from the Dewar enters the cryomodule through a phase separator (PS1). The two cavity reservoirs are then filled with LHe at 4.5 K from the bottom; they are connected on the top by a common vessel (PS2), which recuperates the cold GHe. Part of this cold gas is returned back to the refrigerator while the rest is used to cool the copper thermal shield (60 K) and the two cavity extremity tubes (4.5 - 300 K). The inner tube and HOM couplers are conduction cooled at 4.5 K. Layers of super-insulation, placed on the shield, reduce the radiated heat from the room temperature parts.

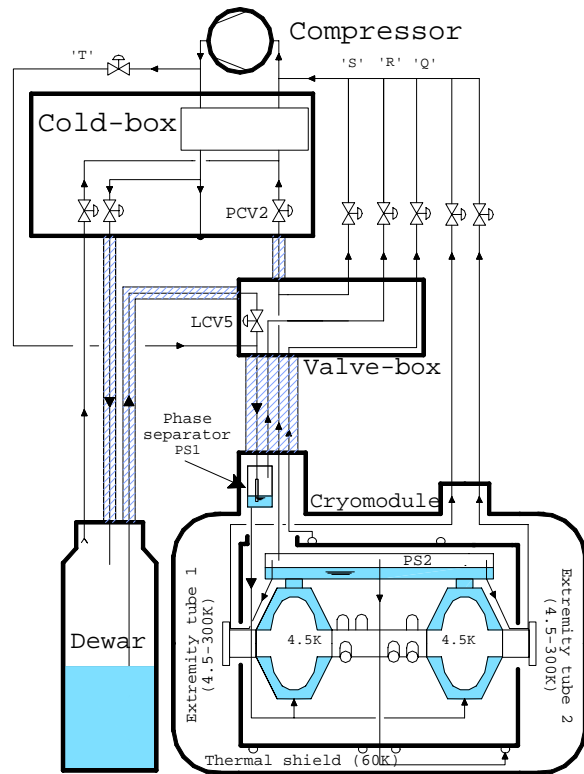


Figure 2: Scheme of the cryogenic system.

The maximum anticipated cryogenic heat load of the different parts (for  $V = 800$  kV,  $I_{\text{beam}} = 400$  mA) are listed in Table 1 [6].

Table 1: Cryogenic load (4 MV/m, 400 mA,  $Q_0 = 2 \cdot 10^8$ )

Components	Load	Comments
2 RF cells	22 W	Directly in LHe bath
2 L-couplers	3 W	Cooled by conduction
4 T-couplers	8.5 W	Cooled by conduction
2 Extremity tubes	0.2 W	With $2 \times 0.05$ g/s cold GHe
Cryomodule static losses	5.1 W	With 0.071 g/s cold GHe in thermal shield (60 K)
Cryo-lines	6.5 W	Assuming 0.5 W/m load
<b>Total refrigeration power at 4.5 K: 45.3 W</b>		
<b>Total warm GHe return: 0.171 g/s <math>\rightarrow</math> 5.2 l/h of liquefaction</b>		

The cryogenic source is a HELIAL 1000 refrigerator-liquefier from AIR LIQUIDE. It consists of a screw-compressor with oil removal unit, a turbine-cold-box and the associated control-command system. The 500 L Dewar, the cryogenic transfer lines and the valve-box are also parts of the AIR LIQUIDE supply. The system is designed to simultaneously provide (in mixed mode) more than 7.5 l/h of liquefaction duty and 65 W of refrigeration power at 4.5 K. That is about 50 % more than the anticipated requirement (Table 1). This margin was considered as sufficient for covering eventual deviation from the calculated values.



Figure 3: The HELIAL 1000 cold-box (Air Liquide)

The “warm operation” of the cryomodule (see section 2.2) is considered as a possible option (in case of cryo-source failure, for instance). At room temperature, although the cavity is detuned and the induced voltage is largely reduced, the beam can still deposit a few hundred watts into the cavity. The cold-box is therefore

isolated (valves LCV5 and PCV2 closed) and the compressor ensures a circulation of “warm” GHe; the lines “T” (inlet) and “S” (outlet) are provided for this purpose. Line “T” is also used to mix GHe with LHe and thus control the temperature of the fluid at the input of the cryomodule during the cool-down process.

Figure 4 shows a simplified layout of the cryogenic system inside the SLS building (the compressor is housed in a dedicated hutch outside). The valve-box, which lies on the ring inner wall, ensures the He distribution between the cold-box and the cryomodule. On one side, it is connected through separate transfer lines to the cold-box (cold GHe return) and to the 500 L Dewar (inlet LHe). A short, standard coaxial transfer line makes the connection between the cold-box and the Dewar. On the other side, a multiple (4-conduit) transfer line connects the valve-box to the cryomodule.

