FABRICATION AND COMMISSIONING OF SUPERCONDUCTING ACCELERATOR UNITS

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Abstract: Today superconducting acclerator units (cavities with cryostats) with accelerating fields above 5 MV/m and rf losses of only a few W/m can be built on a routine basis. These units are used or planned in an increasing number for electron storage rings, for electron and heavy ion linacs and for free electron laser application. At Interatom different types of superconducting accelerator modules e.g. for CERN, INFN, LANL, TRW/USA and for CEBAF are under production or have already been built. For some projects the commissioning is done in a cryogenic test area especially developed for this purpose. The special design features of the superconducting modules, their preparation and assembly and the procedure of commissioning will be reported.

Introduction

Superconducting accelerator units are foreseen worldwide in an increasing number for electron storage rings, electron and heavy ion linacs and for free electron lasers [1].

Interatom is active in the field of superconducting cavities since about 10 years. Dependent on the special project we are performing

- research and developement
- design
- fabrication
- integration and
- commissioning

of complete, turnkey accelerating modules consisting of superconducting cavities, high power input and higher order mode couplers, coarse and fine rf tuners and cryostats [2].

In the following some projects are reviewed and Interatoms facilities for this work are described.

Superconducting cavity projects

CEBAF

Starting with the fabrication of 4 superconducting 1.5 GHz niobium five cell cavities, their assembly to cavity pairs hermetically sealed by kapton windows and their successful cryogenic rf tests [3] we are now fabricating in total all 360 cavities (fig. 1) for the 4 GeV c.w. accelerator CEBAF [4]. Our technical scope of this series project is

- Nb cavity fabrication by deep drawing and eb welding
- surface preparation
- tuning of the structure for reaching the specified frequency within ± 100 kHz and a field flatness better than ± 2,5 %

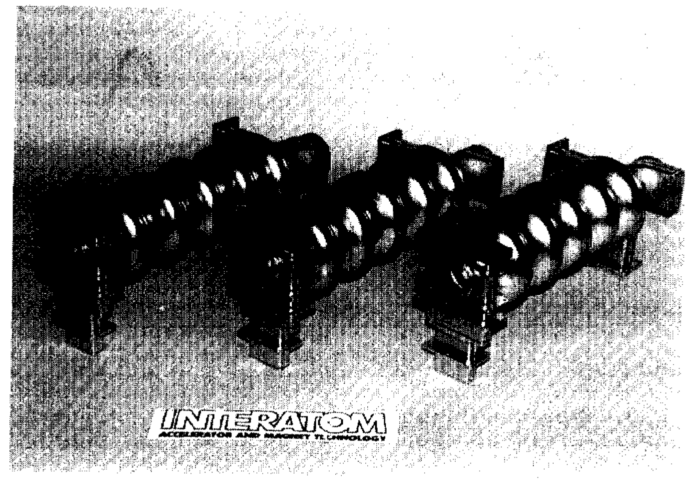

Fig. 1: Photograph of the first 3 CEBAF 1.5 GHz accelerating structures (total length about 60 cm) delivered to CEBAF in April 1990. Accelerating fields between 8 and 11.6 MV/m have been measured in excess of the required value of 5 MV/m.

- tuning of the external Q of the input waveguide coupler to $6.6 \cdot 10^6 \pm 20$ % and
- final machining of coupler and beam pipe flanges within tolerances below 0.05 mm

All steps are followed by an adequate inspection and quality control. Each cavity undergoes a cryogenic rf test at CEBAF site and is formally accepted if an accelerating field E_a of 5 MV/m and a cavity Q of $2.4 \cdot 10^9$ is exceeded and the above specified mechanical and rf requirements are fulfilled.

In a pre series phase 14 cavities have to be fabricated between May and September 1990. Thereafter the series production starts with a constant rate of 12 cavities per month until February 1993.

The fabrication is well in progress. Until now (June) 9 cavities have been delivered to CEBAF in 3 batches each of them more than 4 weeks before schedule. The first 3 have already been cryogenically tested at CEBAF. With E_a values between 8 and 11.6 MV/m, limited in all cases by electron loading and cavity Q values between $3 \cdot 10^9$ and $5.4 \cdot 10^9$ at 5 MV/m [5] the measured values are by far exceeding the required performance.

Los Alamos National Laboratory

In spring 1989 we contracted with the Los Alamos National Laboratory the fabrication of a turnkey superconducting pion momentum compactor.

