Status of JRASRF

D.Proch; T.Garvey

CERN, Nov. 05

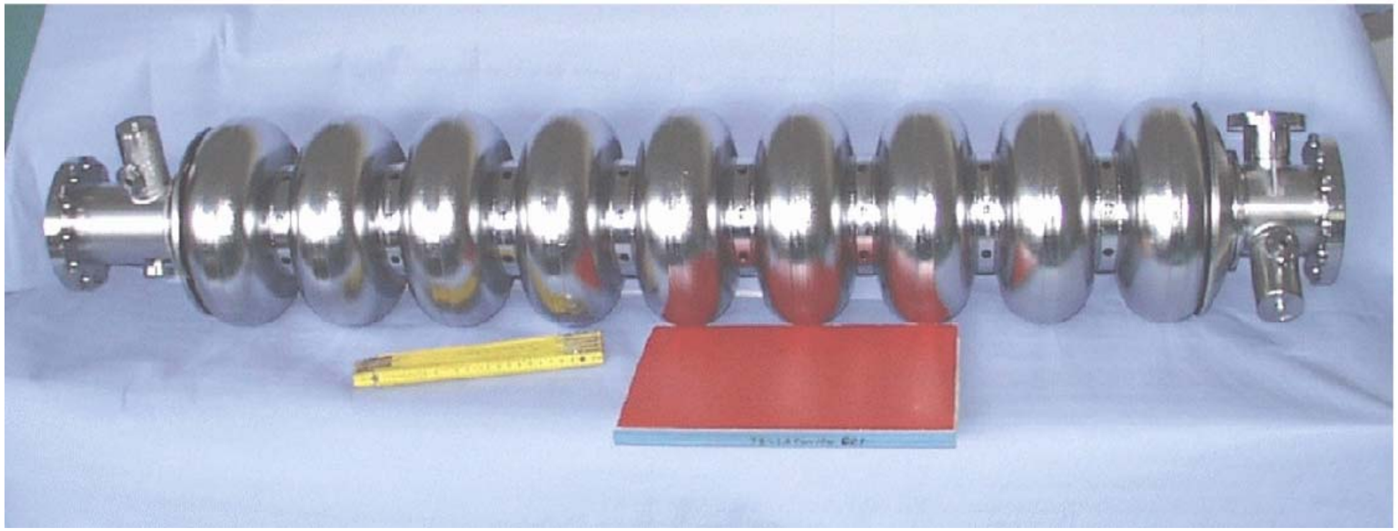
JRA1 (Joined Research Activity) in the CARE
(coordinated accelerator research in Europe) activity

Title: Research and Development on Superconducting Radio-Frequency Technology for Accelerator Application

Acronym: SRF

Co-Coordinators: D. Proch, DESY, T.Garvey, CNRS-Orsay

Deputy: H.Mais



SRF accelerator technology: R&D Subjects

- **High gradients** **(** close to the theoretical limit**)**
  - increase beam energy /shorten linac length
- **High Q value** (= low Rf loss)
  - Reduce cryogenic cooling power
  - Allow long pulse operation (CW)
- **Reliability of cavity and auxiliary components**
  - Availability of accelerator system,
- **Robust fabrication, preparation and assembly technology**
  - Reproducible component and system performance

11 Participating Laboratories and Institutes:

Institute (Participating number)	**Acronym**	**Coordinator**
DESY (6)	DESY	D. Proch
CEA/DSM/DAPNIA (1)	CEA	O.Napoly
CNRS-IN2P3-Orsay (3)	CNRS-Orsay	T.Garvey
INFN Legnaro (11)	INFN-LNL	S. Guiducci
INFN Milano (11)	INFN-Mi	S. Guiducci
INFN Roma2 (11)	INFN-Ro2	S. Guiducci
INFN Frascati (11)	INFN-LNF	S. Guiducci
Paul Scherrer Institute (21)	PSI	V. Schlott
Technical University of Lodz (14)	TUL	A.Napieralski
Warsaw University of Technology (16)	WUT-ISE	R.Romaniuk
IPJ Swierk (15)	IPJ	M. Sadowski

Work packages in JRASRF
2 Improved Standard Cavity Fabrication
3 Seamless Cavity Production
4 Thin Film Cavity Production
5 Surface Preparation
6 Material Analysis
7 Input coupler
8 Cold tuners
9 Low Level RF (LLRF)
10 Cryostat Integration Tests
11 Beam Diagnostics (BD)

CARE WP2: ISCF

Improved Standard Cavity Fabrication

Aim: improving the present fabrication technology.

