MACSE : ACCELERATING ELECTRONS AT SACLAY WITH SUPERCONDUCTING CAVITIES

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Abstract

In order to master all the technological aspects of superconducting RF acceleration, a test facility for fully equipped accelerator modules is under completion at Saclay. First accelerated electron beam is expected by the end of this year.

Introduction

Since 1986, the Département de Physique Nucléaire at Saclay has started an R&D program on superconducting RF cavities. State of the art cavities have been produced[1]. Fundamental research is also being done on superconducting surface RF properties such as field emission, surface resistance[2], thin layer sputtering techniques[3], heat transfer models, and physico-chemistry of Nb oxides. The understanding of the physics of RF superconductivity and the know-how on cavity making, however essential, must be complemented by many other technological skills, before one is able to build and operate a superconducting accelerator.

This is the aim of the MACSE facility. Three cryomodules, with different types of cavities, will successively be built and submitted to full test with beam, so as to gain expertise, to have operation experience and to improve cost effectiveness. The design values for the 5-cell cavities of the first step are an accelerating field E_{acc} = 8 MV/m and a quality factor Q = 6.10^9 at 1.8 K.

The project has started on early 1989. The MACSE facility is being set up in the tunnel of the Saclay ALS 700 MeV electron accelerator, which has been shut down on June 10th 1990 and partly disassembled. First beam is expected by the end of 1990. One year will then be dedicated to successive tests of different prototype cavities and cryomodules.

General set-up, beam injector and diagnostics

Figure 1 shows the complete beam line : the 100 kV, 100 μA electron beam injector, the superconducting capture section, the intermediate tuning point and beam analysis, the 4-cavity cryomodule and the high resolution (10^{-4}) beam analysis.

The electron injector[4,5] has been lent by University of Illinois. It consists of a low emittance electron gun, two chopping cavities and one bunching cavity. These copper cavities have been made by Los Alamos Accelerator Technology Division.

The capture section accelerates 100 keV electrons to about 2 MeV. This cannot be done by a standard, β = 1, cavity. A shorter (β = 0.84), 5-cell superconducting cavity has been designed for this purpose. It is housed in a specific cryomodule.

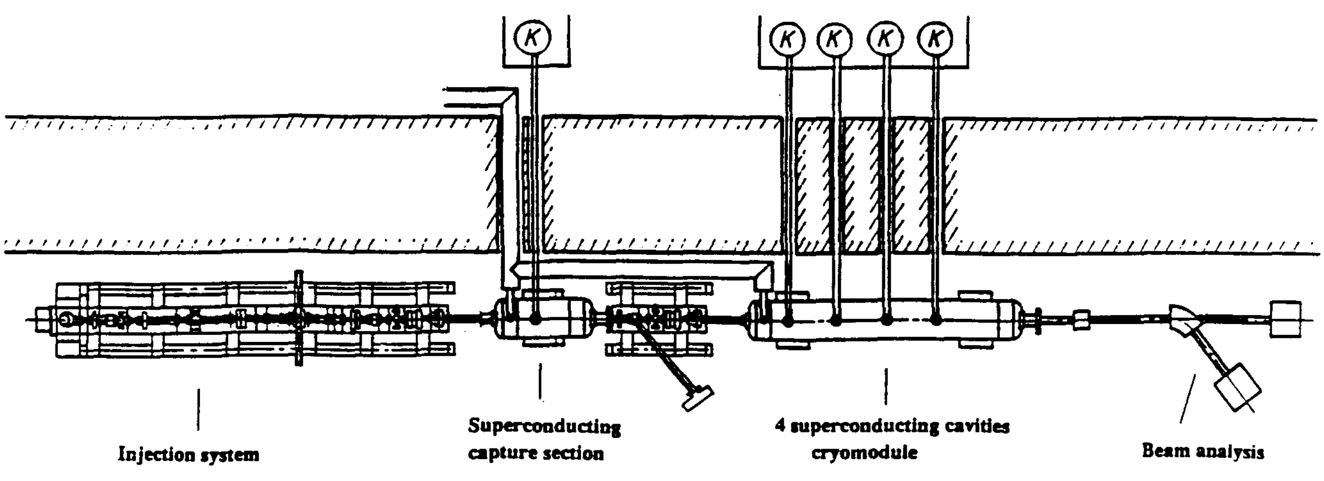

Figure 1 : Layout of MACSE.

Cavities

The design of the 5-cell cavities (figure 2) is derived from the CERN profile. The main coupler port is a pipe with a vacuum seal flange. Two Nb HOM couplers[6], specifically designed for 1.5 GHz, are welded on the beam pipe.

The cavities are fabricated by ATEA (France). They are hydroformed out of 2 mm sheets of Nb (RRR = 200 to 300). The chemical etching is done at Saclay, as well as the final RF surface preparation in a class 100 clean room.

