Overview: Test facilities at SupraLab

1. Sample testing: The quadrupole resonator

New material treatment techniques for niobium (e.g., nitrogen infusion) and new SRF materials (such as multilayer superconductors) can have a dramatic impact on SRF operation, especially for CW systems. Sample tests are best suited to analyze these materials in a controlled manner over a wide range of parameters. The quadrupole resonator provides a very flexible system to analyze the RF performance of materials over a wide range of temperature and RF field level at multiple frequencies, which can rapidly be adjusted for parameter scans. The surface resistance can be measured down to nano-Ohm resolution.

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Capabilities:

- Measure surface resistance vs RF magnetic field
- Measure surface resistance vs temperature
- Measure surface resistance vs RF frequency
- Measure superheating field
- Measure penetration depth
- Perform trapped flux studies
- Measure T_c

Parameter	Value	Comment
RF frequencies	417, 850 and 1300 MHz	
Temperature range	1.5 K – 300 K	
RF magnetic field range	up to 140 mT	Highest fields in pulsed mode
Surface resistance precision	< 1 nΩ	Best at low T
Surface resistance accuracy	10 nΩ	Best at high T
Sample diameter	75 mm	

1. Prototype cavities: The small vertical test stand

A small Helium bath cryostat is available for RF testing of small prototype cavities, such as 1.3 GHz 1-cell or 2-cell. The cryostat is connected to a helium cryogenic plant. For simplicity, it has no LN_2 shield—the thermal radiation shield is cooled by the He-exhaust line. A liquid helium refill is required every 24-48 hours depending on testing conditions. A local clean room allows for particle free mounting of pumping lines. Besides RF measurements, extensive diagnostics for cavity characterization, such as magnetic field mapping, temperature mapping and second sound quench detection, is available.

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Capabilities:

- Measure surface resistance vs RF field in cavities
- Temperature mapping (2 ms aquisition time)
- Magnetic flux mapping (2 ms aquisition time)
- Second sound quench detection measurements
- Cryogenic vacuum tests

Parameter	**Value**	**Remark**
Cooling power	40 W @ 1.8 K	3 W static losses
Operating temperature	1.5 K – 4.2 K	30 μbar stability at $T < 2.2$ K
Usable diameter	564 mm	
Usable height	< 2 cell TESLA	
Maximum He level	1394 mm	
Maximum Helium pressure	1.5 bar	
Magnetic background field	< 1 μT	(Earth field = 50 μT)
Radiation protection	Up to 5 Sv/h	
Broadband RF power	415 MHz – 3.2 GHz	Min. 100 W

2. Cavity acceptance testing: The large vertical test stand

A large bath cryostat that houses full size (multicell) cavities is currently being set up. It can be used for "naked" cavity acceptance tests or tests of cavities with liquid helium tank. The cryostat includes an LN_2 cooled thermal shield. An option for continuous liquid helium filling (level control) is being implemented. For fast turn-around times the cryostat is equipped with 4 kW heaters warm up the cryostat rapidly. Its nearly 1-m inside diameter allows for testing of large-diameter cavities (e.g., with large waveguide HOM damper ports) and low-frequency cavities. The usable height of 2.9 m in theory allows for testing two TESLA type cavities above each other. Assembly of vacuum connections will take place in a local clean-room next to the cryostat.

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Capabilities:

- Measure surface resistance vs RF field in cavities
- Second sound sensors measurements
- Cryogenic vacuum tests

Parameter	**Value**	**Remark**
Cooling power	40 W @ 1.8 K	
Operating temperature range	1.5 K – 4.2 K	
RF Frequency	0.6 GHz – 2.1 GHz	Extendable if necessary
Usable diameter	933 mm	Space for HOM waveguides Horizontal testing of short structures possible
Usable height	2500 mm	2 x 9 cell TESLA in series
Maximum He level	2900 mm	

Parameter	Value	Remark
Maximum Helium pressure	3.2 bar	
Magnetic background field	< 1 µT	(Earth field = 50 µT)
Radiation protection	Up to 5 Sv/h	

3. High-power RF coupler conditioning

An RF coupler conditioning facility is integrated in the bERLinPro bunker for radiation shielding. A variety of RF power sources at power levels up to 270 kW are available, as well as water cooling, vacuum, fast interlock system, diagnostics logging etc.

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4. Cavity Mode Characterization

The RF characterization of the cavity field distribution is possible in an automated x,y,z beadpull system. A second system (z only) is implemented in HoBiCaT to enable "cold bead pulls" of cavities in the superconducting state (helium tank required).
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5. Debugging RF control system: Virtual Cavity testing

RF testing of SRF systems is a costly and time consuming endeavor. And frequently low-level RF control systems, quench detection and similar controls are under development some time before the full SRF system is even available for extensive cold tests. To provide early stage, inexpensive debugging opportunities for cavity controls and machine protection, the virtual cavity uses an FPGA-based "simulator" for hardware-in-the-loop simulations. The system implements a cavity electrical model for the transmitted and reflected voltages and more advanced features such as mechanical vibration modes driven by Lorentz-force detuning or external microphonics, hard quenches, and the Q-slope. As viewed from the RF input and output, this "virtual cavity" acts like a real SRF system. The model in the simulator can be adapted to any specific SRF (or even normal conducting) cavity system.

