Development and Industrial Fabrication of Superconducting Accelerator Modules

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Abstract

Superconducting Accelerator Modules (Cavities with Cryostat) with accelerating fields above 5 MV/m are under production on a routine basis by industry. 230 cavities from a total of 360 made of bulk niobium material have been delivered to CEBAF up to now. The technology of sputter coating niobium onto copper 350 MHz-cavities has been successfully transfered from CERN to Siemens and large scale production has been started. For FEL-linacs our superconducting accelerator modules are in the commissioning phase (INFN) or under construction (JAERI). The technological aspects as well as the current status of our major s. c. accelerator projects are presented.

1. Projects at Siemens

1.1 CEBAF

Within a three years period (9/89 - 3/93) all 360 cavities (fig. 2) for the CEBAF project are to be delivered. By the end of March 1992 230 cavities have been supplied. New and improved deepdrawing technologies have been developed [1] during a prototype phase thus allowing reliable and time saving series production of niobium cavities. The production is now ahead of time schedule and delivery of the last cavity is planned for end of 1992.

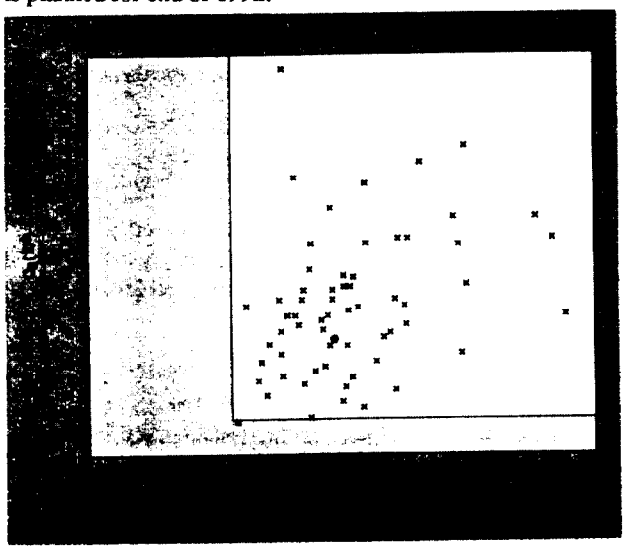


Figure 1: Status of test results as of November 1991 (courtesy CEBAF)

The results of tested cavities (status end of November 1991) are summarized in figure 1 and show that all cavities safely exceed the guaranteed design values (Eacc > 5 MV/m $Q > 2.4 \cdot 10^9$ at 5 MV/m).

Figure 2: Complete CEBAF Cavities and components

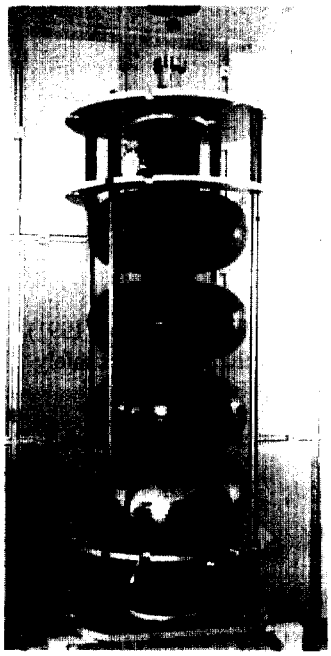
1.2 CERN / LEP 200

Siemens contracted with CERN the production of 52 352 MHz 4-cell cavities in niobium/copper technology and the delivery with He-tanks, tuners, vacuum vessels and cryogenic components completely assembled in 10 m long accelerator modules [2] ready to be installed into the LEP tunnel.

Starting in January 1991 with an intense technology transfer program from CERN to Siemens all necessary installation for

- eb-welding of copper
- chemical treatment of copper cavities
- niobium sputtering

have been established in a half year period. First results from sputtered samples in June 1991 showed that the coating process was mastered [1].



