POWER TESTS OF THE SOLEIL CRYOMODULE

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Abstract

The assembling of the SOLEIL cryomodule has been completed at CERN. Power tests of the two 352 MHz Nb/Cu cavities, designed to damp efficiently all the High Order Modes (HOMs), have been carried out. The results of RF and cryogenic measurements, as well as the running of some critical elements, are presented.

1 INTRODUCTION

For the Synchrotron Light Source SOLEIL, we studied and built the accelerating cryomodule of the main ring. The goal of such a system is, on the one hand, to deliver to the electron beam a CW RF power of 400 kW, in order to compensate for the energy lost over one turn, and on the other hand, to ensure the beam stability.

Studies, construction and tests of the complete cryomodule have been carried out in three years:

- Studies and optimization on a copper model of the RF system
- Mechanical studies and drawings
- Construction of the different parts of the cryomodule
- Assembly (Fig. 1) and tests at CERN (from 09/1999). The first power test was performed at the beginning of December 1999, and the two cavities easily reached the nominal accelerating field.

The campaign of tests made at CERN demonstrated the potentialities of this original system we have developed. Main results are presented in this paper.

2 GENERAL CONCEPT

The concept of a “mono-mode” accelerating structure has been applied in an original way, since the RF structure has the particularity to be composed of two superconducting cavities strongly coupled for the High Order Modes (HOM) [1]. These parasitic modes, induced by the beam but harmful for its stability, are heavily damped by superconducting loop couplers of the same type as those already used for LEP and TTF, but with from 10 to 100 times higher damping factors.

The optimization of these HOM couplers as well as of the complete RF structure, has been made first on a copper model. We already presented the design of these couplers in previous paper [2]. With two pairs of couplers, dedicated respectively to longitudinal and transverse HOMs, the measurements have shown that the required dampings were obtained with a satisfactory safety margin.

3 TEST OF THE CRYOMODULE

3.1 Cavities

The tests made at CERN have shown the stability when running the cryomodule at 4.5 K and with RF power. The accelerating fields initially required for the SOLEIL operation (4.5 MV/m) have been reached with a large enough safety margin (>30%). Moreover, the very small electron field emission at the maximum gradient proves that the assembling of the cavities has been done in very clean conditions.

3.2 Main couplers

During the tests, a fully reflected power of 120 kW has been applied to each main coupler (LEP type II, provided by CERN). With this power level, the arbitrary limit on the gradient of 7 MV/m was reached. Note that, during previous tests, these couplers had reached a RF power level exceeding 250 kW [3].

3.3 HOM couplers

During these tests at 4.5 K, the coupling to the fundamental as well as to some HOMs has been verified.

Due to the orientation and the position of the longitudinal HOM couplers, there is no need to incorporate in the design a notch filter to reduce coupling to the fundamental mode. Indeed, the measured coupling to the fundamental mode ($Q_{ex,fund.} \approx 10^{10}$ at 4.5 K) is low enough.

On the contrary, for dipole HOM couplers, such a filter is needed in order to properly reject the fundamental mode. Though the tuning of the filters has not been completely optimized yet ($Q_{ex,fund.} \approx 10^{8}$ and 410^{8}), it was not a limitation for these tests. The tuning is still progressively improved, and the optimization procedure has to be determined on this prototype cryomodule.

However, the required dampings for both longitudinal and transverse modes at 4.5 K are reached. This is of great importance to ensure beam stability.

Due to fabrication and delay problems, only one HOM coupler of longitudinal type is mounted. The second one is now available and will be mounted for the next test. Another important point, namely the extraction of the HOM power outside of the cryomodule, could not be tested without beam. A semi-rigid coaxial line has been designed for the extraction of several kW of HOM power in the 400 to 1200 MHz bandwidth. These coaxial lines