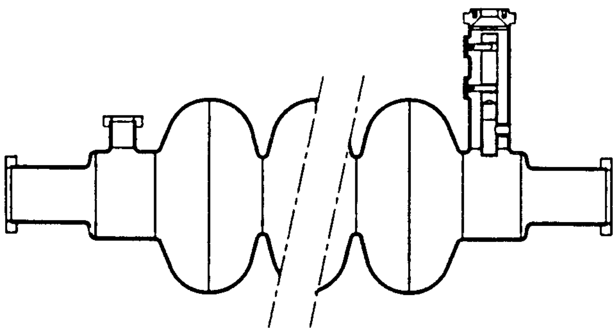

Figure 2 : 5-cell cavity profile.

Six 5-cell cavities have already been built and individually tested in vertical position. The final results are shown on figure 3. Previous erratic results have been discarded. They have all been traced back to inadequate cooling conditions : the cooling speed in the 200 K - 100 K range was too slow. This is now known[7] to increase the surface resistance by a factor 50 in the worst cases.

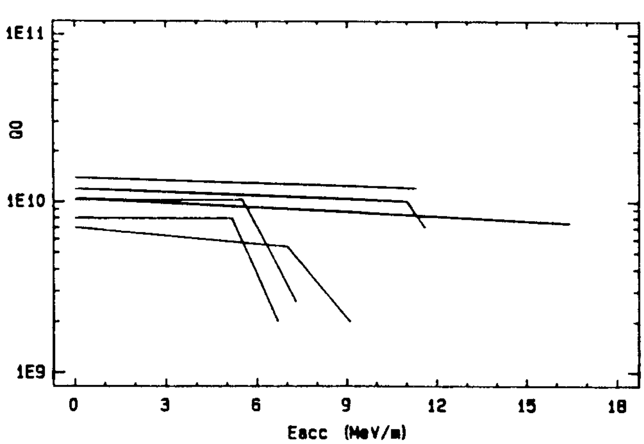

Figure 3 : Q(E) for the first six 5-cell cavities for MACSE.

Other types of cavities are under development. Two 3-cell cavities with much simpler HOM couplers have been tested. They withstand accelerating fields as high as 16 MV/m ; this already gives the same energy gain *per cavity* as the 5-cell prototypes.

Developments are under way for coating copper cavities with a thin layer of a superconductor of higher T_c and of low surface resistance.

Cryomodules

Cryomodule # 1 (Fig. 4) contains four 1.5 GHz, 5-cell niobium cavities. It is fabricated by ATEA (France). The set of four cavities is prepared by pairs in the clean room. The final assembly is done in a clean tent. Each cavity is then equipped with two frequency tuners : a mechanical one, actuated by a stepping motor, and a magnetostrictive rod. Both are immersed in the helium bath. The frequency tuning range is 1.5 MHz, with a resolution of 1 Hz. The 4 cavities assembly is then slid into the helium tank on a pair of aligned shafts. The helium tank is rigid enough to ensure alignment.

There is no feedthrough between cold helium and vacuum. All cavity gaskets are of Helicoflex type, made by Cefilac (France).

The main coupling lines are of coaxial type. A coaxial quarter-wave choke provides the proper RF continuity and an excellent thermal separation between the cold and warm parts.

Cryomodules # 2 and # 3 will be designed to house other types of cavities.

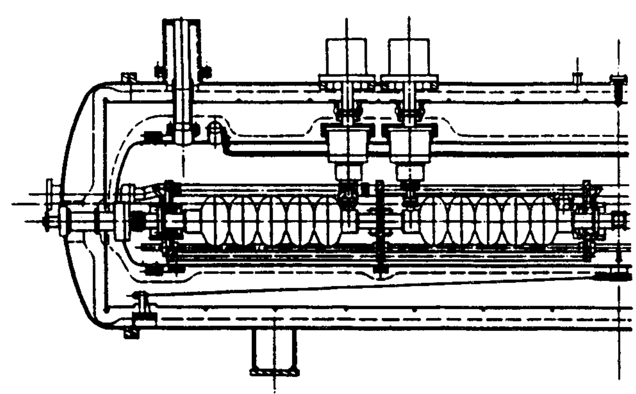

Figure 4 : Cross-section of half a cryomodule

RF power sources

The power sources are 5 kW klystrons resonating at 1497 MHz. Their efficiency is 35%. They are made by Thomson-TE (France). Rectangular L-band wave guides with circulators and 5 kW loads connect the klystrons to the cryomodules. There are three feedback loops[6]: the two faster ones lock the phase and the amplitude of the cavity; the slow one detects the phase shift between klystron and cavity and tunes the cavity frequency.

Helium refrigerator

A commercial Helium liquefier has been purchased from Air Liquide (France). Together with a pumping unit and a 4.2 K/1.8 K heat exchanger, the system is expected to provide a cooling power of 60 W at 1.8 K. In a second step, a cold compressor and heat exchangers will double the cooling power. This set-up is designed and assembled by Saclay/DSM/DPhPE/STIPE.

Conclusion

All the main parts are presently built, and most of them are under assembly and qualification. This technical effort brings together the experience of 20 years of operation of the ALS linac, the expertise gained by successful construction and operation of 50 superconducting cavities for the heavy ion booster of Saclay, and recent efforts in R & D on cavities for electron acceleration. When successful, the present development will add one stone to pave the way for modern accelerator facilities of the future.

Acknowledgements

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