SUCCESSFUL RF AND CRYOGENIC TESTS OF THE SOLEIL CRYOMODULE

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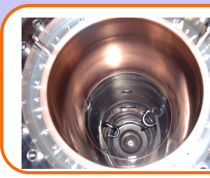


What the electron beam can see when entering the cavity

Brief history :

During the SOLEIL Design Phase, it was decided that the RF system of the SR will be based on the use of superconducting 352 MHz cavities in order to optimise the transfer of power to the beam and prevent coupled bunch instabilities that could be driven by parasitic HOM of the RF cavities.

In June 1996, CNRS, CEA and CERN concluded a collaboration agreement for the design, fabrication and test of a cryomodule prototype.

In December 1999, during the first power tests of the prototype at CERN, an accelerating gradient of 7 MV/m was reached with 120 kW (fully reflected) through each input power coupler (IPC).

In December 2001, the cryomodule was installed on the ESRF SR in order to validate the performance with high intensity beam. The results were quite satisfying : with 3 MV of accelerating voltage and 190 kW through each IPC, the cryomodule contributed to store up to 180 mA of electron beam at 6 GeV. On one hand, the achieved performance met the requirement for the first phase of operation (stored current of 300 mA and reduced number of insertion devices); on the other hand, these tests pointed out a few weak points that could be easily improved before the installation at SOLEIL.

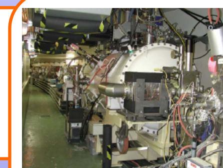
Therefore, it was decided by the end of 2002 that, after a refurbishment, the prototype will become the cryomodule n°1 of SOLEIL, the only one for the first phase of operation. The full performance at 500 mA shall be achieved by implementing a 2nd cryomodule about one year later.

Summary of the Tests at the ESRF in 2002 :

Four test periods were carried out. Each run allowed 17 hours of stable operation at 4K with LHe from Dewar. The SOLEIL cryomodule contributed to store up to 180 mA of electron beam at 6 GeV, by generating a peak RF voltage of more than 3 MV, with a power of about 190 kW through each IPC ; a RF voltage of 4 MV was simultaneously provided by the ESRF normal conducting cavities. The ESRF tests have also pointed out a few weak points :

- undue high fundamental power (~ 2 kW instead of the expected 100 W) was coupled out through the T-type HOM couplers, due to the detuning of their rejection filter,
- relatively poor cooling, it resulted in overheating that produced quench-like events with pressure bursts in the He tank,
- total static losses were evaluated around 120 W, which is 50% larger than predicted.

In December 2002, the cryomodule was removed from the ESRF and transferred to CERN for a refurbishment, aimed at improving the previously mentioned weakness.



SOLEIL Cryomodule in ESRF tstorage ring1

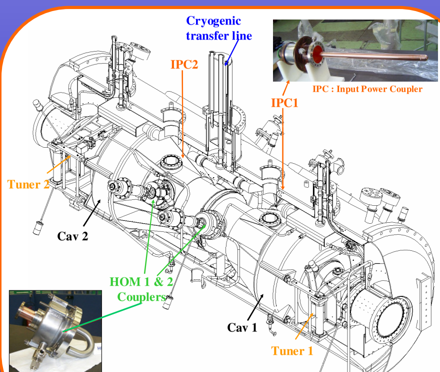
Upgrading of the Cryomodule Prototype

T-type HOM couplers : located relatively close to the cavities, a notch filter is required to reject the coupling at the fundamental frequency. This filter is tuned by adjusting the gap between the stub and the coupler walls, thanks to a single wave bellow. Unfortunately, on the prototype, the bellow flexibility did not meet the initial specifications and thus prevented from tuning the filter. The design and fabrication process of the single wave bellow has been revised; after reshaping, it was machined and welded to the coupler bell. In order to improve the cooling efficiency, the LHe feeding connection was moved towards the cryomodule bottom.

Reducing the high static losses, a copper thermal shield, cooled by liquid nitrogen, has been inserted. Thermalisation straps anchored on the shield were introduced to draw heat from the HOM couplers, the bulky tuning system, the coaxial lines, etc… The He circuitry was modified to accommodate the shield.

IPC coupling was increased in order to better match the different possible operating conditions of SOLEIL, Q_{ext} = 1 10^5 instead of 2.2 10^5, initially. For this purpose, the IPC antennas had to be cut and lengthened by 9.8mm.

Instrumentation, used for the cryomodule prototype tests, had to be replaced with radiation-proof components. In addition, temperature sensors with wider operating range were mounted for proper survey of the cool-down from room temperature to 4K; each of them is mounted on a sensor holder.

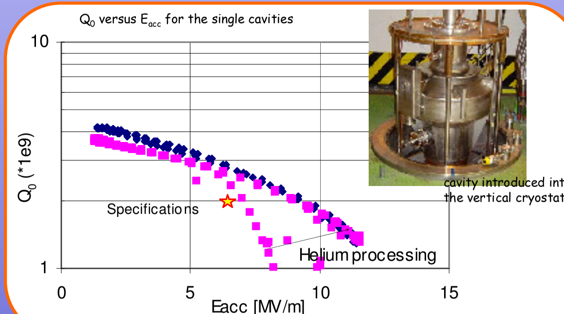


SOLEIL Cryomoudle

Cryomodule partially dismounted in front of the CERN clean room

Thermal shield insertion in vacuum tank

T-type coupler assembling



IPC assembling inside the CERN clean room

SUCCESSFUL CRYOMODULE TESTS AT CERN AFTER REFURBISHMENT

In the framework of a collaboration with CEA and CERN.

The cryomodule was dismounted during the last quarter of 2003.

The cavities were rinsed and re-tested in a vertical cryostat. The measured Q_0 of each cavity is larger than the specified value of 2 10^9 at Eacc of 6 MV/m.

After re-assembling in autumn 2004, the first cryogenic and RF power tests were carried out during December 2004, in spite of the missing T-type HOM couplers. The cryomodule was supplied in He from a CERN 18 kW liquefier, through a buffer Dewar. The tests demonstrated that :

- the insertion of the thermal shield reduces the cryogenic losses by more than a factor 2, from 117 W down to 51 W. The lower cryogenic losses allowed to regulate the LHe at 50% of the collecting box volume, insuring that the He fed into the HOM couplers is liquid.
- the lengthening of the antennas well resulted in the anticipated Q_{ext} of 1 10^5 (± 1 10^4).

After mounting the T-type HOM couplers, the second cryogenic and RF tests were completed in February 2005. Each IPC was conditioned up to **200 kW CW with full reflection** and an **accelerating voltage of more than 2.5 MV** was achieved in each cell. This performance exceeds the requirements for the SOLEIL normal operation : 150 kW per coupler and 1.5 MV per cavity.
The notch filter of the T-type HOM coupler has proved to be easily tuneable and the rejection of the accelerating mode is -34 dB (instead of -19 dB obtained with the previous HOM couplers).
In addition, one could verify the functionality of the tuner, driven with the standard control unit of SOLEIL.

The cryomodule is now waiting at CERN for a few minor modifications before its final installation in the SOLEIL SR, scheduled for Autumn 2005. An intervention is scheduled in August for the mounting of two HOM coaxial lines, which are still under repair as well as motor encoders, which are presently under tests at CEA.

Cryomodule in the CERN test facility