How?

2.1 - **Reliability analysis** based on the operating experience with SC cavities in the TTF

2.2 - **Improved component design: retrieving the experience of other labs, study of existing components (flanges, ancillaries, etc)**

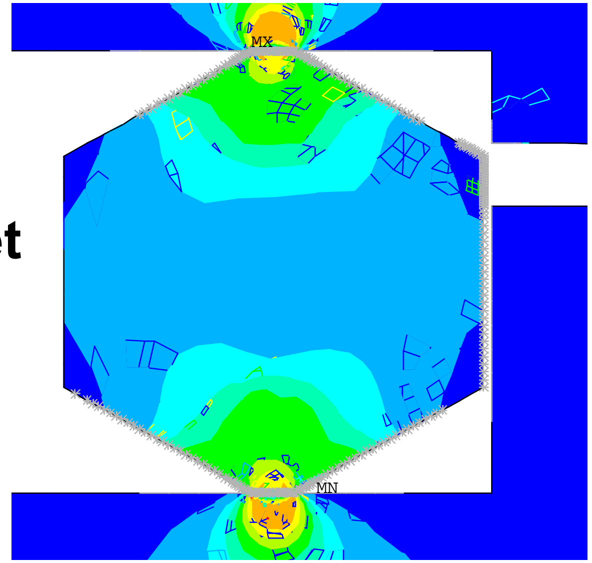
2.3 - **EB welding optimization, welding fixture design and construction, in vacuum mechanics (UHV motor) tests**

FEM analysis results: stess and plastic strain

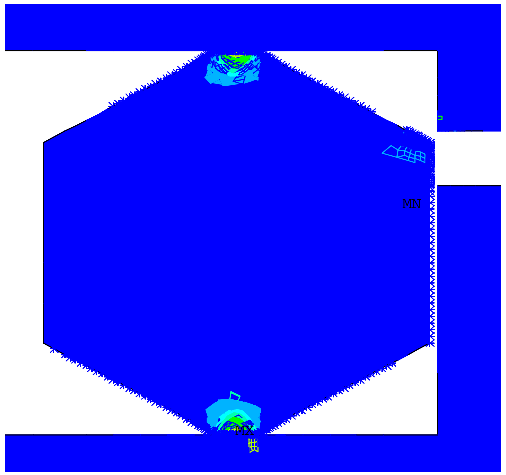
Stainless steel

Sealing gasket
AL MG Si 05

NbTi (1400°C Firing)

