THE INFRASTRUCTURE FOR THE TESLA TEST FACILITY (TTF) - A STATUS REPORT

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Abstract

The TESLA collaboration is preparing the installation of a 500 MeV superconducting linear test accelerator to establish the technical basis for a future 500 GeV e^+e^- collider. The setup consists of 4 cryomodules, each containing 8 solid niobium cavities with a frequency of 1.3 GHz. The infrastructure to process and test these cavities has been installed at DESY. The facility includes a complex of clean rooms, an ultraclean water plant and a chemical etching installation for cavity surface preparation and cavity assembly as clean as possible. To improve the cavity performance a firing procedure at 1400°C in an ultra-high vacuum furnace is foreseen. An existing cryogenic plant has been modified to cool down the cavities below 2K and measure them in vertical and horizontal test cryostats. The RF power will be provided by a 4.5 MW klystron (pulse length 2 ms) in connection with a modulator. This system will also be used for a high peak power RF treatment to further improve the cavity performance by eliminating potential sources of field emission. The components of the complete infrastructure for the TESLA Test Facility are described and their status is reported.

I. INTRODUCTION

The theoretical accelerating gradient in a niobium superconducting cavity is limited to around 50 MV/m by the maximum value of the magnetic surface field occuring at the cavity equator. In practice the gradient is limited to substantially lower values by field emission from localized regions of the cavity surface. In the past few years however there has been dramatic progress both in the understanding of field emission mechanism and in its cures. By means of high pressure ultra clean water rinsing (HPR), ultrahigh vacuum baking at 1400°C with titanisation or by high peak power RF processing (HPP) developed at Cornell multicell structures at S- and L-band frequencies have exhibited more than 20 MV/m accelerating gradients.

To develop the surface treatment methods and the fabrication procedures required to produce high gradient multicell cavities on an industrial scale the TESLA collaboration first has started to construct and test forty 9-cell 1.3 GHz solid niobium cavities [1].

The necessary semiconductor standard clean rooms and the surface treatment facilities to process these cavities have been installed at DESY together with the equipment to test the cavity performance.

The most important components of this infrastructure are:

- a complex of clean rooms (300 m^2) for dustfree cavity assembly and treatment, to avoid cavity contamination
- a chemical etching facility complying with the purity standards of semiconductor industry
- an ultraclean water supply for rinsing the inner cavity surface to remove potential sources of field emission
- a high pressure rinsing facility for improved cleaning with ultra pure water of the inside of the cavity
- an UHV furnace to bake out the cavity up to 1500°C to improve the niobium material properties and to eliminate field emitters
- a high peak power RF facility to process cavities for further reduction of field emission
- vertical and horizontal helium cryostats to cool down and test the cavity performance at 1.8 K
- a cryogenic plant to provide liquid helium at 1.8 K and 4.5 K as well as helium gas at 70 K for the cryostats and the planned test linear accelerator

II. COMPONENT STATUS

The TESLA Test Facility (TTF) is located in an experimental hall of about 3000 m^2 surface area, which also houses the planned 500 MeV superconducting linear accelerator[2].

An overview of the TTF is shown in Fig.1.

A. Clean Room and Assembly Area

In order to avoid contamination of the cavity surface during processing and assembly a clean room has been built with an area of approx. 300m^2. The complex is divided into different classes, ranging from class 10000 down to class 10 (Federal standard 209), the last one being used for the most critical operations like mounting the input couplers to the cavity or connecting the cavities to a string for a cryomodule. Integrated in the clean room is the area for chemical etching of the cavity surface, the high pressure rinsing station and the UHV furnace. The clean room is operational since September 93.

B. Chemistry

Inside the chemistry area a cabinet for etching of the niobium cavities is installed. The acid in use is a mixture of $HF(40\%)/HN0_3(65\%)/H_3P0_4(85\%)$ of VLSI quality in a

