GENERAL LAYOUT OF THE SOLEIL SRF UNIT

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Abstract

A superconducting RF system is under study for the Synchrotron Light Source SOLEIL in a collaboration of CERN and CEA Saclay. The cryostat will contain two 352 MHz Nb/Cu single cell cavities. These cavities will be strongly coupled through a large beam pipe which allows the damping of HOMs by superconducting couplers. The high frequency HOM power will be dissipated outside the cryostat along the tapered metallic transitions.

1 Introduction

The development of a superconducting RF system for the storage ring of the synchrotron light source SOLEIL is under way in a collaboration with CERN.

SOLEIL is a synchrotron light source project aiming at covering the spectral range between 10 eV to 10 keV (VUV-X Rays). The storage ring is about 100 m in diameter, the linac and the booster are located inside [1]. The relevant parameters of the machine are given in table 1. The beam current needed for the high brilliance multibunch mode is 500 mA, the energy is 2.5 GeV, and the bunch length is about 4 mm. These beam characteristics (with a total rf buckets filling by 396 bunches) generates a high power of HOMs which have to be efficiently damped in order to reduce the beam instabilities to an acceptable level. Superconducting cavities with large apertures allow the propagation and the damping of the HOMs outside the cavity cells.

This paper presents the general layout of the SRF system (Fig. 1) which is in development : the two 352 MHz asymmetric cavities powered by the two type LEP couplers, the HOM dampers, the tuning system, and the cryogenic supply.

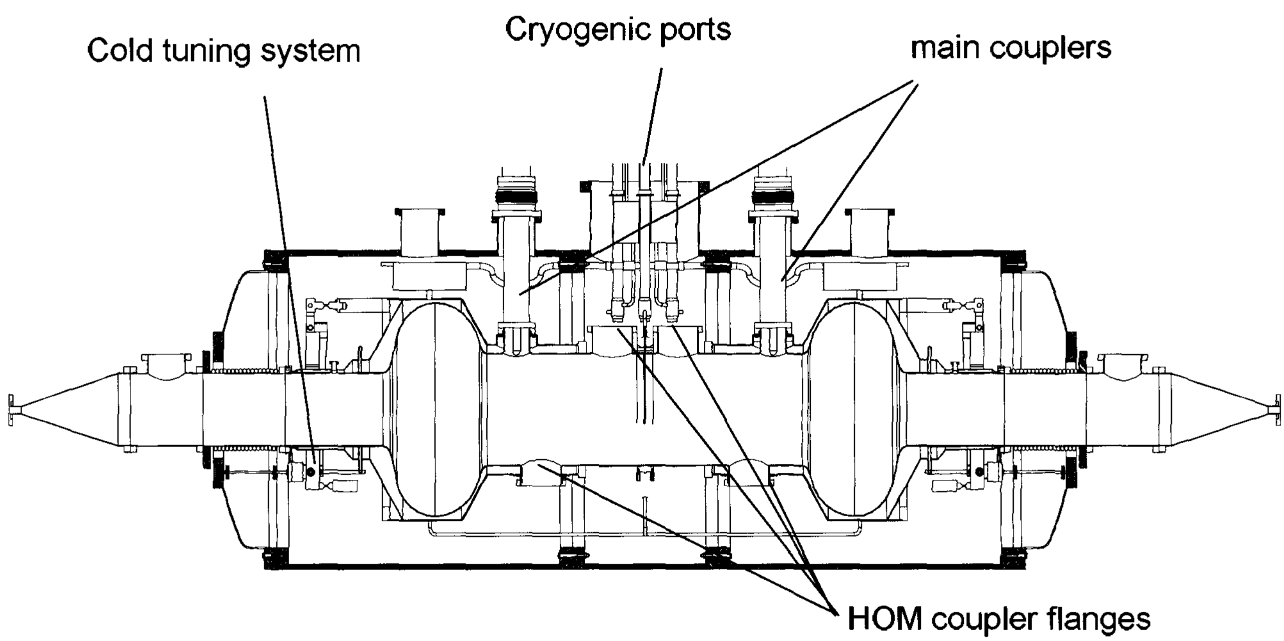

Figure 1 : Schematic view of the cryostat with the two SRF cavities

The cryostat ended by the two tapers and the pumping system must fit in a short straight section of the storage ring with a length lower than 7 m.

Within collaboration between Saclay and CERN, Saclay is in charge of the design of the cryomodule containing 2 cavities, the HOM couplers, and the tuning system. CERN will fabricate the sputter coated Nb/Cu 352 MHz cavities and provide the two 200 kW LEP type main couplers. The assembling in clean room, the RF tests in vertical cryostats, the high power RF tests and the cryogenic tests will be made at CERN by Saclay and CERN teams.