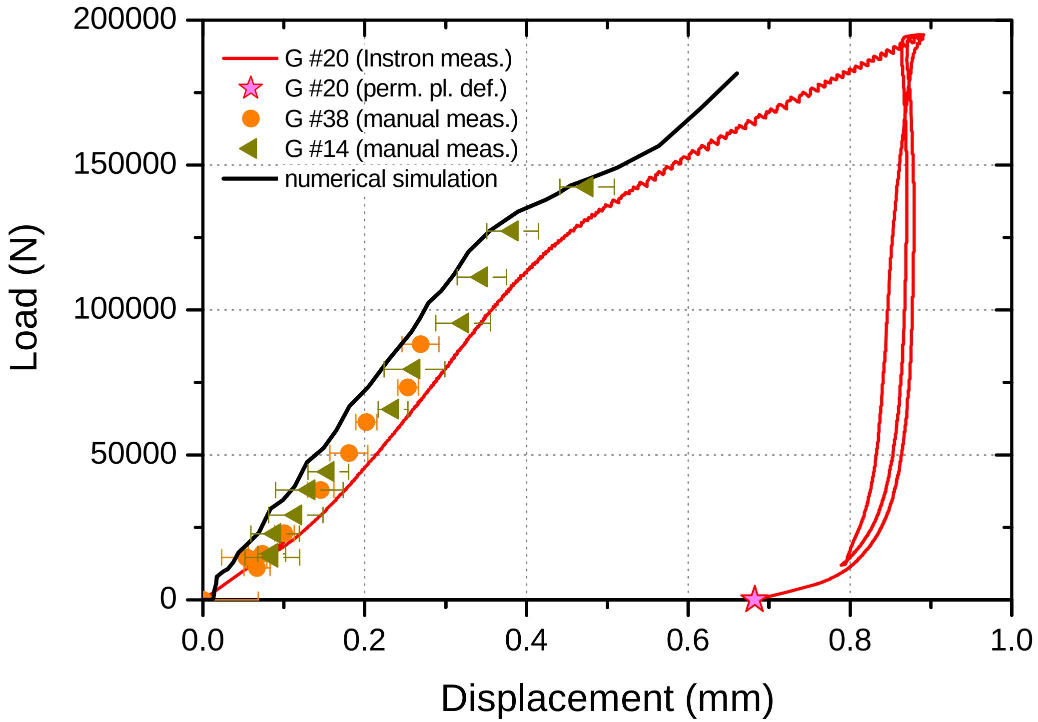


The von Mises stress in the gasket for a compression force of 80 kN (approximately 28 Nm of torque on any bolt).



The equivalent plastic strain in the gasket for a compression force of 80 kN (approximately 28 Nm of torque on any bolt).

Conclusions and future development



Good agreement between the experimental measurements and the FEM model

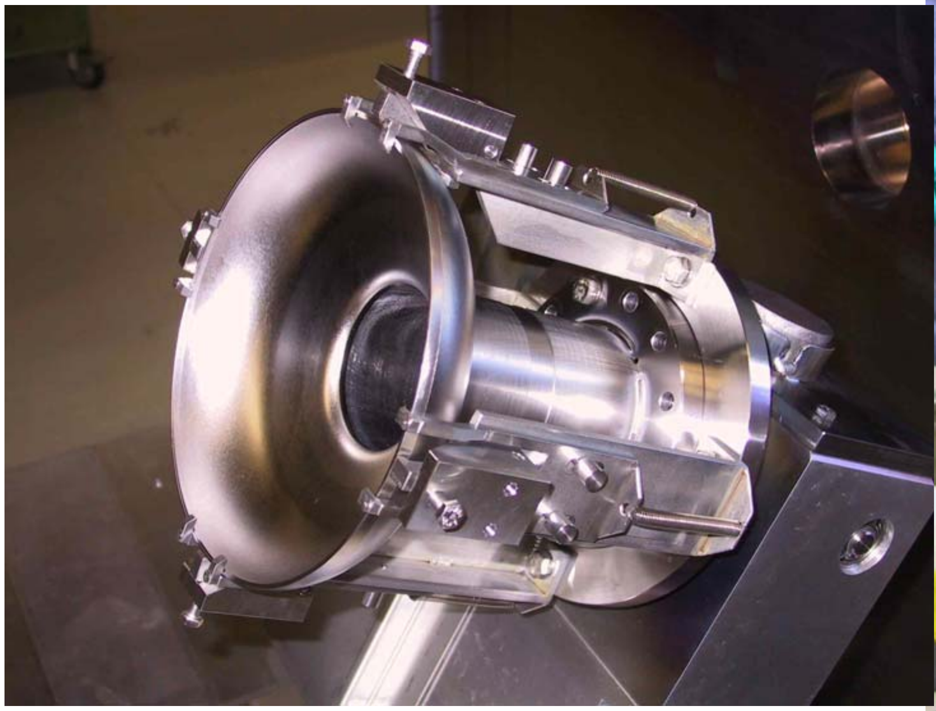
•**<u>The actual geometry seems to be well designed.</u>**