The scope of this project comprised R&D work, design, fabrication and commissioning of a superconducting 402 MHz cavity with a mechanical coarse and a piezo electric fine tuner as well as a high power (10 kW) variable rf input coupler all components housing in an especially optimised cryostat (fig. 2).

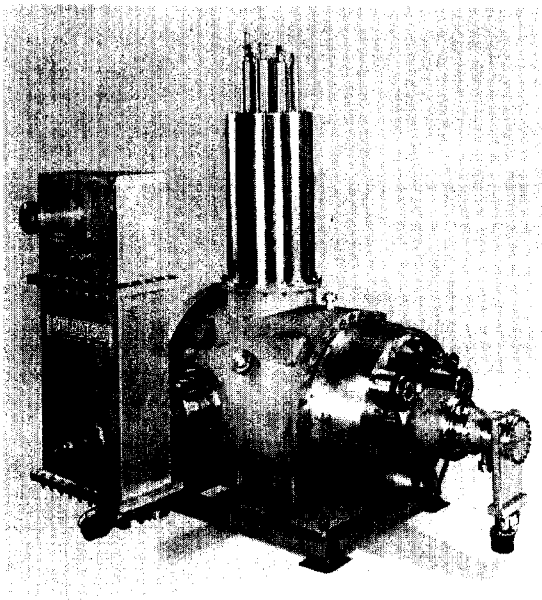

Fig. 2: Superconducting pion momentum compactor for LANL consisting of a single cell 402 MHz LHe pipe cooled Cu/Nb cavity, a variable high power rf input coupler with waveguide/coax transition (left) and a coarse and fine (piezo electric) tuner (right) installed in the cryostat.

The cavity was fabricated out of a Cu/Nb sheet composite produced by the explosion bonding technique [6]. The 4.2 K cooling of the complete cavity is performed by Cu pipes welded on the outer surface of the cavity.

With this new approach all advantages of pipe cooling instead of standard helium bath cooling which are especially significant reduc tions in:

- cryogenic inventory
- pressure safety risks
- frequency sensivity due to LHe pressure variation

are utilised.

In figure 3 the cavity is shown during the assembly procedure in a class 10/100 clean room. On both beam pipes of the cavity special designed mylar windows are mounted to keep the cavity clean and under ultra high vacuum conditions during operation (near the target) at Los Alamos.

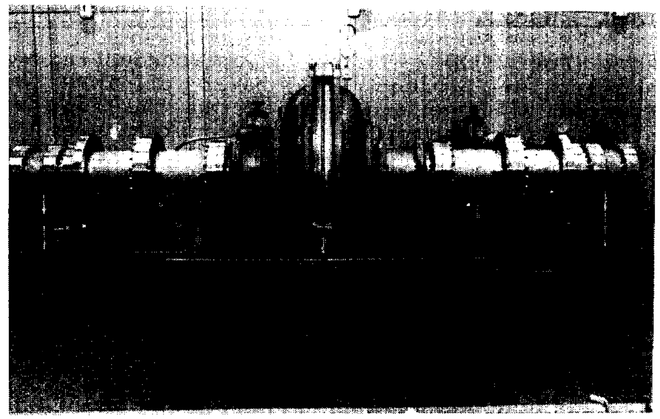

Fig. 3: Assembly of the single cell 402 MHz Cu/Nb cavity in a class 10/100 clean room

For on line adjustment of the rf power coupling during the pion beam operation a high power input coupler was developed with an external Q which can be mechanically varied between 10^7 and $5\cdot 10^9$.

After a first cryogenic low rf power test of the complete system (fig. 2) at Interatom/University of Wuppertal (see below) the module was delivered to Los Alamos. In April 1990 a high power test could be successfully performed at Los Alamos. A maximum accelerating field of 7 MV/m and a cavity Q of $2\cdot 10^9$ at 5 MV/m [8] could be reached meeting the values guaranteed by Interatom. Standby losses for the cryostat of 7 W have been measured in agreement with expectations. In table 1 the characteristic rf and cryogenic data of the momentum compactor unit are summarised.

