Technology Infrastructure - DESY (Germany)

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Technological Infrastructure at DESY

DESY is one of the worldwide leading institutes in SRF electron accelerator science and technology. While top-level expertise in specific aspects and components of SRF technology is available at a number of other institutes, most of which are long-term cooperation partner of DESY, the laboratory has the full knowledge and expertise to develop and build high performance cavities, design and supervise the production of complete accelerator modules, take care of the full assembly, perform extensive testing, install many SRF based modules, and operate them for a long time. During the recent years DESY coordinated the construction of the European XFEL Accelerator which is by now the largest superconducting linac worldwide.

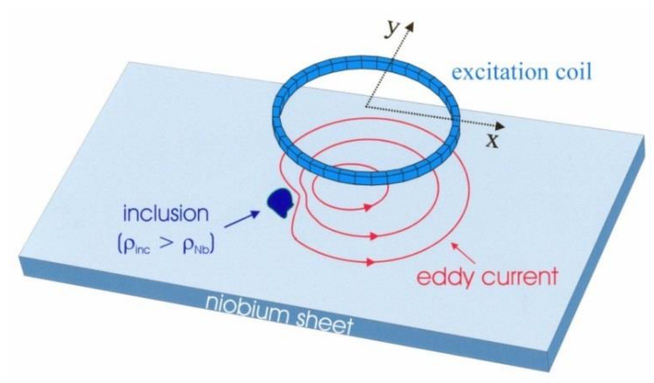
Future SRF based projects, be it the upgrade of existing facilities like FLASH and European XFEL towards long pulse or continuous wave operation, or the design of injectors for other future facilities require dedicated R&D activities: Fundamental questions concerning the general feasibility e.g. of high-gradient SRF electron guns, and investigations related to limitations in quality factor and to the long time behavior of SRF cavities in operation are to be addressed. Technical development towards fabrication of optimized accelerator components is to be carried out. The still continuing technology transfer to industry and to other research institutes remains important.

The unique DESY infrastructure and the competences of well-trained technical groups can be offered within the AMICI program. Partners can profit from dedicated state-of-the-art clean rooms (class 10), cavity treatment (chemical, particle-free high pressure water, dry-ice), assembly facilities for cavities and accelerator modules, and highly developed cold RF testing set-up. Specific infrastructure can be listed as follows:

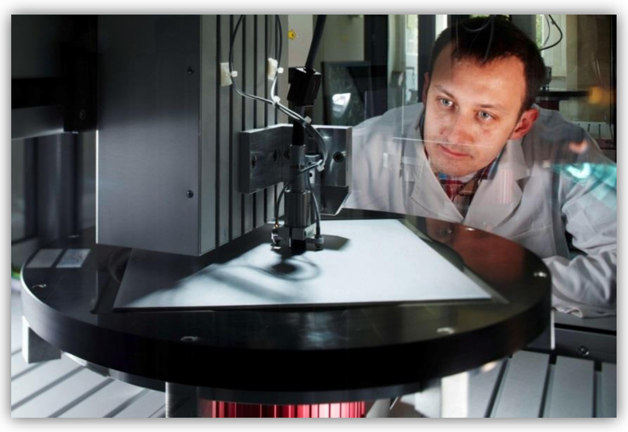
> Laboratory for the detailed examination of large series of niobium sheets for the production of superconducting cavities.
> Metallurgy laboratory for the examination of material needed for the production of superconducting cavities.
> Dedicated facilities for the preparation of superconducting cavities including 800°C and 1400°C baking, chemistry for surface treatment (BCP and electro-polishing), high pressure water rinsing, CO2 cleaning with dry ice, large ISO4 clean rooms.
> Several vertical test stands for the characterization of superconducting accelerator cavities
> Dedicated Assembly infrastructure for the first assembly / dis-assembly and repair of superconducting accelerator modules.
> Preparation and assembly of particle clean vacuum systems.
> Several horizontal test stands for the characterization of completely assembled superconducting accelerator modules.
> Test stand for the characterization of smaller superconducting quadrupole magnets.