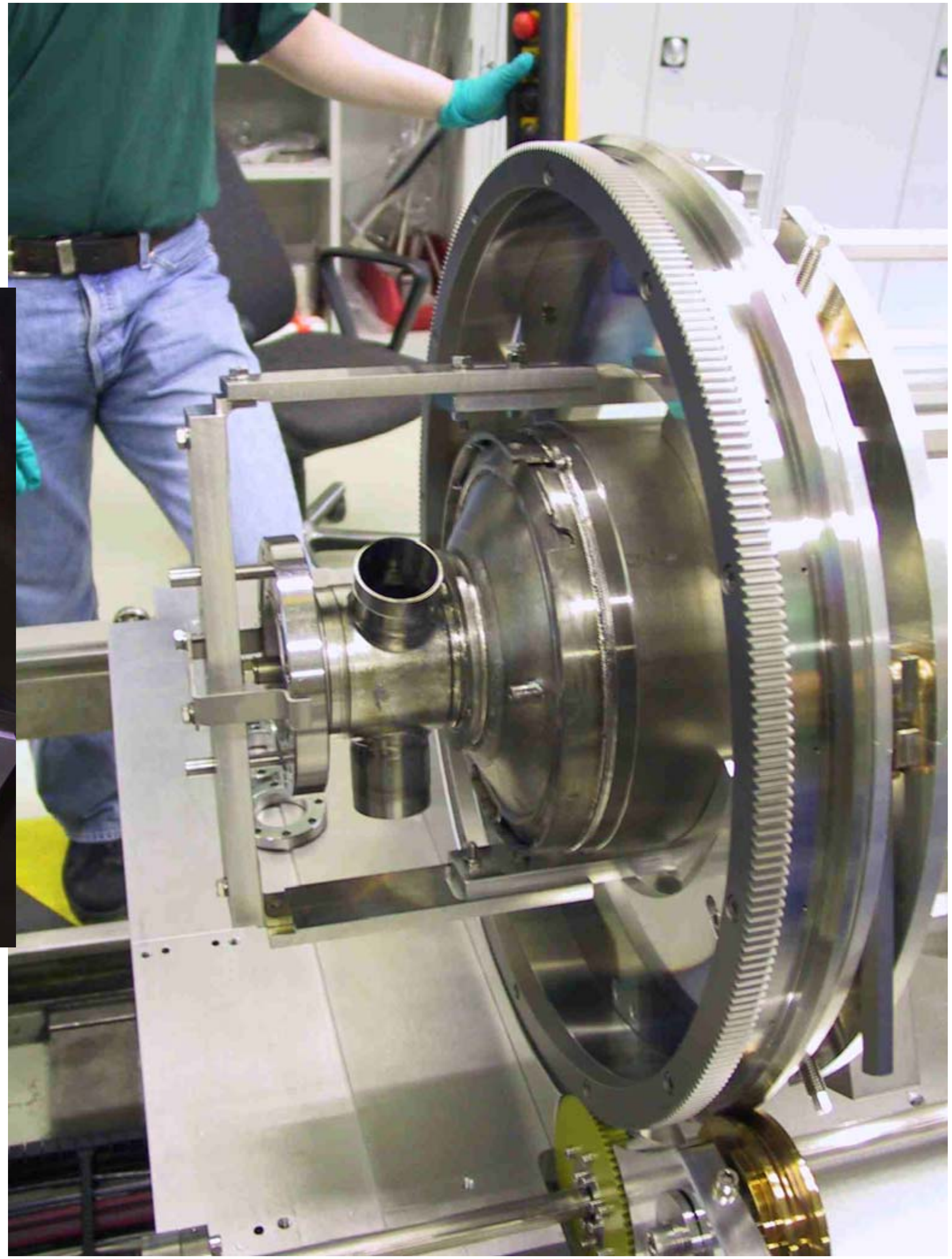
•As a matter of fact, a typical temperature cycle produces a variation of the compression force of 10 kN, that can be compensated by the elasticity of the gasket used.

•An improvement on the flanges performances can be obtained with new optimized geometry (flanges thickness, seal shape) or using different materials able to better compensate the temperature effects.

