SRF Cavity Diagnostics

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PHYSICS AT THE TERA SCALE
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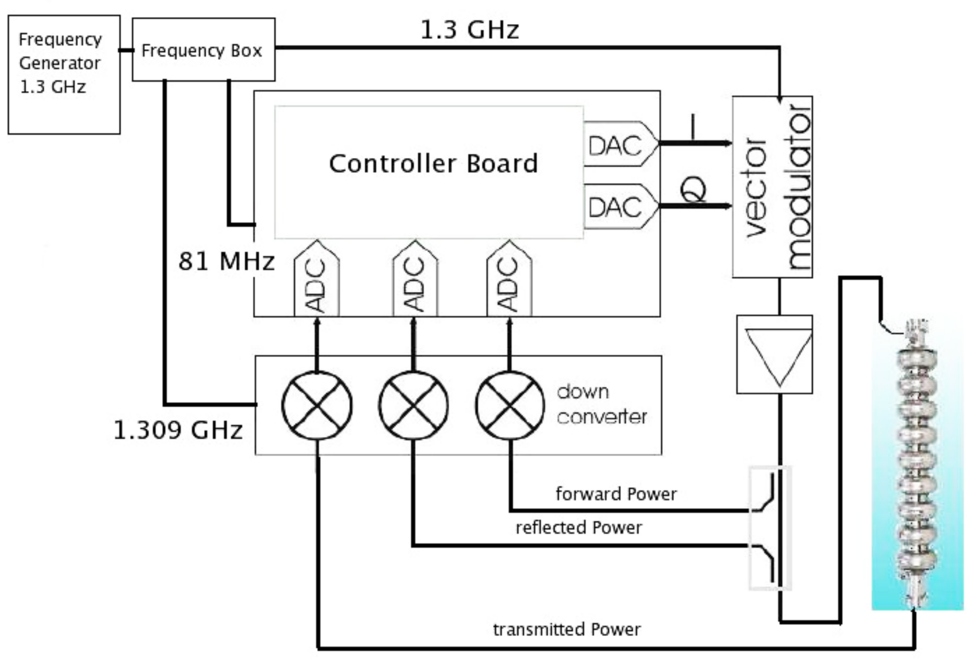
Introduction

To reach the energies of the Terascale with a Linear Collider a high accelerating gradient is mandatory to contain the length of the accelerator. Superconducting RF-cavities (SRF) made out of Niobium have seen tremendous improvements over the past decade and record gradients have been achieved in individual cavities. However, to meet the ambitious production requirements of the ILC an extra effort is needed. Special diagnostic tools have to be developed. Rapid and reproducible testing will be possible with the designed *vertical insert* and the *digitally controlled vertical test stand*. One of the limitations at high gradients is the breakdown of the superconducting state (quench), which can be investigated and located with *second sound* and *optical inspection.*

Digitally controlled vertical test stand

The Q-value, indicative of the resonant properties of the cavity, is a key parameter that is measured e.g. in the vertical test stand for operation at 2K at DESY. The variation of the Q-value as a function of the electrical field characterises the performance of the cavity and hints to limiting mechanisms. Using a novel digital control for the test stand addresses two topics. The measurement can be done faster, relieving the operators from manual intervention. An automated system yields reproducible measurements. In addition the controller hard- and software resembles the controller used at FLASH so that the relevant quantities are recorded. The high integration of the measurement thus serves as a testing ground for ILC SRF applications.



