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Technical Design Report for the Cryo-Module Test Bench

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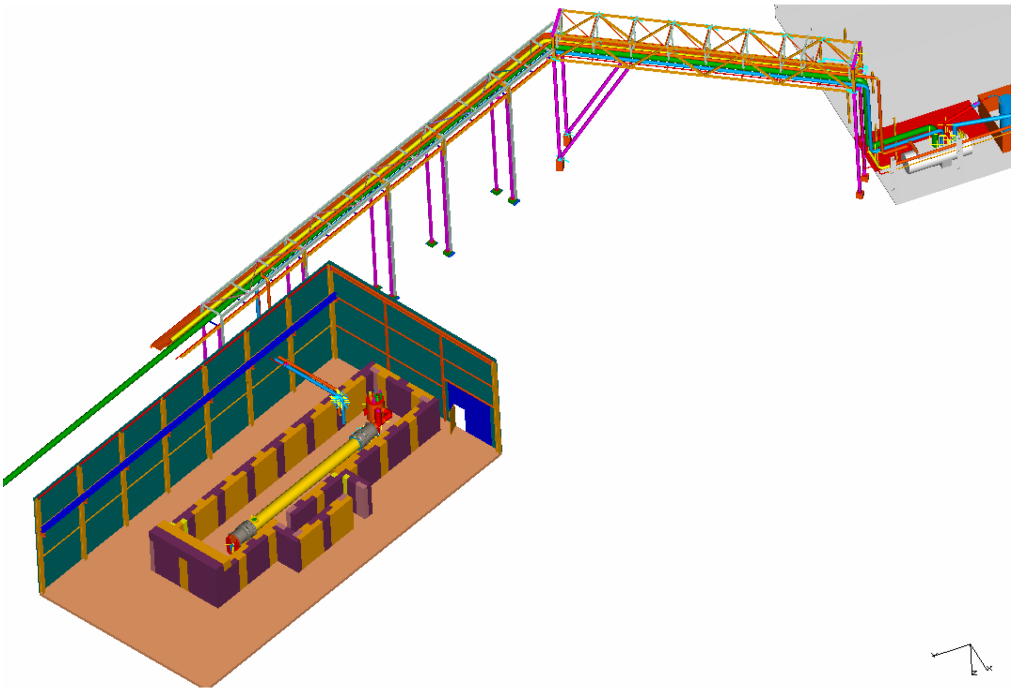

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1. Introduction

In the framework of the construction of superconducting linac based light sources as the BESSY FEL and in particular in view of the European XFEL-project, cryomodule prototypes have to be developed and the serial production of cryomodules has to be prepared. During the development of prototypes, complete system-tests of cryomodules have to be conducted. For these investigations a **C**ryo**m**odule **T**est **B**ench **(CMTB)** is being erected at DESY, supported by the EUROFEL design study within the program of Work Package DS 6.

On the test bench, the operation of all different sub-systems of a cryomodule has to be verified; only the beam operation is excluded. Changes of the design and assembly procedures, which may be introduced as consequences of the **XFEL-Cryomodule Design & Assembly Industrial Studies** (see also EUROFEL design study DS6), have to be validated. In particular, the test bench has to supply all cryogenic and radio frequency (RF) stationary and transient operating conditions. Also fault conditions will be investigated. Based on the TESLA superconducting linac technology and the TESLA Test Facility prototype designs, the CMTB has to adapt different cryomodule designs.

This report describes the technical specifications and the design of the Cryomodule Test Bench.

2. Test program

As input for the CMTB design, the test program has to be defined.

2.1 Mechanical check of the components

Before the installation of the cryomodules on the test stand the alignment of all components, which have to be connected to the CMTB – beam tube, cryogenic tubes, coupler and vacuum flanges, feedthroughs etc., have to be checked.

2.2 Leak tests of the vacuum systems

Beam vacuum, coupler vacuum and isolation vacuum have to be checked for leaks. The cryogenic helium process tubes have to be set to their test pressures and leak checked in addition. All leak tests have to be conducted under warm conditions and after the cool down of all helium circuits to the operating conditions.

2.3 Conditioning of the main RF-couplers (cavities off resonance)

The main RF-couplers have to be conditioned. The procedure could be similar to the usual conditioning at the horizontal test of single equipped cavities (CHECHIA-test) and at the TTF-linac. The conditioning can start before the cool down of the module and can be continued during the cool down.

2.4 Conditioning with resonant cavities (check of tuning systems)

The cavities have to be tuned to their resonant frequencies by means of the cold tuning systems – this will include a system test of the cold tuning systems. The conditioning of the couplers has to be continued with the cavities on resonance.

2.5 Measurement of the dynamic cryogenic loads of the cavities

The dynamic heat loads of the individual cavities in the modules have to be measured to get the Q versus E_{acc} characteristics of the cavities and their maximum acceleration fields. These tests may be repeated after different steps of HPP-treatment of the cavities (see 2.6).
During these tests, the gamma radiation around the cryomodule has to be monitored, to get some indication for field emission events in the cavities.

2.6 HPP-treatment of the cavities

Depending on the performance of the cavities in the module in comparison to the original tests results during the vertical tests of the individual cavities and depending on the onset of field emission, the cavities will be treated by HPP procedures.