Beam energy	2.5 GeV
Beam intensity	500 mA
Bunch length	≈ 4 mm
Maximum number of bunches	396
RF frequency	352.2 MHz
Total RF voltage	4 MV
Total RF power	400 kW
Number of cavities	2
Power per input coupler	200 kW
Loss factor for both cavities	0.75 V/pC
Loss factor due to tapers	≈3 V/pC

Table 1 : selected parameters for SOLEIL

2 Description of the SRF system

2.1 Design of the cryomodule

As described in reference [2], only one cryomodule will be installed in the storage ring to provide the total RF voltage of 4 MV (table 1).

The fundamental power is delivered by one klystron, and the 200 kW necessary for each cavity will be transferred to the beam through the LEP type main couplers [3].

The cavities are linked with a large superconducting beam pipe (Fig. 1),the diameter of which has been chosen for having a small coupling between the two cavities for the accelerating mode ($f_{res} < f_{cut\text{-}off}$) but a strong coupling for the HOMs.

Couplers are located on the large inner pipe, where HOMs exhibit large standing waves field patterns. The optimisation of the diameter and the length of this tube, as well as the geometry of the couplers, are presented in paragraph°3. Two pairs of couplers, mounted on the inner beam pipe, are designed to damp the longitudinal and the transverse modes.

At frequencies above cut-off frequency of the outer pipe, HOMs waves propagate outside the cryostat and can be damped at room temperature in the conical tapers made out of metallic alloy. For these RF absorbers, we are measuring the surface resistance of different materials. Additional room-temperature couplers will be used if necessary.

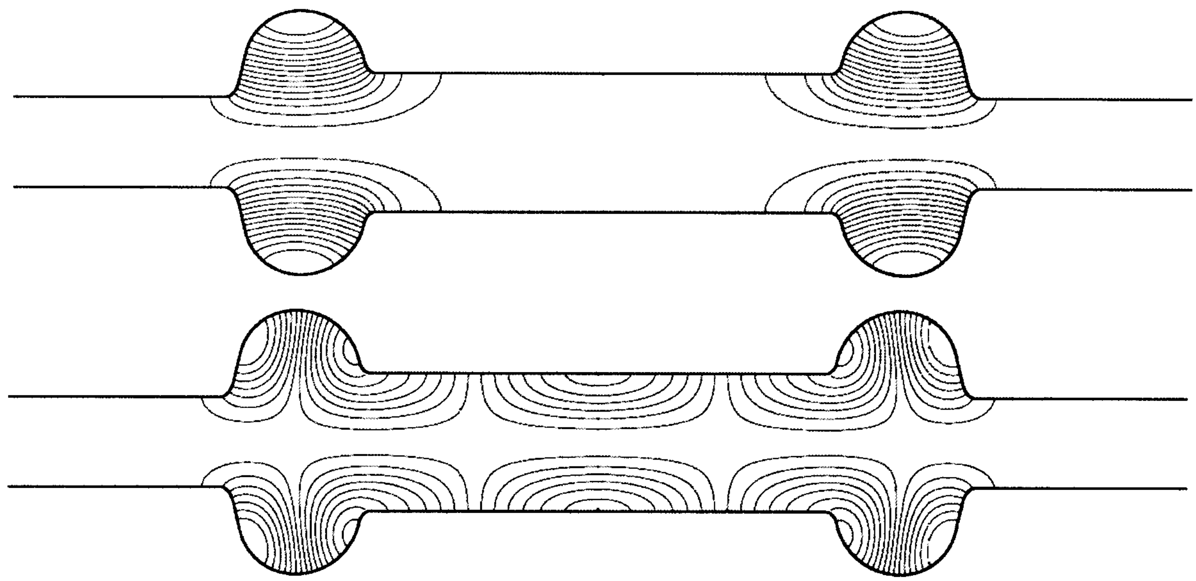

Figure 2 : Electric field lines for the fundamental mode (top) and the highest R/Q monopole HOM (bottom)

To reduce the power dissipated in the cryogenic area, we avoid any normal conducting bellow between the two cavities. Therefore, the only fixed point of the system is the flange separating the two cavities (fig. 1). Consequently, during cool down, the two main couplers situated near the cavity cells move by about 2 mm each. Movable wave guides supports must allow this displacement without generating too much stress on the couplers, and in particular on the ceramic windows of the door knob.

As for the LEP cryostat, the vacuum chamber is made of a rigid structure on which are placed dismountable staves allowing a large accessibility without having to disassemble the whole cryostat.

2.2 Cryogenics

Each cavity has its own helium tank, and two liquid helium circuits : the first one feeds the cavity helium tank, and the second ones provides the cooling of the dipole HOM couplers. The two monopole couplers, farther from the cell, can be outside the helium tank and be simply cooled by thermal conduction.