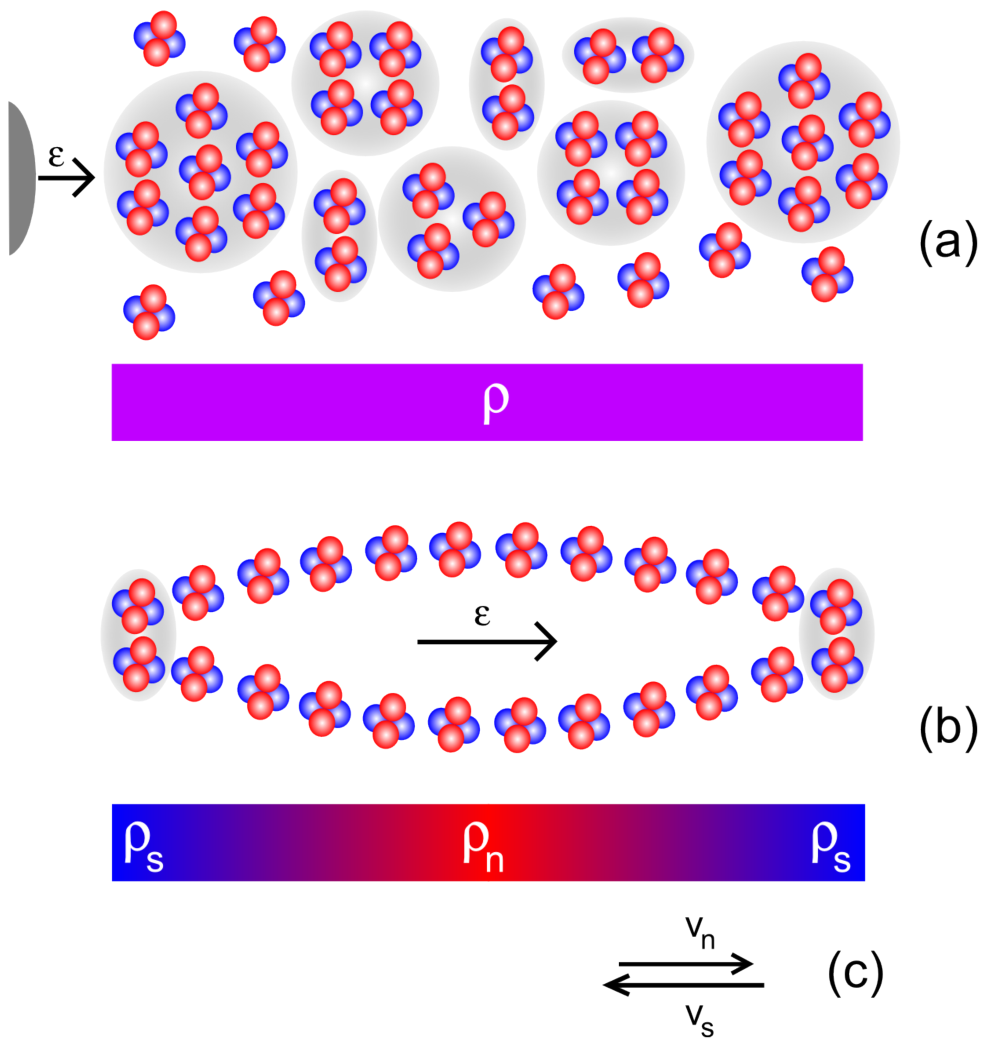
Schematic view of digital test stand

Vertical Insert

More than 800 SRF cavities will be required for the European XFEL, an ideal opportunity to understand the quality requirements for mass produced cavities and understand the failure modes that limit the gradient. In order to guarantee a most reproducible work environment the cavities will be shipped from the manufacturer in sets of four, supported by a so-called vertical insert. This mechanical structure supports four cavities and the required supply and diagnostics lines to carry out the cavity characterisation in the vertical test stand (Helium bath).
The mechanical structure has been designed in the DESY group and will be the basis for the cavity tests starting end 2010. DESY is the only place worldwide that will have access to a statistically significant sample of cavities (5%) prior to the construction of the ILC.