2.7 Test of the superconducting quadrupole

The superconducting magnet package will be powered. The operation of conduction cooled current leads will be investigated during this test. There will be no magnetic field measurements. According to the present XFEL cryomodule design, the quadrupoles will be operated in the 2K liquid helium bath.

The use of current leads and the corresponding 2K heat loads will be studied. Also the consequences of quenches in the 2K circuit will be monitored.

2.8 Measurement of the static cryogenic heat loads
The static cryogenic heat loads on the different temperature levels in the module cryostat will be measured (40/80 K, 4.5 K, 2.0 K temperature levels).

2.9 Measurement of the alignment of the cavities during cool down and warm up
At least some of the modules will be equipped with wire position monitor measurement system to investigate the effects of cool down and warm up on the alignment of the cavities.

2.10 Monitoring of dark currents
At one end of the beam tube of the cryomodules, a monitor for the measurement of dark currents will be installed.

2.11 Fault conditions and thermal cycling
For the time being, the design of the pressure release installations of the TTF, TESLA and XFEL cryogenic systems is based on numerical simulations only. Beside the investigation of technical details, the concepts of the safety systems for superconducting linacs have to be demonstrated to official authorities and safety review committees.
As a consequence, at least on the scale of one cryomodule, the simulations have to be validated by experimental data.
The test program will include the sudden venting of the insulation vacuum and the beam vacuum with air and helium.
In addition, prototype cryostats and the related systems must be extensively thermally cycled, to investigate the influence on the performance of the cryomodules.

2.12 Inclined two-phase bath cooling
Effects of inclined operation on the two-phase bath cooling of the cavities will be investigated.

3. Design of the CMTB sub-components

3.1 Cryogenics
The Test Bench will be placed in a new experimental hall. The hall will be situated close to the building 28 on the DESY Hamburg site, in immediate proximity to a service bridge carrying a transfer line from the HERA cryo-plant to the XFEL sub-cooler box in the building 28. The CMTB cryogenic system will be connected to the existing cryogenic distribution system, which supplies the VUV-FEL-linac and the TTF-test area at present.
The cryogenic system comprises a transfer line, a test facility and a warm piping. The transfer line[1] connects the FEL sub-cooler box with the test facility. This transfer line will come to the CMTB hall using the same service bridge. The test facility[2] includes a feed box and a feed and an end caps. The feed box is connected to the feed cap via an L-shaped transfer line. The feed box is intended for forming and distributing cryogenic flows while the feed and the end caps serve as interface components between the cryo-supply and the cryomodule. The feed and the end caps will be supported to the ground by an L-shaped support structure. The warm piping serves mainly for transient processes as cool down or warm up, relief of helium, etc.

3.2 RF-System
The radio frequency (RF) supply consists basically of a modulator, a pulse transformer, a klystron and a wave guide system. The modulator[3,4] converts energy from the mains into pulsed energy. The 10 kV pulses have a repetition rate of up to 10 Hz and a width of 1.7 ms. The modulator then transmits the electrical energy into the pulse transformer[5], which transforms the 10 kV pulses to the 120 kV-150 kV level required by the klystron[6]. This voltage is applied to the klystron cathode. The klystron produces radio frequency of 1.3 GHz and 10 MW output power with a pulse length of 1.5 ms. The 10 MW multibeam klystron has two outputs and can supply with the RF energy up to 4 cryomodules with 32 superconducting cavities.
For transporting the RF energy to each single cavity of a cryomodule a waveguide distribution system[7-13] is required. The applied waveguide distribution system is built on the basis of the WR650 standard. Among other elements the waveguide distribution system contains circulators[14] protecting the klystron from disruption by reflected waves.

3.3 CMTB Infrastructure

3.3.1 Radiation shielding
The shielding protects the environment against an ionizing radiation, produced during RF operation of the cryomodules, by means of shielding elements. The walls of the shielding will be made of ore loaded concrete blocks of 0.8 m thickness. Concrete blocks of 0.8 m thickness will cover the roof. At both ends additional lead plates of 0.15 m thickness will cover the inner sides of the concrete shielding. All main components of the cryo-equipment will be placed inside the shielding and exposed to the ionizing radiation. The inner dimensions of the shielding are 22.4m (L) x 4.8m (W) x 3m (H).

3.3.2 General infrastructure
General infrastructure supplies the Cryomodule Test Bench with utilities – water, compressed air and electrical power. The demand in cooling water of 500 litres/min and compressed air of 15 Nm^3/h will be covered from the existing water towers and compressed air station situated in the building 28. The water and compressed air pipes will be laid on the service bridge. The electrical power will be supplied from a 725 kVA transformer situated close to the CMTB building.

3.3.3 CMTB experimental hall
The experimental hall houses the CMTB. The dimensions of the building (standard industrial building) are 31.8m (L) x 16m (W) x 9m (H). Since the building does not represent a permanent working place the sanitary equipment of the building 28 will be used. The heating is designed such that the temperature does not fall below dew point. Only natural ventilation of the building is foreseen by means of remotely controlled windows in the building roof. The building is equipped with a 20 t crane and disposes of a number of cable channels. The figure below shows the placement of the CMTB.

Fig.1: CMTB-experimental hall, status 23 July, 2005

The CMTB experimental hall is conceived as extendable in length for a later up-grade of the test facility, to allow for tests with beam and with a string of maximally 4 cryomodules.