Laboratory for the detailed examination of large series of niobium

The production of state-of-the-art superconducting accelerator cavities requires high quality niobium material. Therefore DESY developed and is using a special eddy current scanning device to search for inclusions in the Niobium sheet material. A total of almost 15,000 sheets delivered from different vendors were scanned for the European XFEL project. Also all sheets needed for the production of LCLS-II cavities were scanned at DESY. In-kind contributors to the ESS project profit as well from the existing infrastructure.



Principle of eddy current measurement

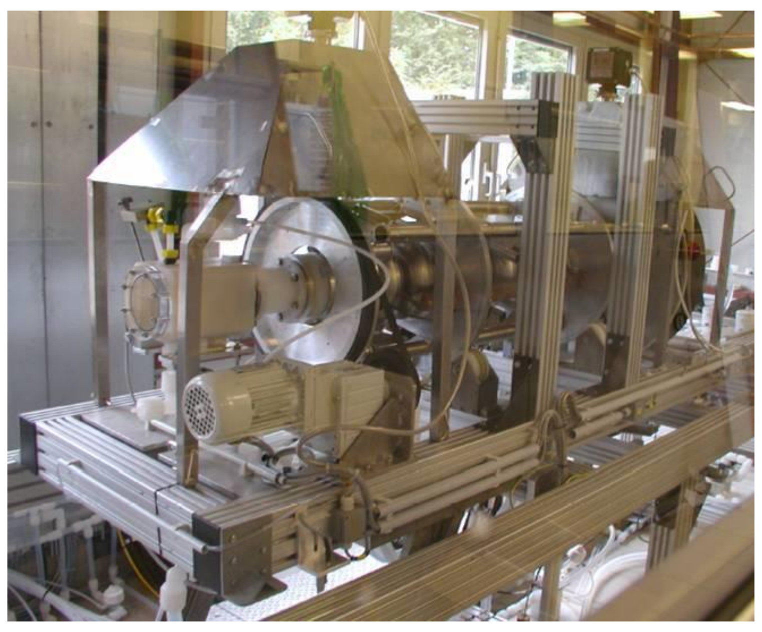


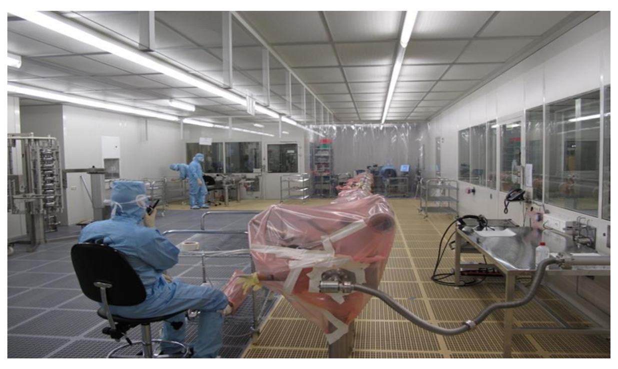
Niobium sheets are scanned at an operating frequency of 170 kHz. The achieved visible sheet's depth is approximately 500 µm, and the minimal detectable inclusion size is about 80 µm. The scanning result is used to fix the RF active surface i.e. the later inner side of the accelerating structure.

Dedicated facilities for the preparation of superconducting cavities

including 800°C and 1400°C baking, chemistry for surface treatment (BCP and EP), high pressure water rinsing, CO2 cleaning with dry ice, large ISO4 clean rooms