EB welding machine at DESY with extreme good vacuum conditions

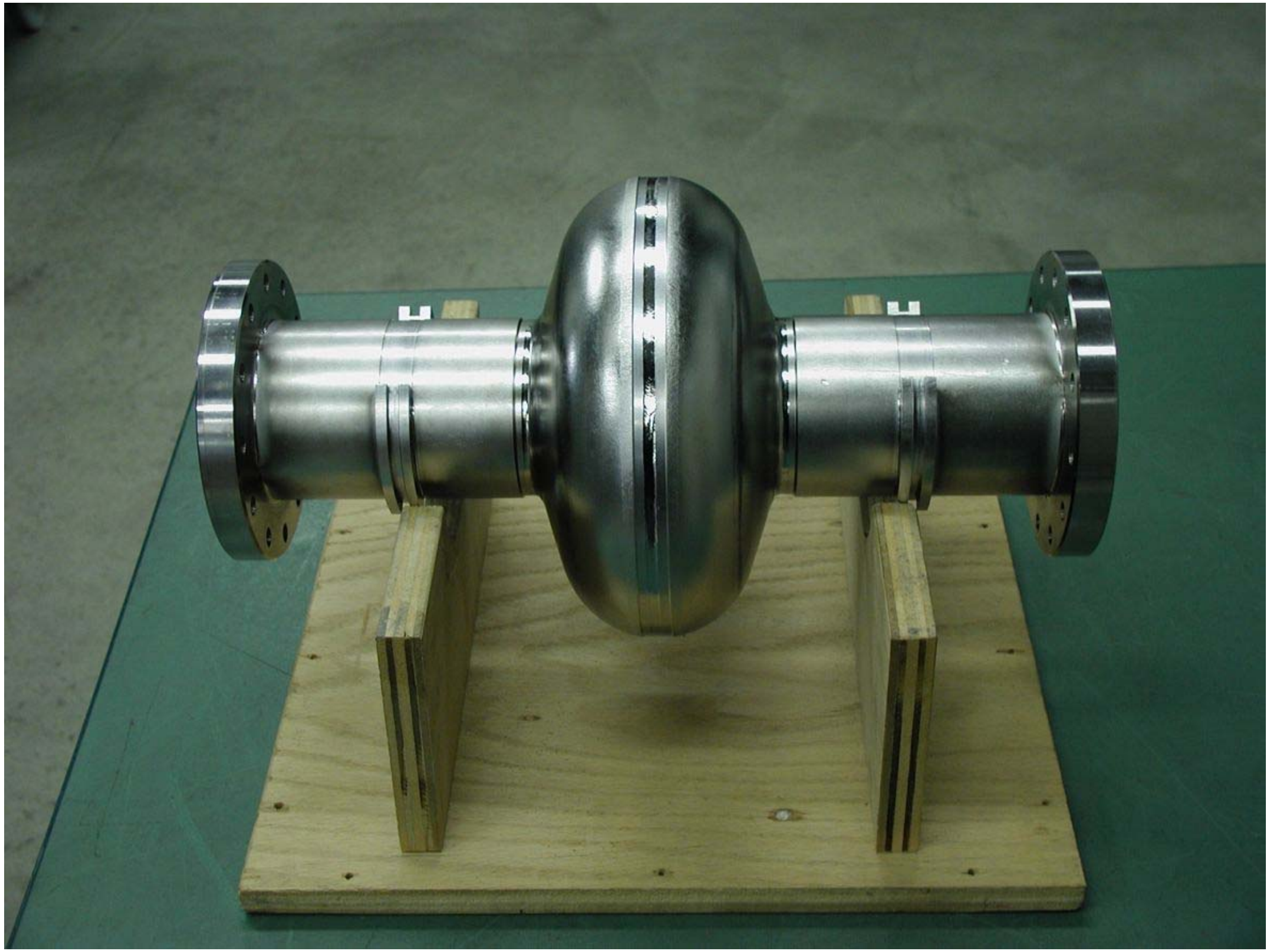
Welding tools for single & multicell cavities





Production of single cell cavities (some 30) for R&D activities:

- **Qualification of Nb material from new vendors from Russia and China**
- **Test cavities for industrial electro-polishing**
- **New material from single crystal ingots**
- **Dry ice cleaning tests**

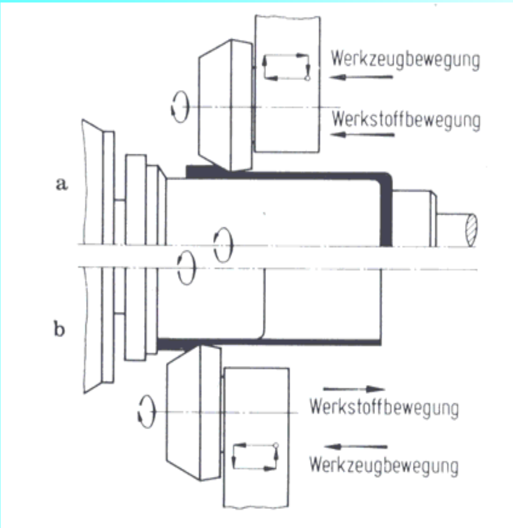


Status “improved standard fabrication”