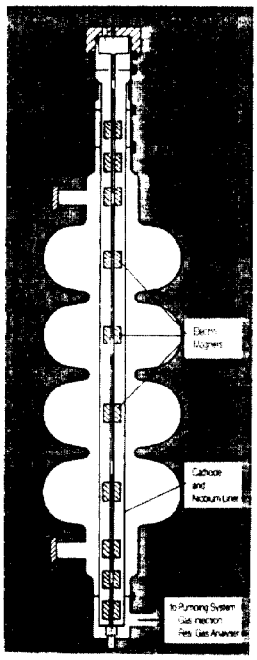


Figure 3 (top left): A 352 MHz LEP cavity in front of a laminar flow wall

Figure 4 (top right): Schematic view of the magnetron sputtering process. With a DC voltage applied between the niobium cathode and the copper cavity and a magnetic field around the cathode a plasma is generated in an argon atmosphere thus producing a thin (1 μm) niobium layer on the copper surface.

A first 4-cell cavity was chemically treated and coated with our new facilities in July 1991. Up to now in total more than 9 coatings have been completed.

Almost all tested cavities have reached or exceeded the design accelerating field of 6 MV/m and almost reached the design quality factor of $Q = 4 \cdot 10^9$ at 6 MV/m. Figure 6 shows the result of cavity serial no. 302 with a maximum accelerating field of 7.5 MV/m limited by electron field emission loading and a cavity Q of $3 \cdot 10^9$ at 6 MV/m.

The series production of cavities and components has been started. The assembly procedures are currently being established in collaboration with CERN by mounting of a test module i. e. one cavity with He-tank, vacuum tank, tuners etc.

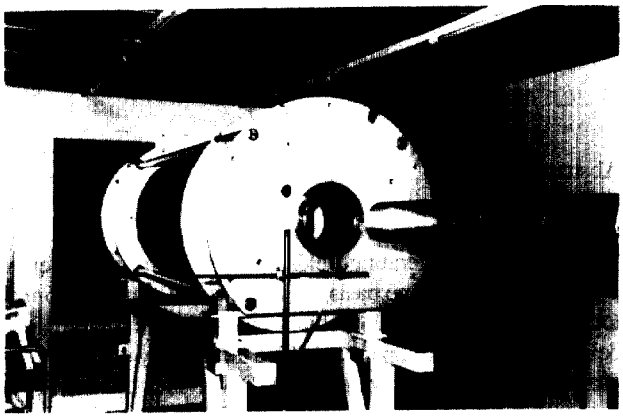


Figure 5: After sputtering the cathode is dismantled in a clean room

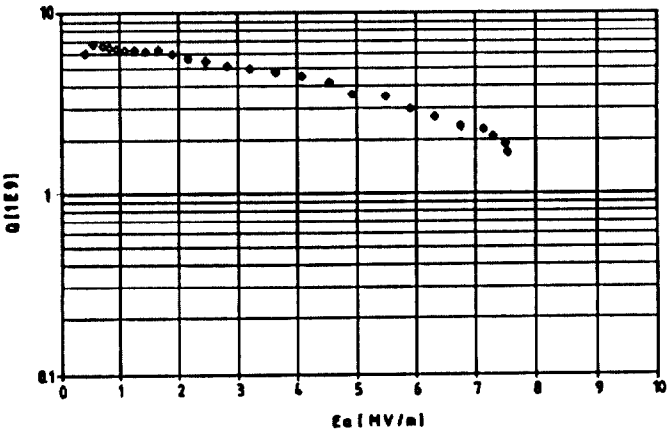


Figure 6: Cavity Q as function of accelerating field of a 352 MHz niobium coated copper cavity fabricated by Siemens

1.3 INFN, Frascati

For the FEL-project LISA at INFN, Frascvati we have designed and fabricated four superconducting accelerator modules. Each module contains a four-cell niobium cavity

(f = 500 MHz) in a liquid helium tank. The four modules were delivered in spring 1991 after they had been tested in our test area with the following initial results after only a very short He-processing time (few minutes):

Module No	Eacc, max MV/m	Q at 5 MV/m prior to He-processing at INFN
1	5.8	1.1 10^9
2	6.1	1.5 10^9
3	5.9	0.6 10^9
4	5.3	1.0 10^9

The Q values at low field level were about 3 · 10^9. The accelerating field of all cavities has been limited by electron field emission. The reduced Q values at 5 MV/m are still due to electron loading.Meanwhile all modules were mounted in the LISA tunnel and first cool down has been successfully performed.