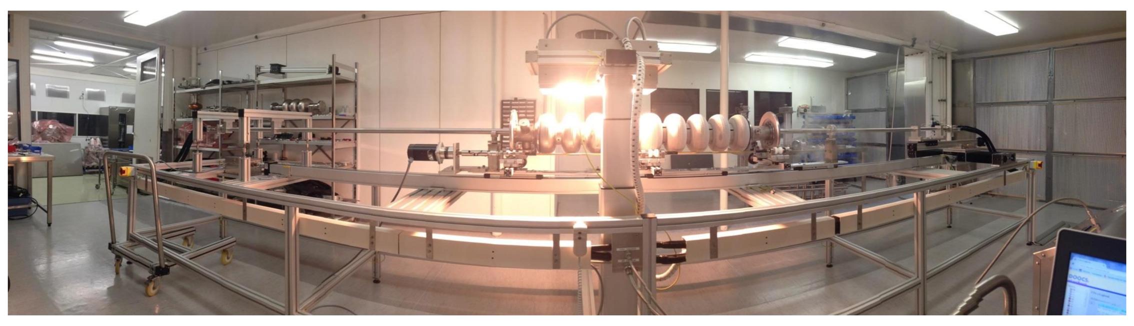
The surface treatment recipe used for the production of 800 superconducting European XFEL cavities was developed by DESY and its partners. Required infrastructure was prototyped in-house and later used to define standards for the industrial production. A large number of TESLA cavities were prepared by DESY since the mid 90-ies. Today emphasis is on smaller production series but also on special cavities like SRF guns, single-cell or cavities from research partners. Further optimized recipes are under study. Larger parts of the infrastructure are installed either next or even in the clean rooms used for the particle-free assembly of cavities to test stand inserts, or to complete cavity strings.





The assembly of superconducting accelerators requires large clean rooms of ISO4 class. DESY is operating such infrastructure since almost 25 years. The picture is taken during the so-called string assembly of a standard European XFEL accelerator module.

Electro-polishing of superconducting cavities is part of the state-of-the-art surface treatment. The shown infrastructure is operated at DESY. The equivalent devices at cavity vendors are based on the DESY version..



Dry-ice cleaning is successfully used to surface clean normal-conducting accelerating structures. The treatment of superconducting cavities is under study.

Ultra High Vacuum (UHV) ovens are used to high temperature treat niobium cavities prior to the chemical surface treatment. While industry needs to produce and treat cavities with well established procedures, new recipes can be developed in the research laboratories. Recently DESY modified the shown oven to follow new baking schemes developed by partners at Fermilab / U.S.

Metallurgy laboratory

for the examination of material needed for the production of superconducting cavities

The quality control of Niobium material used for cavity production profits from the operation of a metallurgy laboratory at DESY. Long time expertise is used to study defects found during eddy current scanning. The control of essential niobium properties is of utmost importance for reaching high accelerating gradients and low cryogenic losses.

Electrical & thermal properties
- Residual Resistivity Ratio
- Thermal conductivity

Impurities
- Eddy current method
- Gas analysis
- X-ray element analysis

Mechanical properties
- Hardness HV
- Thickness
- Bulging test
- Tensile test

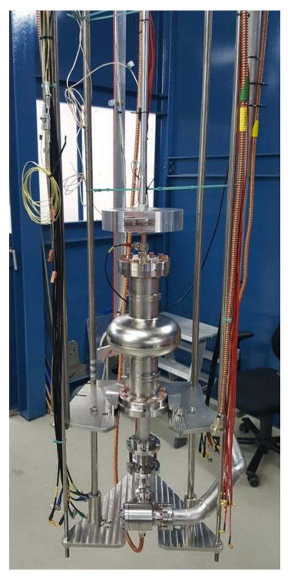
Surface analysis
- Roughness
- Surface profile
- Metallography
- Light microscopy
- 3D Imaging

Typical material properties are investigated using the respective tools and methods. The procurement of large amounts of niobium sheets requires QC at both sides (producer and vendor).

Vertical test stands

for the characterization of superconducting accelerator cavities

The characterization of superconducting cavities usually happens in so-called vertical test stands. The cavities are attached to the insert of a large dewar. The cavity vacuum system is pumped, the cavity cooled down to typ. 2 Kelvin. At DESY the inserts are adaptive for different cavity types, and usually have an adjustable RF antenna. Typical measurements start with the accelerating gradient as a function of the loaded quality factor (eq. to cryogenic losses). More sophisticated are RF measurements in the different pass-band modes, the temperature map or a second-sound measurement to locate quenches. Sensors checking radiation caused by field emission and magnetic flux complete the picture.