- Reliability analysis almost finished, some correlations established between early assembly mistakes and reduced final performance
- Flange design was analyzed, needs only minor improvements
- EB welding program in full swing

WP3: Seamless cavity production

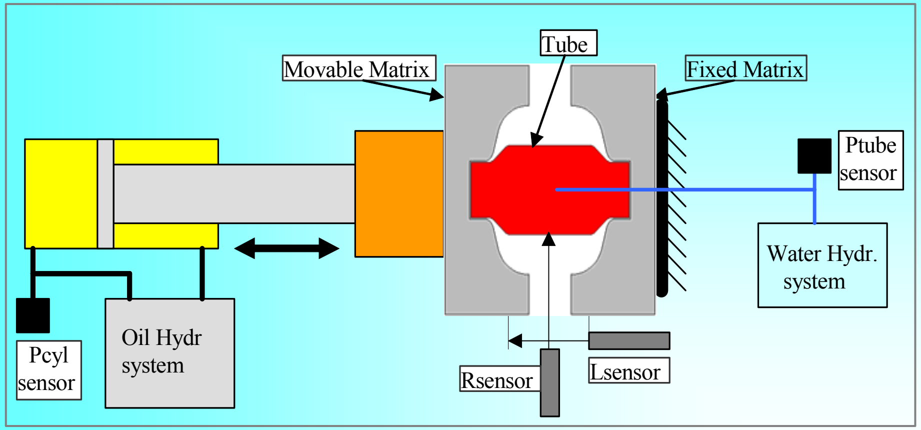
- Promise of seamless cavity production
  - Faster and cheaper than standard welding method (but excluding endgroups)
  - No welds means no welding problems
- Two technologies are under development
  - Hydroforming
  - Spinning



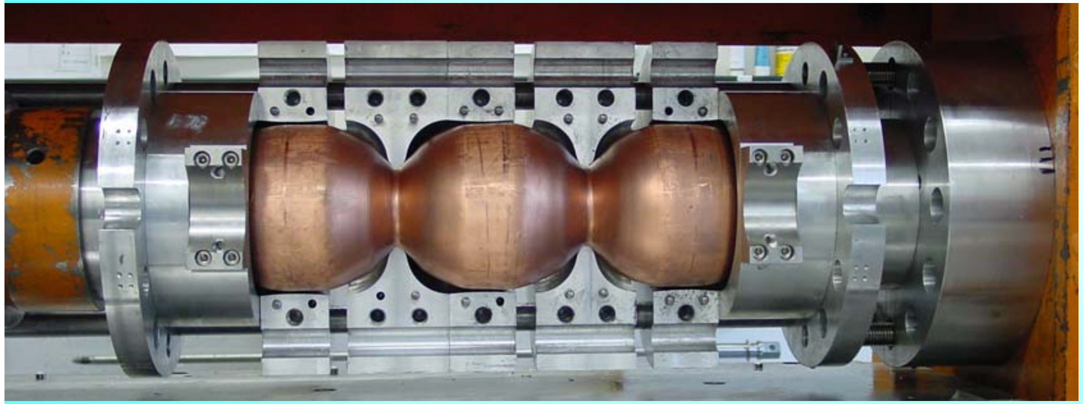
Flow forming

Flow forming was done in forward direction. Wall thickness tolerances of the tubes: +/- 0.15 mm what should be sufficient for subsequent hydroforming.

