Abstract: Today superconducting accelerator 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 development
- 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 Interatom's 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 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 %
- tuning of the external Q of the input waveguide coupler to $6.6 \cdot 10^5 \pm 20 \%$
- 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 and a cavity Q of $2.4 \cdot 10^9$ 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 piezoelectric fine tuner as well as a high power (10 kW) variable rf input coupler all components housing in an especially optimised cryostat (fig. 2).

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 reduction in:

- cryogenic inventory
- pressure safety risks
- frequency sensitivity 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.

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 $5 \times 10^9$.

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 $2 \times 10^9$ 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.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency at 4.2 K</td>
<td>402.500 MHz</td>
</tr>
<tr>
<td>Coarse tuning range</td>
<td>2 MHz</td>
</tr>
<tr>
<td>Fine tuning range</td>
<td>75 kHz/min</td>
</tr>
<tr>
<td>Coarse tuning rate</td>
<td>12 kHz</td>
</tr>
<tr>
<td>Tuning resolution</td>
<td>$&lt; 10$ Hz</td>
</tr>
<tr>
<td>Q of input coupler</td>
<td>$10^7 - 5 \times 10^9$ (variable)</td>
</tr>
<tr>
<td>rf power of input coupler</td>
<td>$\geq 10$ kW</td>
</tr>
<tr>
<td>Accelerating field</td>
<td>7 MV/m</td>
</tr>
<tr>
<td>Q at 5 MV/m</td>
<td>$2 \times 10^5$</td>
</tr>
<tr>
<td>rf losses at 5 MV/m</td>
<td>12 W</td>
</tr>
<tr>
<td>Stand by losses</td>
<td>7 W</td>
</tr>
</tbody>
</table>
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)
- a cryostat (Interatom design).

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 special 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)
- 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 $3 \times 10^9$ 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.

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 enjoyable collaboration in this most interesting technology. The very close and fruitful collaboration with the University of Wuppertal is highly appreciated.

References

[1] Proc. 4th Workshop on RF Superconductivity, KEK, Tsukuba, Japan, 1989
[2] U. Klein et al., ibid ref. 1
[6] B. Dwersteg et al., ibid ref. 3, 1430
[7] A. Aragona et al., ibid ref. 3, 52