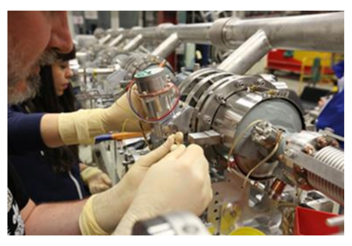


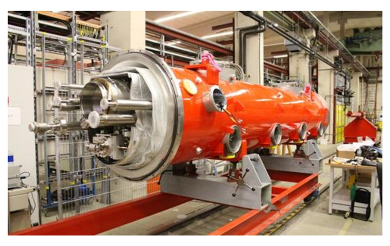
The standard DESY insert takes four cavities which are cooled down together. The testing at 2K is done four the individual cavities. The right picture shows a single cell 1.3 GHz cavities tested as part of the ongoing R&D program.

Dedicated assembly infrastructure

for the first assembly / dis-assembly and repair of superconducting accelerator modules

While the string of accelerating cavities is assembled in ISO4 clean rooms, the further assembly of the closed vacuum system to the so-called cold mass which is the inner structure of the cryostat is done in dedicated assembly areas. DESY has developed the respective infrastructure and uses it for standard European XFEL or FLASH modules.

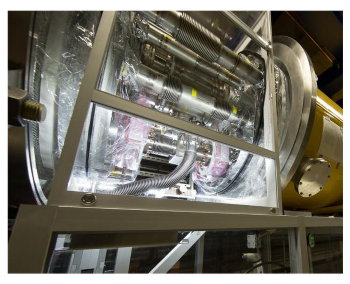




The outside clean room assembly work includes installation of frequency tuners, magnetic shields and others. Finally the cold-mass is moved in to the outer vacuum vessel. The picture shows the almost finished European XFEL 3.9 GHz module after assembly in the DESY infrastructure.

Particle clean vacuum systems

Installation of a superconducting linear accelerator requires the beam line vacuum system next to accelerator sections to be particle-free. Thus dedicated cleaning is done prior to installation. Often complete sections of some few meters length are pre-assembled in clean rooms.



Cleaning of beam line components in dedicated clean rooms is essential. The later installation profits from specially designed local clean rooms. All work requires well-trained experts.

Horizontal test stands

for the characterization of completely assembled superconducting accelerator modules

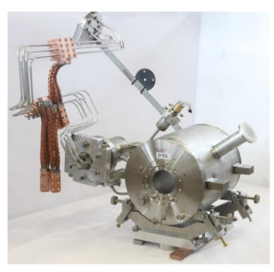
Assembled accelerator modules are extensively tested at cold temperature. After the initial incoming inspection the modules are attached to the vacuum and cryogenic system of the test stand which is installed in a shielding enclosure. Waveguides connect to the radio frequency supply. DESY is operating several of such test stands. Three of them were used for the European XFEL series testing. One additional test stand allows for more sophisticated studies including long pulse are even continuous wave operation.

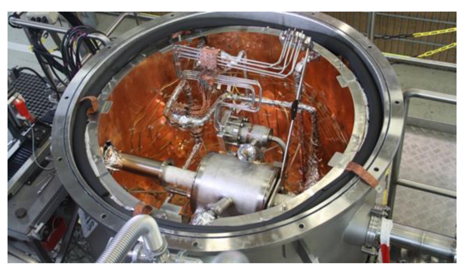
All European XFEL accelerator modules were extensively tested at DESY prior to tunnel installation. The existing test stands are adaptive to a variety of modules. Extension to e.g. special cryostats housing superconducting rf prototypes are under preparation.

Magnet test stand

for the characterization of smaller superconducting quadrupole magnets

Accelerator modules build in the so-called TESLA technology include small superconducting quadrupole magnet packages. Testing of such magnets is done prior to the module assembly.





The quadrupole magnets of the European XFEL were provided by CIEMAT, and testing was done in a dedicated test cryostat operated by IFJ PAN Cracow. The facility remained available for future use at DESY.

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European XFEL