Hydroforming machine



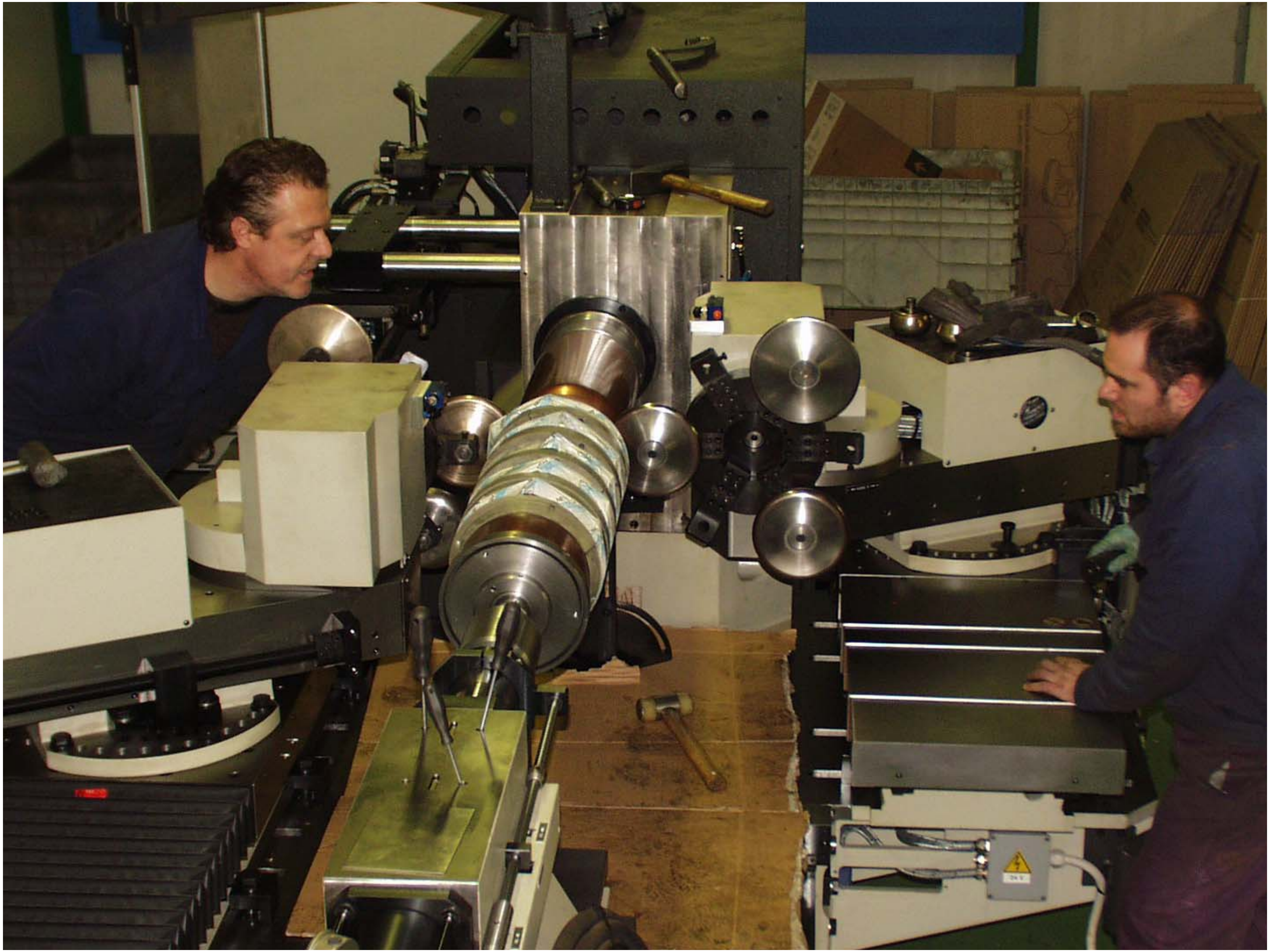
Principle of hydroforming



DESY hydroforming machine

Hydroforming machine was provided with new moulds for fabrication of multi cells.

Hydroforming of cells can be done or as three cells simultaneously or cell by cell



