Status of the HoBiCaT Superconducting Cavity Test Facility at BESSY*

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Abstract

BESSY recently constructed the HOBICAT cryogenic test facility for superconducting TESLA cavity units, including all ancillary devices (helium tank, input coupler, tuner, magnetic shielding). It is designed to house two such units in a configuration similar to that envisaged for the superconducting CW linac of the BESSY FEL. These units are being fabricated, prepared and assembled by industry. HOBICATwill be used to address many of the issues that must be considered prior to finalizing the design of the proposed linac. Rapid turn-around-tests permit the investigation of items such as RF regulation, microphonic detuning and cryogenic parameters/achievable pressure stability. These test will also serve as the first step towards qualifying the industrial production of assembled cavity units. The commissioning of HOBICAT began in Spring 2004 and the current status is presented here.

INTRODUCTION

TESLA superconducting radio-frequency (RF) cavities were originally developed for use in the TESLA linear collider and the TESLA XFEL.[1] These machines are planned for high-energy operation and require high accelerating gradients to limit their lengths. But the refrigeration cost dictates that these machines be pulsed to limit the dynamic cryogenic losses.

TESLA equipment has been operating reliably for some time now at the Test Facility (TTF). Due to this success, several recent proposals call for the use of TESLA technology for CW VUV to soft-xray light sources, such as the BESSY FEL[2], the Cornell Energy-Recovery Linac (ERL)[3], and the 4GLS[4]. These machines use driver linacs of moderate energies (2–5 GeV) with little beam loading, so that CW operation can be realized.

Most of the TESLA technology can be used “as-is” for CW operation. However, several new issues uniquely related to CW operation (and therefore not necessarily addressed at TTF) now need to be investigated. They include:

1. Optimize of the bath temperature to minimize the capital and operating cost of the refrigeration plant.
2. Determination of the CW power limit of the input couplers under standing-wave conditions.
3. Operation of very-narrow-bandwidth cavities with a high-gain RF feedback system. The gain limits and attainable cavity-voltage stability must be measured.
4. Passive measures to reduce the microphonic detuning of cavities.
5. Demonstration of active compensation of microphonic detuning using a piezo stack integrated in the tuner.
6. The dynamic cryogenic load can be as high as 40 W/cavity in some CW linacs (e.g., Cornell’s ERL). Steady CW cryogenic operation and a high degree of pressure stability must be demonstrated.

BESSY therefore constructed a horizontal test facility named HOBICAT (Horizontal Bi-Cavity Test-facility) that permits rapid-turn-around testing of superconducting cavity equipment. Its design is based upon the CRYHOLAB[5] and CHECHIA[6] systems developed at the Orsay and Saclay institutes, respectively.

STATUS OF THE HOBICAT FACILITY

The HOBICAT test facility includes a cryostat, feedbox, helium refrigeration plant, RF power supply and two TESLA cavities as well associated ancillary equipment. HOBICAT is designed to have a cooling capacity of 80 W at 1.8 K but operation at lower temperatures at reduced power is also possible.

Details of the facility are provided in References [7] and [8] so that here only a review of the current status of the system is presented.

Cryostat

Fig. 1 depicts the HOBICAT cryostat and vertical feedbox in the radiation enclosure. The cryostat and feedbox were produced by Linde and delivered to BESSY in January 2004. The 3.5-m long, 1.1-m diameter cryostat provides room for two 1.3-GHz 9-cell cavities with their helium tanks, tuners and input couplers. Currently, though, the cryogenic commissioning is being performed with a “dummy” helium tank (no cavity) that has a LHe volume roughly equal to that of a TESLA-cavity tank.

The 180-l/hr BESSY-II refrigeration plant supplies 4.5-K helium via a 150-m long Nexans transfer line (FGL-10/66). The liquid helium is collected in a 25-l reservoir in the HOBICAT feedbox. It then flows through a heat exchanger and a JT valve to be cooled further. The latter feeds directly into the 96-mm two-phase supply line of the helium tank. The supply line is terminated by a reservoir which contains a level meter and compensation heater for level control and load balancing, respectively. The layout was intentionally chosen to mimic that of the TESLA

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Figure 1: The HoBiCaT cryostat and feedbox in the radiation enclosure.

Figure 2: A combination of Leybold RA7001FU roots blowers and Sogevac SV1200 rotary vane pump is used to pump the HoBiCaT helium bath to 16 mbar.

modules modified for CW operation[9] to be able to investigate their cryogenic behavior with large heat loads. From the reservoir, the boil-off gas is shunted through the heat exchanger. Outside the feedbox, the return gas is warmed to room temperature in a 10-kW heater (see Fig. 1) prior to being pumped by vacuum pumps and reliquifaction by the refrigeration plant.

Vacuum pumps

The pumping system used to maintain a helium pressure of 16 mbar has also been installed and is operational. Its configuration is shown in Fig. 2. Two parallel systems, each consisting of a Leybold RA7001FU roots blower that is pumped by a Sogevac SV1200 rotary vane pump, combine for a total pumping speed of 6400 m^3/hr. Pressure stability is maintained by a combination of frequency control, a pump-bypass valve and a (cold) control valve before the heater.

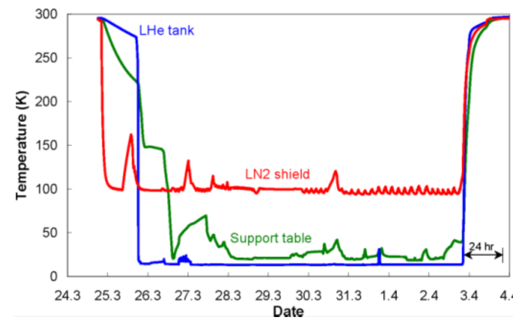

Figure 3: Temperatures of the LN_2 shield, the support table and the dummy helium tank during HoBiCaT commissioning. Measurements were made with CLTS sensors which were not fully calibrated at LHe temperatures and therefore bottom out at around 10 K.