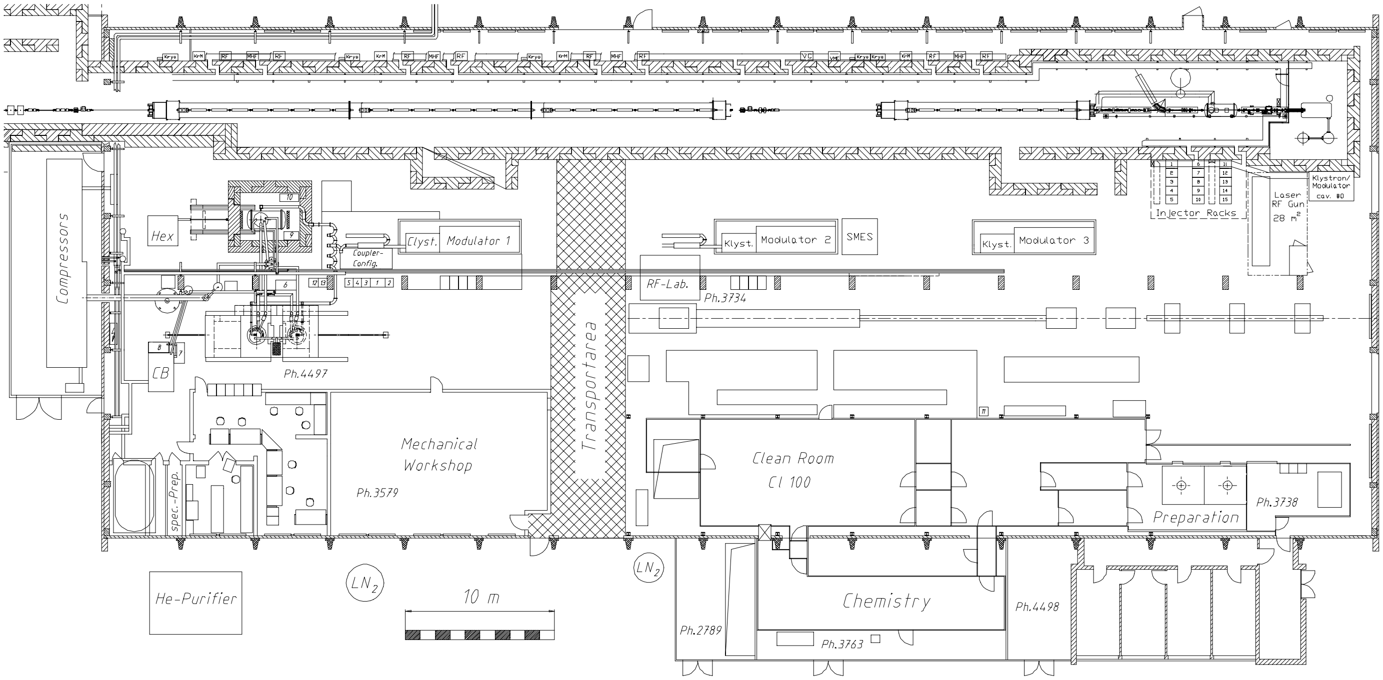

Figure 1: Overview of the TESLA Test Facility (TTF) at DESY.

1/1/2 volume ratio. For etching the cavity can be connected to one of two closed loops. One is operated with acid spoiled from earlier operations performed with a cavity right after reception or after titanisation, the so-called titanium loop. The other is operated with "clean" acid, the so-called niobium loop. In these loops the acid is circulating between the cavity and the storage tanks, which are located in a separate room outside the cleanroom. The pumps, tubes (made from PVDF) and filter elements (0.2µm size) of the chemical distribution system fulfill the standards of semiconductor industry.

The cavity can be etched from inside or from outside separately. For outside etching the cavity is sealed completely and inserted into a vessel which is then connected to the loop.

The standard cavity treatment consists of 5 etching operations. In the first two operations in a precleaning step for later furnace treatment and titanisation about 10 µm are etched off on the inside and on the outside of the cavity just after reception from industry. After titanisation the titanium-niobium surface is removed by etching off about 80 µm on the inside and 30 µm on the outside. Finally after tuning of the cavity outside the clean room a "clean" etching of about 20 µm in the "niobium loop" is performed in order to achieve the highest quality on the inner RF surface. The temperature of the acid can be set between 0° and 20°C with a mass flow of 10 *l*/min (improvement to 20 *l*/min is foreseen). The process itself and the safety interlocks are controlled by a computer to reach high safety and reproducibility standards. After the etching process the cleaning procedure is finished by an ultrapure water rinse. After the last "clean" etching a high pressure rinsing with ultra pure water is performed.

C. Ultrapure Water Supply

An ultrapure water plant supplies the cavity cleaning facilities with water of 18.2 MΩcm specific resistivity under (nearly) particle free conditions. Its first stage consists of a reverse osmosis unit (300 *l*/h), the second stage is equipped with nuclear grade mixed bed ion exchangers, augmented by filters and an ultraviolet light source. The point of use filters have a mesh size of 0.04 µm. A storage tank of 4000 *l* capability allows the use of large quantities of ultrapure water for cavity surface rinsing and cleaning. This plant is in continuous operation since August 93.

Figure 2: Cavity assembly in the clean room

Added to this facility is a high pressure rinsing station (up to 200 bar), which has been developed and built by CERN.

This unit allows the ultimate cleaning of the inner cavity surface and is in operation since July 94.

Fig. 2 shows the mounting of a cavity in the chemistry. The chemical facility is in operation since April 94.