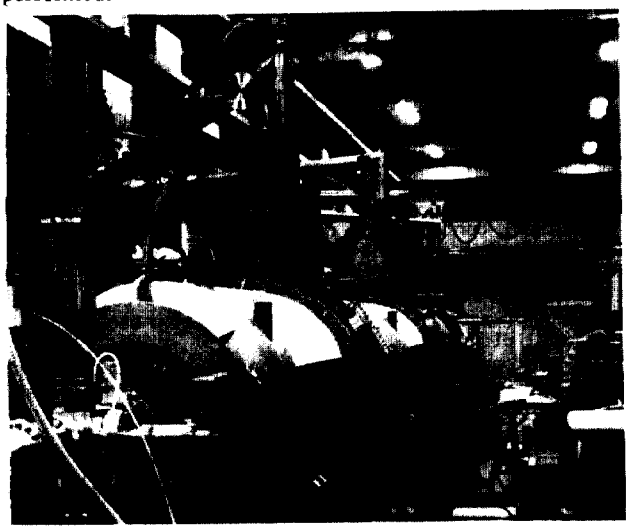


Figure 7: The four 500 MHz modules inside the Accelerator Hall of INFN, Frascati

1.4 JAERI

For the JAERI FEL experiment the 4 superconducting accelerator modules (2 five cell 500 MHz and 2 single cell 500 MHz cavities) are under production.

During the design phase special care has been taken for the cryogenic performance. As the cavities are operated in pulsed mode (1 % to 3 % duty cycle) the 4.2 K cryogenic losses are dominated by the standby losses of the cryostat. By using e. g. duplex heat shield (20 K, 80 K) the standby losses are designed to be below 3 W per module.

Furthermore a power coupler (waveguide to coax-transition) with adjustable coupling factor has been developed with the following data:

Coupling factor:	$5 \cdot 10^5 < Qext < 1 \cdot 10^9$
Reflection coefficient:	r < 1.0 % at 500 MHz
	r < 10 % at 500 ± 10 MHz

Today all 4 cavities have been fabricated and all major components (vacuum vessel, He-tank, tuning system, heat shields) are ready. The next steps are chemical preparation of the cavities and final assembly. First cooldown and cryogenic rf-test will take place during summer 1992.

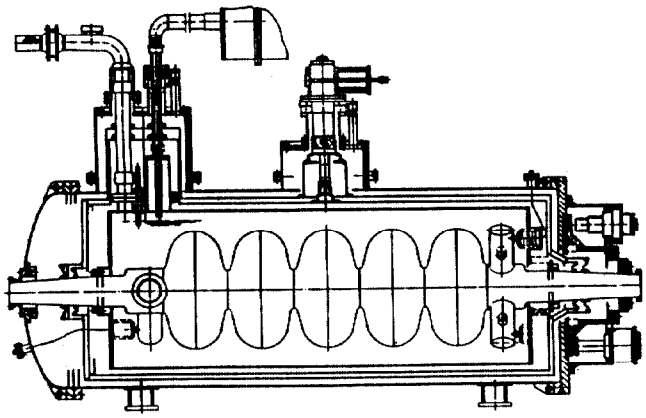


Figure 8: Layout of the JAERI 5-cell cavity module

2. Acknowledgements

We would like to thank all our partners in the national and international institutes for many fruitfull discussions supporting the development of technology in the field of rf-superconductivity.

References

[1] D. Kiehlmann et al., „Development and Fabrication of Superconducting Accelerator Modules and Systems", Proceedings of the 5 th workshop of RF superconductivity August 19 - 21, 1991, DESY, Hamburg

[2] C. Benvenuti et al. „Superconducting Niobium sputter coated copper cavity modules for the LEP energy upgrade", Proceedings of the 1991 Particle Accelerator Conference, May 5 - 9, 1991, San Francisco