Among the total helium gas generated at 4.2 K by the heat losses, one part is used for cooling the outer tube of the power coupler, and another part for cooling the transition tube between the cavity at 4.2 K and the end of the cryostat at 300 K (figure 1). This tube has the same inner diameter Φ260 mm as the outer cut off tube of the cavity. It is made out of stainless steel plated with a copper film to reduce the power deposited by propagating HOMs.

Like in LEP cryomodules, no liquid nitrogen shielding is used.

The estimations of the heat losses are listed in table 2.

	Parts		Comments
static losses		W	
radiation losses	300 K-MLI-4 K		
	cold mass (4 K)	14	40 to 80 layers
conduction	instrumentation	5	
	system supports	5.4	stainless steel F10, L400
	circuits	2	
	main couplers (no RF)	2x1=2	vapour cooled
	extremity tubes (no RF)	2x1=2	vapor cooled
convection	cold mass	< 0.2	$P<10^{-4}$ mb
TOTAL		30.6 W	
RF heat losses			
	main couplers	2x0.2 g/s gHe	2x300 W between 4 and 300 K
	extremity tubes	2x0.14 g/s gHe	2x200W between 4 and 300 K
	dipolar couplers	2x4 LHe	peak values
	monopolar couplers	2x1 LHe	peak values
	cavities	2x25	
TOTAL		60 W	

Table 2 : Estimated cryostat heat losses

2.3 The cold tuning system

The tuning system works at 4.2 K inside the cryostat, and is actuated by a motor which is placed outside for a better accessibility. This cold tuning system (CTS) is composed of a stepping motor, a gear box (Harmonic Drive), a double lever mechanism, and a screw-nut system.

The body of the helium tank is used as a mechanical reference. It should be therefore a stable structure to reach the accuracy required by the resolution of the CTS.

The cavities stiffness and their sensitivity to mechanical deformations were calculated. The tuning sensitivity is $\Delta f/\Delta L$=186 KHz/mm and the tuning force is $\Delta F/\Delta L$=17 KN/mm. The

CTS stiffness aimed at is 200 KN/mm ; the flexibility is mainly due to the double lever. The design of the CTS allows a theoretical resolution better than 10 Hz, which is much more than needed.

The cavities will work in continuous mode, and the maximum field level will be 5 MV/m. For this field the Lorentz forces detuning of a cavity harnessed by the CTS is about 40 Hz, 10 Hz of which is due to the flexibility of the CTS.

3 RF damping system optimization

In order to optimize the geometry of the 2-cavities structure, a code computing the expected values of the external Qs has been developed. For each parameter set, mainly the beam tube radii and the cavity spacing, and after re-adjustment of the equator diameter to get the right accelerating mode frequency (352 MHz), the fields are computed. Then, the location of the coupler minimizing the impedances is sought by a scan all along the inner beam tube. The damping efficiency for the n^{th} mode is characterized by the value $R_n = R/Q_n{*}Qex_n$, which is calculated for all the modes below the cut-off frequency of the outer beam tube and for a given coupler location. Only the highest value R_{max}=Max(R_n) corresponding to the worse mode damping is retained, the better coupler position being obviously the one giving the minimal value of R_{max}.

The curves presented on figureÊ3 shows that the inner tube radius of 200 mm with a cavity spacing of about 3λ/2 is optimal for both transverse and longitudinal modes. For this geometry, the R/Q and predicted Qex for the dipole and monopole modes are listed in table 3.

Freq (MHz)	R/Q (W/m)	Qex (10^3)	Freq (MHz)	R/Q (W)	Qex (10^3)
403	4.8	0.80	579	0.2	0.15
404	51.6	0.90	594	2.7	1.27
454	0.01	0.50	611	11.6	0.30
482	61.6	0.27	632	0.1	0.48
493	6.7	5.01	663	6.3	0.30
504	100.0	0.49	699	8.35	0.25
540	2.5	0.21	723	1.9	1.49
587	2.4	1.53	746	0.3	0.23
636	14.6	0.96	788	0.9	2.61
674	3.4	1.11	844	0.5	0.11

Table 3: Frequency, R/Q and predicted Qex for dipole (left) and monopole (right) modes below cut-off.