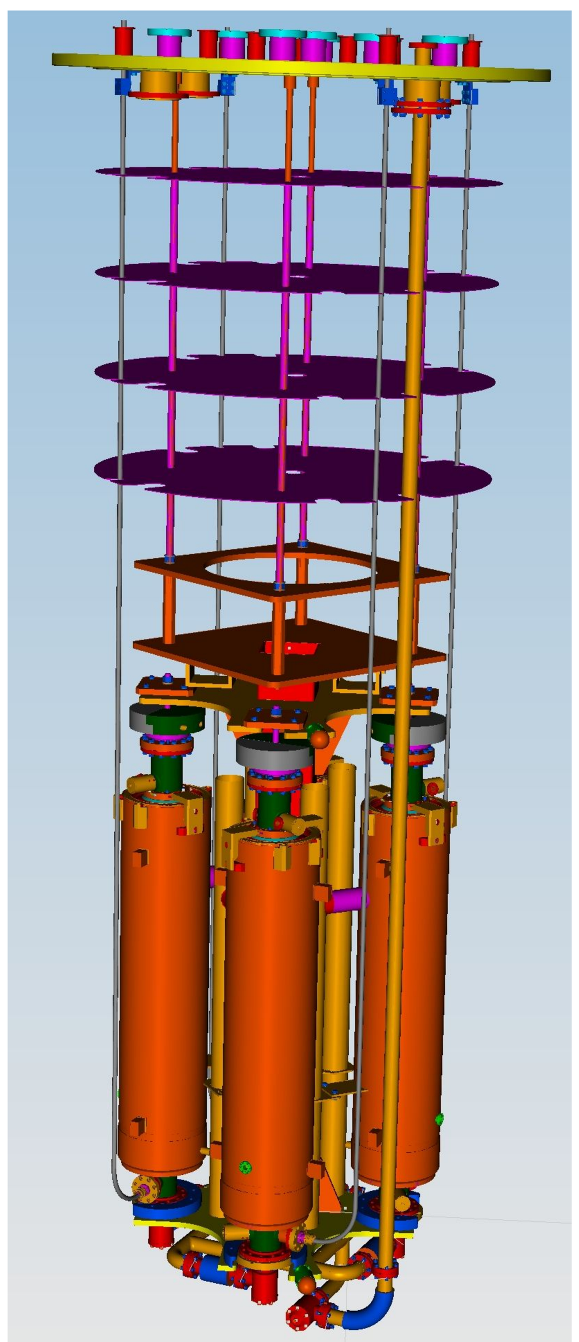
Second Sound

A local breakdown of the superconducting state generates heat that propagates into the Helium bath. Since the cavities are operated below the λ-point this energy creates the second sound of the phase transition of superfluid Helium to Helium I.

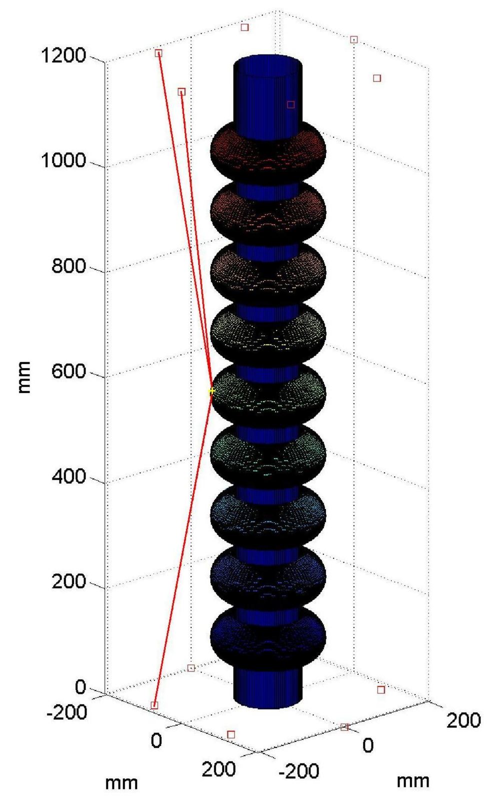


Mechanism of second sound (He II → He I)

For measuring the phase transition produced by this quench, oscillating superleak transducers (OSTs) will be used to locate the quench spot via triangulation. There are several advantages compared to temperature mapping (T-map) like faster measurement and easier mounting. The feasibility of this approach has been demonstrated at Cornell University (2008). There are plans for designing a similar setup at DESY and the optimised positions of the OSTs are being studied by numerical simulation of quench events and the propagation of the 2nd sound.