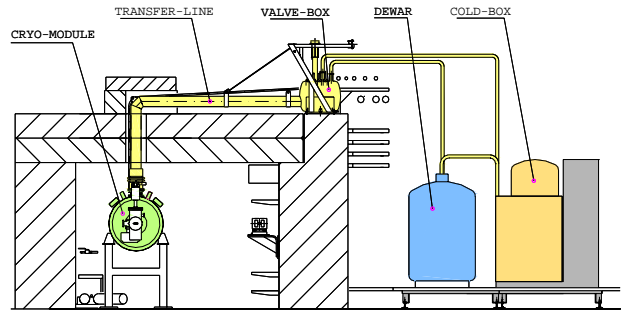


Figure 4: Layout of the cryogenic system

### 2.2 Process Control

A schematic of the cryogenic process control is presented in Figure 6. It is organized around two main machine states, “warm operation” and “cold operation”, and two main transitions, “warm-up” and “cool-down”. Additionally, there are two exceptional states, “warm parking” and “emergency operation”. Starting initially from an idle state with the cavity completely separated from the cold-box and not conditioned, the system goes to the “Ground State Conditioned” (GSC) after a conditioning transient. The GSC is the fundamental state from which the system can go to the “cold operation” state by performing a “cool-down” transition at the issue of a command and reversibly, back to the GSC and then “warm-up”, if a “warm operation” is desired. Also, in case of faults, the system leaves whatever state it has and returns in the GSC. When the cavity is in “cold operation” state, if a cold-box failure occurs, the system goes in the “emergency operation” where the cavity is cooled solely with LHe from the 500L Dewar. In “warm operation”, the beam is active and the cavity is cooled with room temperature He from compressor. During long shutdown periods (no beam), the cavity can be pushed into a “warm parking” state with no He circulation.

A Siemens-7 PLC will locally ensure the process control. For each operation mode or transition state, it will either regulate or monitor all the relevant values of pressure, LHe level, temperature, GHe and LHe flow ,

using the various sensors and the controlled valves of the system. It will be linked to the general SLS control (VME/EPICS) via Ethernet bus for remote control.

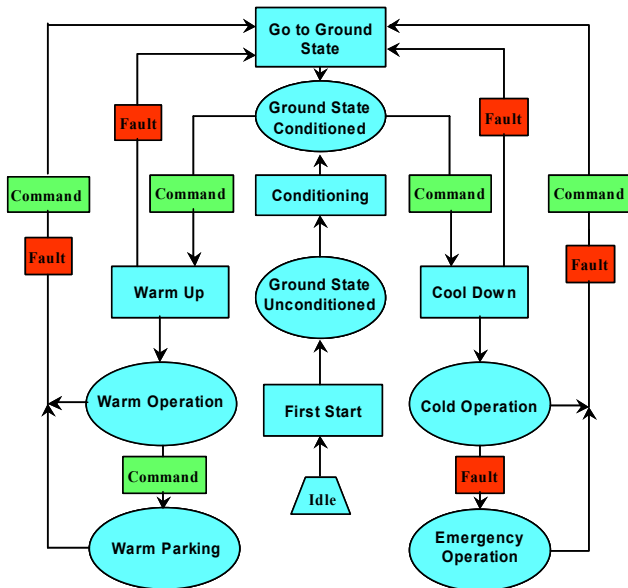


Figure 6: SUPER-3HC cryogenic process control

### 3 PROJECT STATUS

The fabrication and the cold tests of the “bare” cavity at CERN were completed in October 2001. Figure 7 shows the measured quality factor  $Q_0$  (at 4.5 K) versus accelerating field [7]. At the operating field of 4 MV/m,  $Q_0$  is about  $2.6 \cdot 10^8$  for both cells.

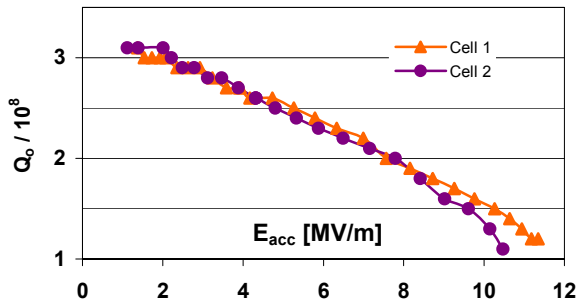


Figure 7: Measured  $Q_0$  (at 4.5 K) vs. field for the 2 cells.

Tests of the complete cryomodule (Figure 8) at CEA-Saclay confirmed the previous results [8].

The cryogenic source is being installed in the SLS and should be commissioned in June, using the Dewar with an internal heater as dummy load.

The installation of the cryomodule in the SLS ring is scheduled in the shutdown of June 2002. It will be operated in the “warm regime” with beam for one month and then cooled down during the shutdown of July for the final commissioning in “cold operation” with beam.



Figure 8: Cryomodule assembly

### 4 REFERENCES

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