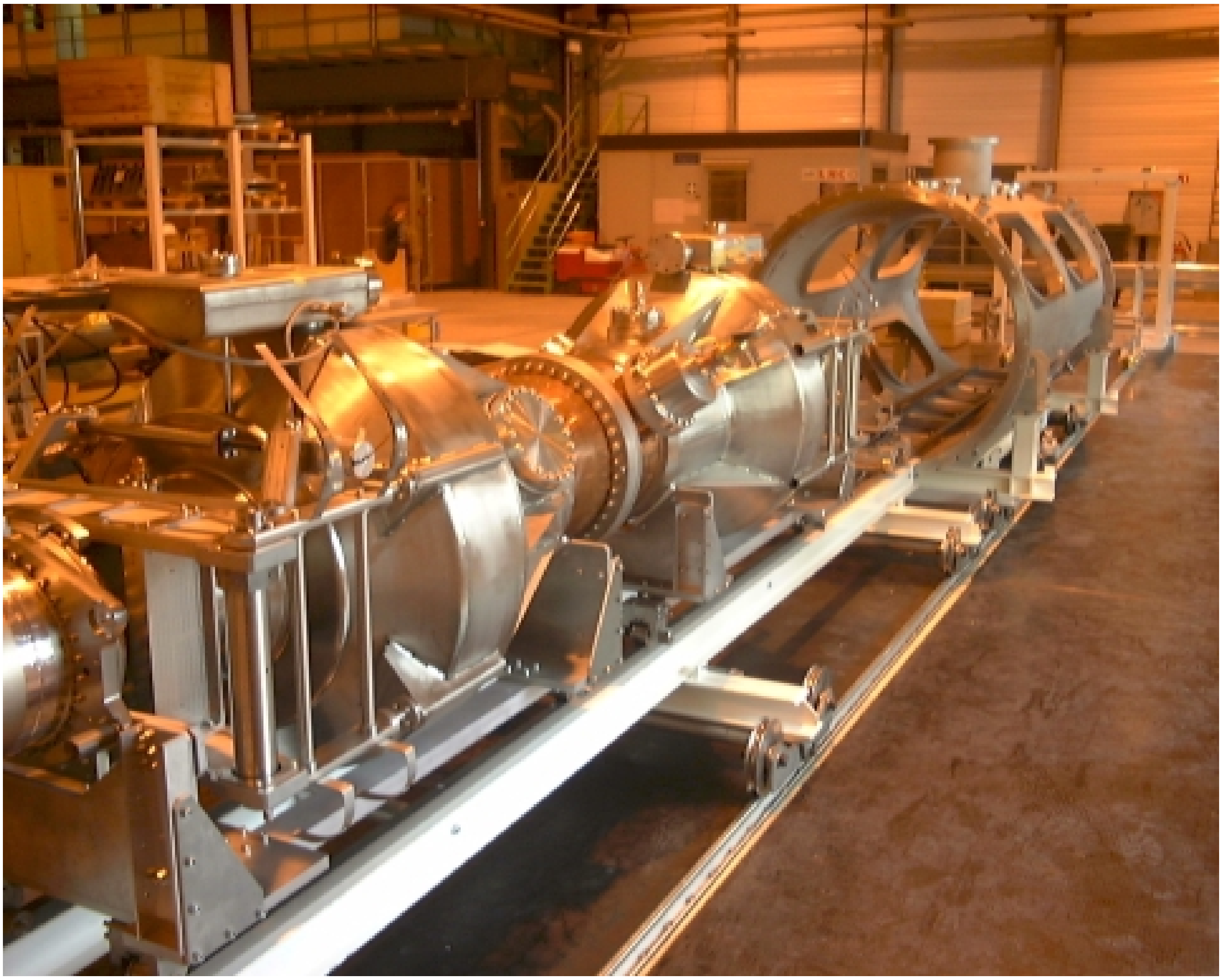

Figure 1: Assembly of the SOLEIL cryomodule at CERN

will be tested first with RF power at Saclay, before being mounted in the cryomodule for the tests now planned at ESRF (§ Ch. 4).

3.4 Cryogenic losses

Static losses were measured at about 20W, which is lower than expected [4], thanks to the care taken in the mounting of the super-insulation, as well as the good stabilization of the liquid helium (LHe) level around the cavities.

The operation of the phase separator and of the Helium forced circulation inside the HOM coupler loops could not be validated. This is mainly due to the fact that the cryomodule was not designed to run with the CERN cryogenic plant because it delivers liquid Helium having too a high gas ratio. Next tests will be performed with a large phase separator placed just before the supply of the cryomodule in order to simulate conditions close to those of a SOLEIL run.

For the same reason, we could not determine the power dissipated in the two cavities at nominal field. However, it had already been precisely measured in vertical cryostat (Pdiss=24 W at 4.5 K and 4.5 MV/m).

Taking into account estimated losses of the extraction system for 10 kW HOM power, we evaluate the total cryogenic losses at 85 W. This is about 30% lower than initially estimated.

3.5 Behavior of other elements

The cold tuning system [5] has a measured sensitivity of 170 kHz/mm, in good agreement with calculations. Its resolution is smaller than 10 Hz, its possible range +/– 3 mm and its linearity and reversibility are very well satisfied. The measured mechanical stiffness of 55 kN/mm ensures the required stability during operation. However, the mechanics jammed during long term cold tests. The reason is the lack of adherence of the lubricating carbon layer on the main screw due to an imperfect surface state. This is not matter of concern, since similar systems, with right preparation, have already shown a good and reliable behavior on Tesla Test Facility.

The cooling of the external tube linking the cavities at 4.5 K to the vacuum tank at 300 K and ensured by a helium gas flow is fully satisfactory. This system will be especially active to evacuate the power dissipated by HOMs with frequency higher than 1 GHz when working with a beam.

No mechanical problem occurred during the thermal cycles of the cryomodule. The use of bellows "seen" by the beam was rejected to reduce any extra RF losses. Thus, during the cool down, bellows located outside the beam tube between the cavities and the vacuum tank end flanges compensates the shrinking of the cavities. In the same time, the power couplers move by about 2 mm along the cavity axis, and to prevent any failure of the alumina window, we designed free doorknob supports to accommodate this displacement.

4 FUTURE PLANS

ESRF is interested in testing the SOLEIL cryomodule, and proposed to install it on their main ring. Fruitful discussions, in particular with J.M. Filhol and J. Jacob, led us to plan three series of tests at Grenoble during year 2001:

- Cavities at room temperature with beam
- Cavities at 4.5 K with beam but without RF power
- Cavities at 4.5 K with beam and RF power

These experiments will allow a complete validation of the cryomodule since frequency and beam intensity are fully matched for it.

Modifications of the system are in progress to prepare these tests. The cryomodule will be sent to ESRF after we completed the essential following operations and tests:

- Mounting in clean room the missing HOM coupler for longitudinal modes
- Repairing the main screw of the cold tuning systems
- Improving the thermalisation of HOM couplers and tuning systems
- Verifying the LHe cooling of the HOM coupler loops
- Mounting the coaxial lines dedicated to the extraction of HOM power

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