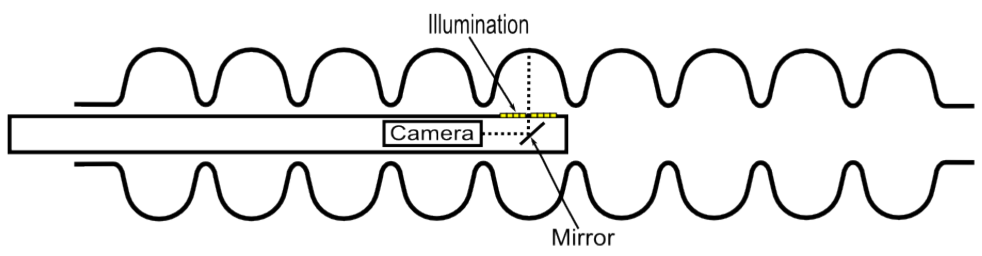
Design of vertical insert



Study of triangulation of quench position using OSTs for 2nd sound detection

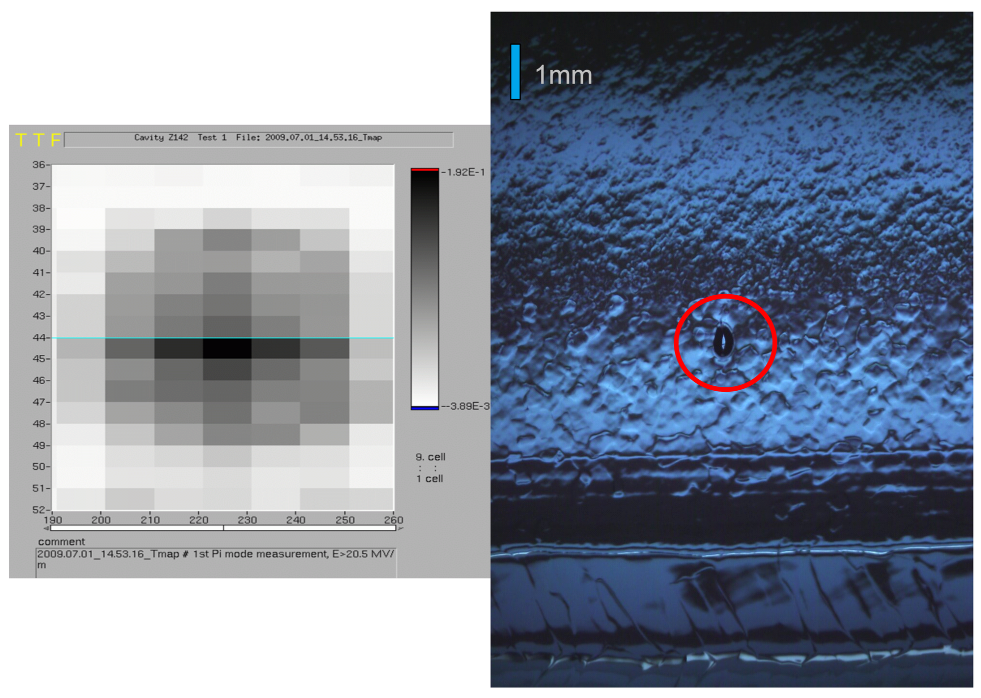
Optical Inspection

A system for the optical inspection of the inner surface of SRF cavities is in operation at DESY since August 2008 and has been used for the complete inspection of more than 20 cavities. It has been developed at KEK and Kyoto University. By the combination of a high resolution camera together with an illumination system that allows lighting from different angles for adaptation to the surface profile, the inspection system delivers detailed pictures of the inner surface.



Schematic view of optical inspection setup

The inspection can be done in situ without the cutting of samples as would be necessary for microscopy. The development of a setup for automated inspections with minimal need for an operator is ongoing. Correlations between the hotspot at the quench location determined by T-map (or 2nd sound) and a defect found by optical inspection of the respective spot on the inner surface of the cavity have been found in several cases. These correlations allow to categorize features on the welding seam with the goal to predict whether they limit the performance of a cavity. Subsequent inspections carried out in different stages of the surface preparation process are used to track the evolution of defects. This knowledge combined with an optical inspection in an early step of the cavity production cycle is expected to improve the yield of cavities with high gradient in a large production scale – as is required for the ILC.



Correlation of hotspot and defect found by optical inspection

DESY

SEVENTH FRAMEWORK PROGRAMME

Deutsches Elektronen-Synchrotron DESY
Georg-August Universität Göttingen