LANL superconducting pion momentum compactor	
over all size	2 m
frequency at 4.2 K	402.500 MHz
coarse tuning range	2.0 MHz
coarse tuning rate	75 kHZ/min
fine tuning range	12 kHz
tuning resolution	< 10 Hz
Q of input coupler	10^7-$5\cdot 10^9$ (variable)
rf power of input coupler	≥ 10 kW
accelerating field	7 MV/m
Q_0 at 5 MV/m	$2\cdot 10^9$
rf losses at 5 MV/m	12 W
Stand by losses	7 W

Tab. 1: Characteristic parameters of the superconducting pion momentum compactor

INFN Frascati

For the linear superconducting accelerator project LISA built at INFN, Frascati [7] we are fabricating the four s.c. accelerator modules each consisting of (fig. 4):

- a 500 MHz four cell niobium cavity (DESY design)
- a high power rf input coupler (DESY/CERN design)
- 3 higher order mode couplers (DESY/CERN design)
- a coarse tuning system (DESY design) and
- a cryostat (Interatom design).

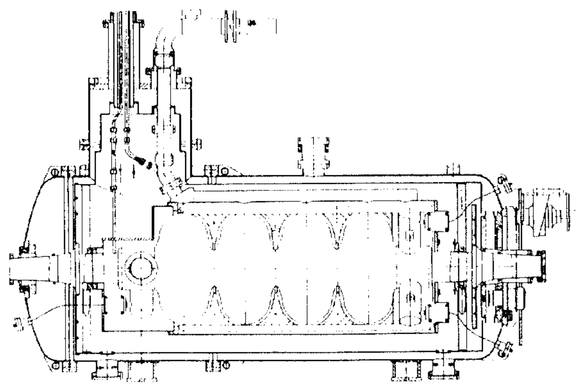

Fig. 4: Design of the superconducting 500 MHz INFN, Frascati accelerator unit

Until today all module components have been fabricated. The first two modules have been completely prepared and assembled. For the cryogenic rf tests of these units a sepcial test area has been built up at the University of Wuppertal consisting of

- a concrete building for adequate radiation shielding during rf processing of the units
- a 500 MHz rf set up with a high power rf amplifier (25 kW) and
- a helium transfer and recovery system.

In May of this year the first unit has been tested without the main coupler at low rf power (fig. 5).

Standby losses for the complete unit of 5 W were measured in agreement with experiences of other projects and with calculations.

The cavity Q at low accelerating field was $3 \cdot 10^9$ decreasing above $E_a = 3$ MV/m due to electron field emission loading.

In the next step it is foreseen to drive the second unit with an installed main coupler with high rf power.

The high power performance tests of all units are planned to be accomplished until late summer this year.

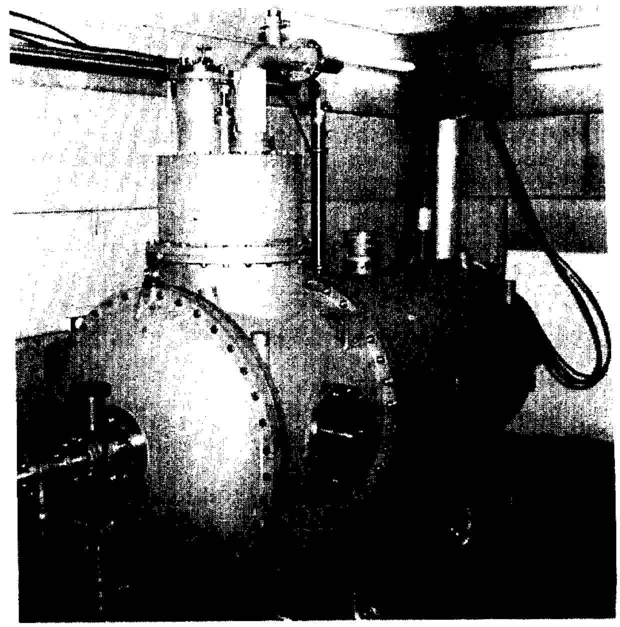

Fig. 5: Photograph of the first superconducting accelerator module for LISA installed in the concrete building for cryogenic rf test. The total length of the unit is about 2.7 m.

Conclusion

Interatom is designing, fabricating, integrating and commissioning superconducting cavities and complete modules for several customers.

We could demonstrate that turnkey s.c. accelerating units as well as series products both with guaranteed values especially for accelerating field and rf losses can be fabricated by industry.

Acknowledgement

We would like to express our gratitude to all our partners worldwide in the universities, research institutes and industrial companies for the enjoying collaboration in this most interesting technology. The very close and fruitful collaboration with the University of Wuppertal is highly appreciated.

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