Cryogenic commissioning

Cryogenic commissioning of HoBiCaT began in March 2004. So far, the system has been cooled twice to 1.8 K. The final acceptance tests have not yet been completed, so the results presented here should be considered preliminary.

Fig. 3 depicts one cooldown cycle of HoBiCaT. Shown are the shield temperature (cooled with LN_2), the temperature of the table (cooled with 4.5-K He) and that of the helium tank. Roughly 24 hours are required to cool from room temperature to 4.5 K, although slower cooldown times may become necessary when cavity units are installed to avoid thermal stresses. Similarly, warm up times are on the order of 24 hours if the insulation vacuum is spoiled with nitrogen gas once the temperature rises above 100 K.

The table supporting the helium tank requires a significant time to reach full thermal equilibrium. It is made of stainless steel and cooled by liquid helium siphoned off from the 4.5 K supply line. Design changes (including using aluminum for better conductivity) are being considered for an improved version.

So far a maximum dynamic load of 30 W at 1.8 K has been dissipated using a heater on the helium tank. This is sufficient for single cavity tests. Presently, the pressure drop across the return-gas heater limits the pumps' ability to maintain 16 mbar at loads greater than 30 W. The heater is therefore being redesigned to reduce its flow impedance and to enable loads up to 80 W for two-cavity tests.

Ultimately, the cavity quality factor (and hence the dynamic losses) will have to be determined by measuring the rate of helium boil-off because the cavities will be overcoupled by a factor of 100 or more. To that end, a Hastings flow meter measures the helium flow after the pumps. To achieve a good signal-to-noise ratio, the static losses need to be small. Measurements during commissioning have demonstrated that static losses are on the order of 1.3 W with the dummy helium tank. This value will increase slightly when the main coupler and connections for diag-

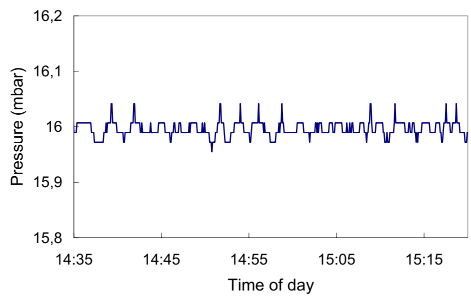

Figure 4: Helium bath pressure in the helium tank used for HoBiCaT commissioning. The dynamic load at this time was of order 20 W.

nostics are installed, but we expect the total static load with a single cavity to be on the order of 2–3 W.

The helium pressure stability is also of importance because pressure fluctuations detune the cavity. First measurements are shown in Fig. 4. So far the control loop has not been optimized and measurements of the system's response to a step load change still needs to be determined. Nevertheless, a pressure stability of ± 0.05 mbar (peak) with a dynamic load of 20 W has been demonstrated. For reference, such pressure fluctuations detune a TESLA cavity by about 1 Hz.

Cavity units

Two cavity units are being produced by ACCEL Instruments. The production includes all steps required for the assembly of a unit—that is the production of the input couplers and cavities, the etching of the latter with BCP, the high-pressure rinsing, the bead pulls for field flatness, the welding of the helium tank, as well as the clean-room-assembly and mounting of field pickups and the input couplers. Thus this production run will qualify for the first time the ability of industrial partners to achieve high fields in complete cavity units while maintaining a good quality factor.

So far the couplers and the bare cavities have been produced. The integration of the first cavity in the helium tank and the mounting of the coupler is currently underway.

Prior to final assembly, the cavities are tested at DESY on the vertical test stand. Fig. 5 depicts the first two tests. The very first cavity achieved 16.6 MV/m at a Q of 1.6×10^9. It was limited by field-emission loading and will be reetched for a renewed test. The second cavity performed significantly better, reaching 20 M/m at $Q = 10^{10}$ and 23 MV/m at $Q = 4 \times 10^9$. Above 20 MV/m, the cavity displays the well-known Q slope associated with BCP treatment and it was limited by a quench whose source is currently unknown.

At the BESSY-FEL operating gradient of 16 MV/m the quality factor was about 1.5×10^{10}, exceeding the design value of 1.3×10^{10}, even though the measurements were made at 2.0 K rather than 1.8 K. Measurements with the first cavity demonstrated that the residual Q indeed improves significantly to about 3.5×10^{10} when the bath is pumped to 1.8 K.

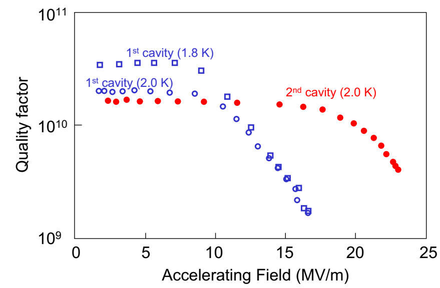

Figure 5: Vertical cavity tests of the HoBiCaT cavities at DESY.

RF system

A 1.3-GHz klystron based on the 1.5-GHz CEBAF design has been procured from CPI (VKL7811). The transmitter is currently being constructed. The power supply was delivered from FUG, operating at 15.5 kV. This is sufficient for 12-kW RF-power operation.

In future it is planned to add a second, IOT-based transmitter currently under development at CPI. Operation at up to 20 kW will then be possible.

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