D. UHV Furnace

Heat treatment of the complete cavity reduces potential sources for field emission and improves the niobium material properties like residual resistivity ratio ($RRR=R_{300K}/R_{10K}$) which is connected to thermal conductivity and homogeneity. During this process (at 1400°C and a vacuum of 10^{-7}mb) titanium is evaporated and builds up as a film on the inner and outer cavity surface. This effect leads to a solid-state gettering process for residual gases, especially oxygen, during high temperature annealing. The furnace for the TESLA cavities is in operation since December 94.

E. High Peak Power Processing (HPP)

Besides heat treatment in an UHV furnace the application of high power RF pulses (≈ 1 MW) for a short time (≈ 1 ms) to the cold cavity has proven as very effective to remove potential field emitters from the inner cavity surface. To apply this method for the TESLA cavities an HPP test stand has been built. It consists of a modulator supplied by FNAL and a klystron with a peak power of 4.5 MW at a pulse length of 2 ms. This setup (shown in Fig.3) is connected through RF wave guides with the vertical and horizontal cryogenic cavity test stands. The HPP facility is in operation since July 94.

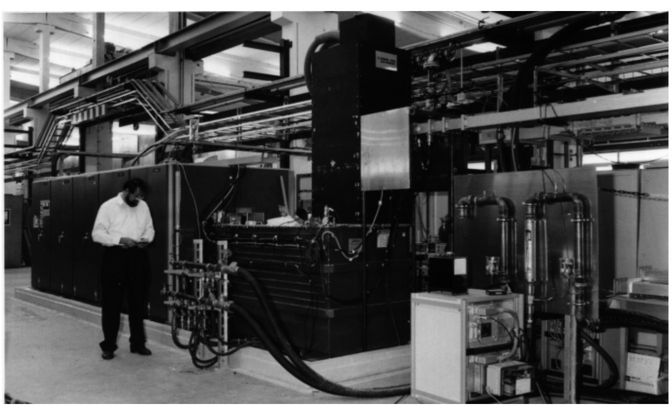

Figure 3: RF setup for HPP treatment

F. Cryogenics

For cooldown and test of the TESLA cavities an existing liquid helium plant has been extensively modified. By adding vacuum pumps and screw compressors a temperature of 1.8 K can be reached, with a refrigeration power of 100 W, which will be increased to 200 W for the test linac operation. The unit, which in addition provides helium at 4.2 K (400 W) and 70 K (2000 W), is connected to two vertical cold test stands built by FNAL and a horizontal test cryostat provided by CE Saclay. The liquid Helium plant is operational since December 93.

G. Cavity Performance

The first 9-cell cavities for TTF have been treated and tested using the above described infrastructure. The cavity treatment consisted of an inner and outer etching of 10 µm, a furnace treatment and titanisation of 4 hours at 1400°C followed by a chemical treatment removing 80 µm on the inside and 30 µm on the outside. After a mechanical tuning a chemical etching of 20 µm on the inside and a high pressure rinsing with 100 bar water pressure was performed. The mounting to the RF coupler was done in the class 10 clean room.

The Q_0 vs $E_{acc.}$ curves during CW operation before and after high peak power processing are shown in Fig.4. As can be seen from the graph the initial Q_0 is about $2*10^{10}$. With high peak power processing it was possible to raise the acceleration field to above 22 MV/m. The decrease in Q_0 value after HPP treatment is due to higher helium temperature.

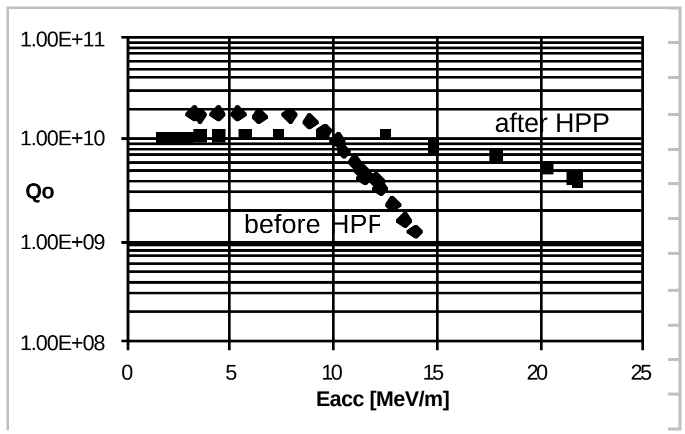

Figure 4: Performance of cavity D2 before and after HPP

III. SUMMARY

For the TESLA Test Facility (TTF) at DESY the complete infrastructure for superconducting cavity processing and testing is in operation. First series cavities have been processed with good results. It is expected that the so far achieved field strength of 22 MV/m during CW operation can still be improved by optimization of the process parameters.

IV. REFERENCES

[1] Proposal of the TESLA collaboration. TESLA Report 93-01.

[2] H. Weise, DESY, for the TESLA collaboration. Contribution to this conference.