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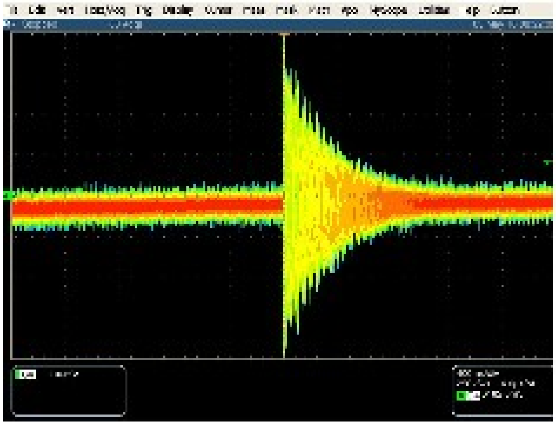

6. Dressed cavity testing: HoBiCaT

The HoBiCaT facility is designed for tests of “fully-dressed” SRF cavities in CW mode. Cavities in HoBiCaT can be equipped with all components that are needed for subsequent operation in an SRF module (e.g., HOM loads, tuner, coupler, magnetic shield …). Thus final acceptance testing prior to module integration can take place in HoBiCaT. Heat intercept stations are available at 4.2 K and 80 K.

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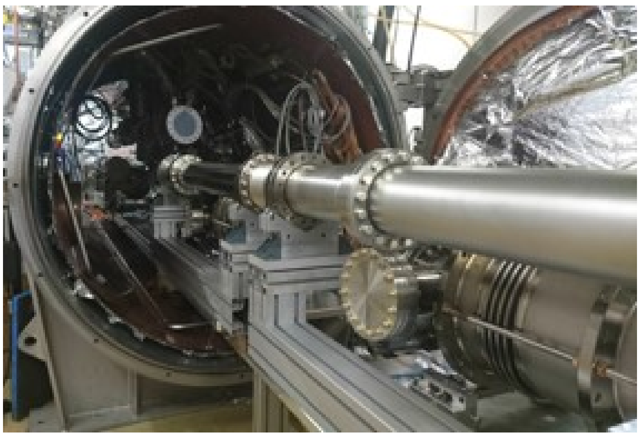
Capabilities:

- Horizontal testing of up to two fully dressed TESLA type cavities simultaneously
- Continuous cryo-operation
- Tuner testing
- High power coupler testing up to 15 kW @ 1,3 GHz
- Cernox based temperature diagnostics
- Second Sound sensors in liquid helium tank
- Cold bead pull for multi-cell cavity field profile measurements in the superconducting state.

Parameter	**Value**	**Remark**
Cooling power	80 W @ 1.8 K	10 W static losses
Operating temperature range	1.5 K – 4.2 K	
Usable frequency	0.4 – 3.1 GHz	
Usable diameter	~1m	Space for HOM waveguides
Usable length	2 x 9 cell TESLA	
Magnetic background field	< 5 µT	When no cold shield is provided
Radiation protection	Up to 5 Sv/h	



Installation of cavities for tests at HoBiCaT

7. Magnetometry and Thermometry

A novel technology for the magnetic characterization of cavities has been developed at HZB: Anisotropic magnetoresistive (AMR) sensor arrays have been adapted to operate in the cryogenic environment of the small vertical test stand and are arranged to measure and monitor the 3-D magnetic field distribution at arbitrary locations around an operating cavity. For the characterization of trapped magnetic flux in the walls of a superconducting cavity, PCB boards have been designed that allow to position a large number of sensors next to the cavity wall. A triple Helmholtz coil setup allows for exposure of the DUT to external DC magnetic fields up to 2 mT at arbitrary orientation. The magnetometry can be combined with temperature mapping to correlate RF power dissipation with trapped magnetic flux.

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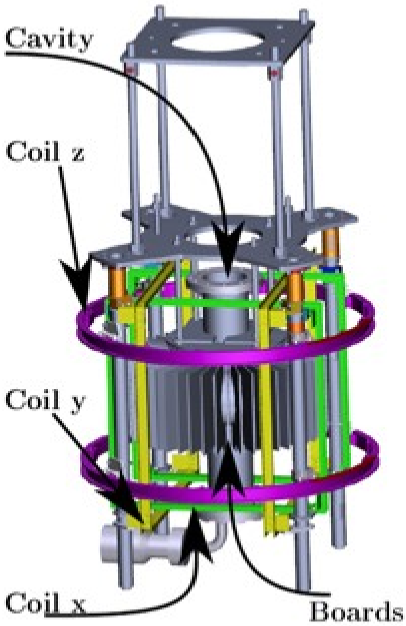

Cavity arrangement with magnetic field mapping boards as shown on the right and temperature mapping boards. Three sets of Helmholtz coils permit the application of magnetic fields in arbitrary orientations.

Parameter	**Value**	**Remark**
Field resolution	0.02 µT	
Field accuracy	0.2 µT	
Field precision	2 µT	Determined by inherent offset changes
Map acquisition time	2 ms	Entire B-field and T-maps without cross talk

8. Conditioning normal-conducting cavities

Many storage-ring facilities employ 500-MHz normal conducting RF cavities. For conditioning, radiation protection is required. At SupraLab, an RF test stand is available for conditioning cavities up to 80 kW CW, employing local radiation shielding.

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9. Cryogenics

SupraLab includes a large cryogenic infrastructure that is primarily intended for SRF research. However it also enables many other tests under cryogenic conditions such as sensor testing, material testing (e.g. mu-metal characterization), testing of stability of joints etc. The adaptation for tests has to be checked individually and potential users are encouraged to contact HZB to discuss capabilities and details.

Three helium liquefication plants with a capability at 4.5 K of either 200 l/h or 700 l/h are available. Since the plants are connected to helium dewars of up to 10.000 l capacity and equivalent gas storage, higher flow rates over limited time can be realized.
For lower temperatures there are different helium vacuum pump stands to pump down the helium to temperatures of 1.8 K at 250 W cooling capacity. Temperatures down to 1.5 K at reduced power level are possible.
Temperature levels of 1.8 K, 4.5 K and shield temperature 40-100K are available.

Depending on the experiment, cryogenic adaption may be required even though HoBiCaT and the vertical test stands are designed for universal use.

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