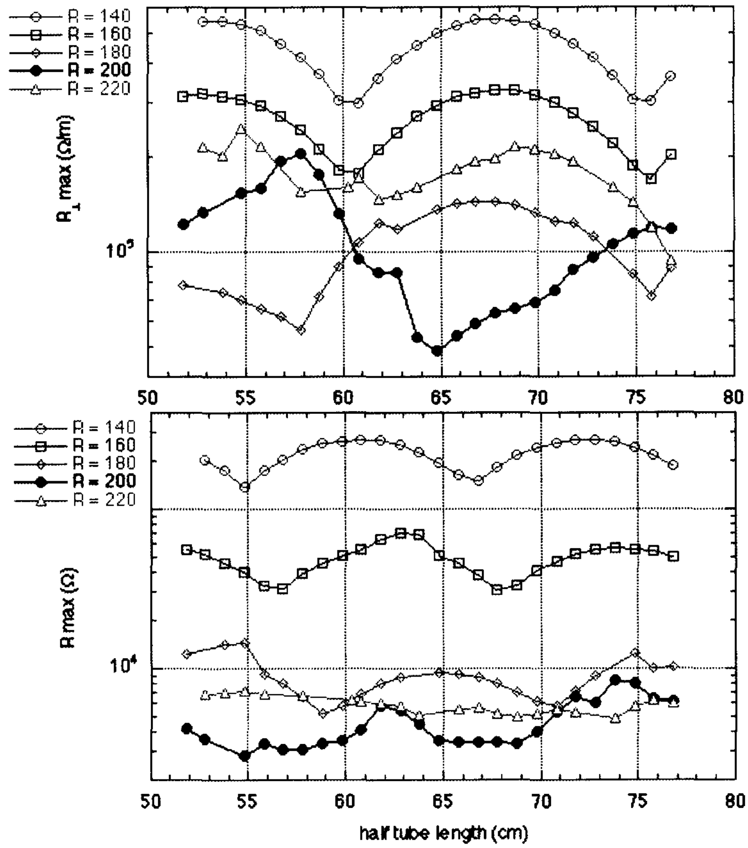

Figure 3 : Maximal impedances for dipole (top) and monopole (bottom) modes, as a function of the inner tube length and for different tube radii.

The optimization of the HOM couplers geometry is in progress using a copper assembly made of two 352MHz cavities (CERN fabrication), and HOM couplers " meccano " (figure 4). The damping system is composed of a pair of loop couplers [4,5] : the loop plan is perpendicular to the beam axis for the dipole modes, and parallel for monopole ones.

For the dipole modes, the first measurements of the coupler response are in good agreement with calculations. The damping levels greatly exceed the requirements for the first ten dipole modes. The optimal cavity spacing is 1270 mm from iris to iris, and with the optimized coupler geometry, the distance between the iris and the HOM coupler axis is 220 mm. The monopole modes damping optimization is in progress.

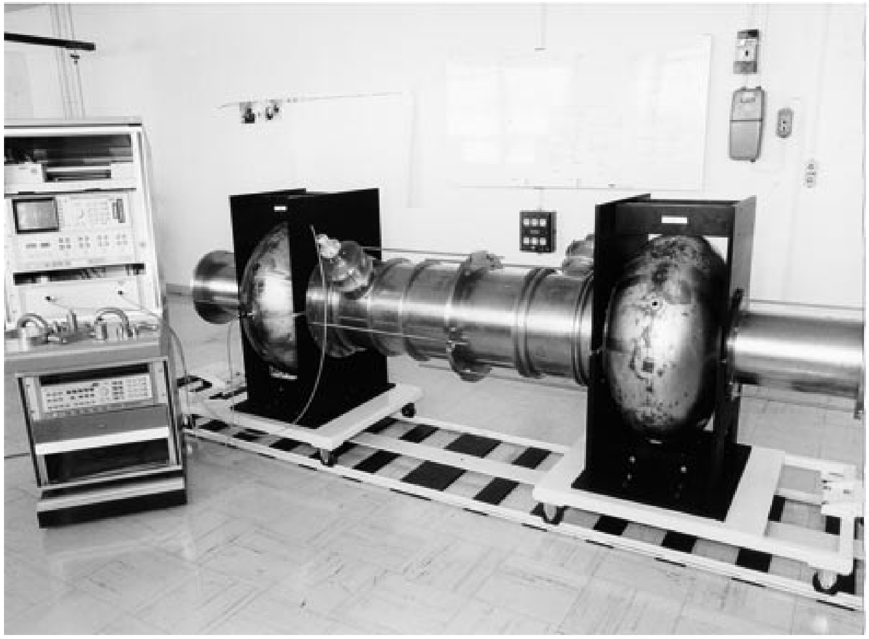

Figure 4 : The copper assembly used for the damping optimization

4 Future plan

After the final experimental optimization of the RF structure, the design of the cavities with their end tubes and HOM couplers ports will be fixed on November. The fabrication of the two Nb/Cu cavities will start at CERN at the beginning of 1998. The low power RF test of the two cavities in vertical cryostat is scheduled in June at CERN. The final test of the whole SRF cryomodule at nominal RF power is planed in July 1999 at CERN.

5 References

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