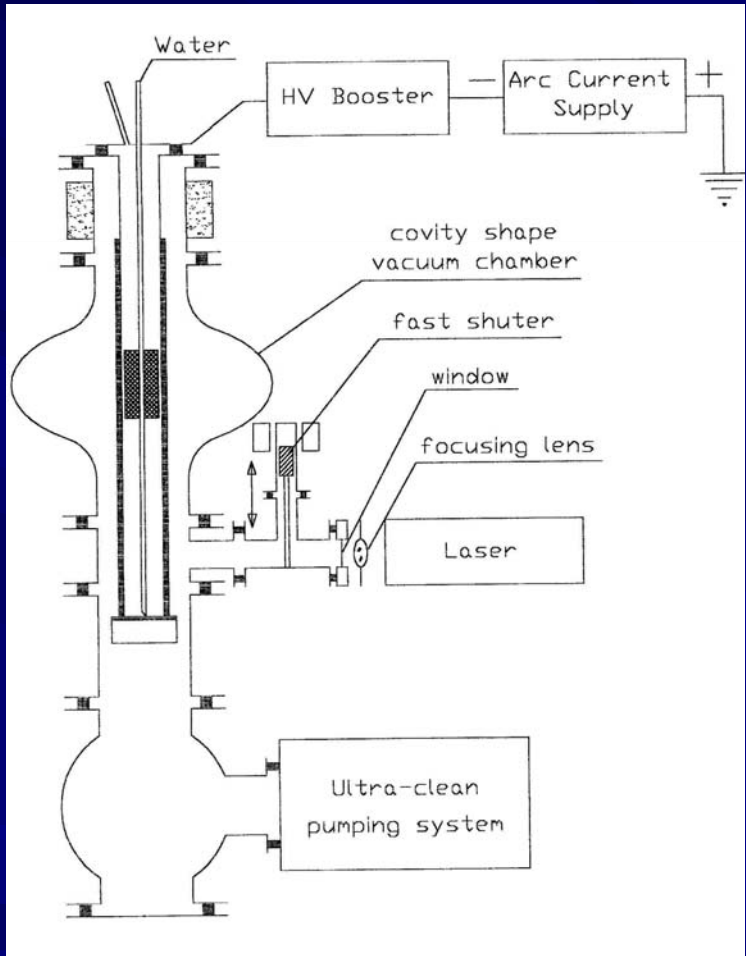
Status Seamless cavity production

- Two technologies are developed
  - Hydroforming
  - Spinning
- Both need seamless tubes with uniform mechanical properties
- Three cell cavity production is mature, RF results compare to welded cavities
- Nine cell production: upgrade of tube and spinning / hydroforming apparatus

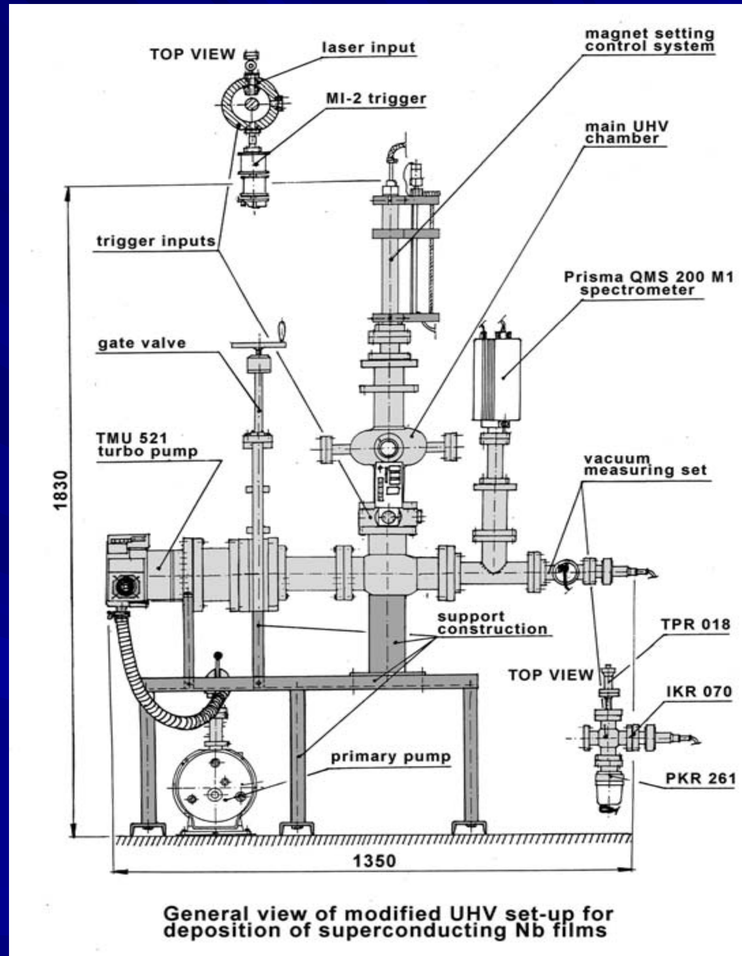
WP4 - Thin film cavity production

- Expectations: Higher quality factor (lower RF losses) than bulk Niobium
  - But sputtered films show degradation of quality factor at high gradient
- Develop a new method of thin film coating by means of arc discharges under ultra-high vacuum conditions.
- Two alternative technologies are investigated:
  - Linear cathode arc coating
  - Planar cathode arc coating

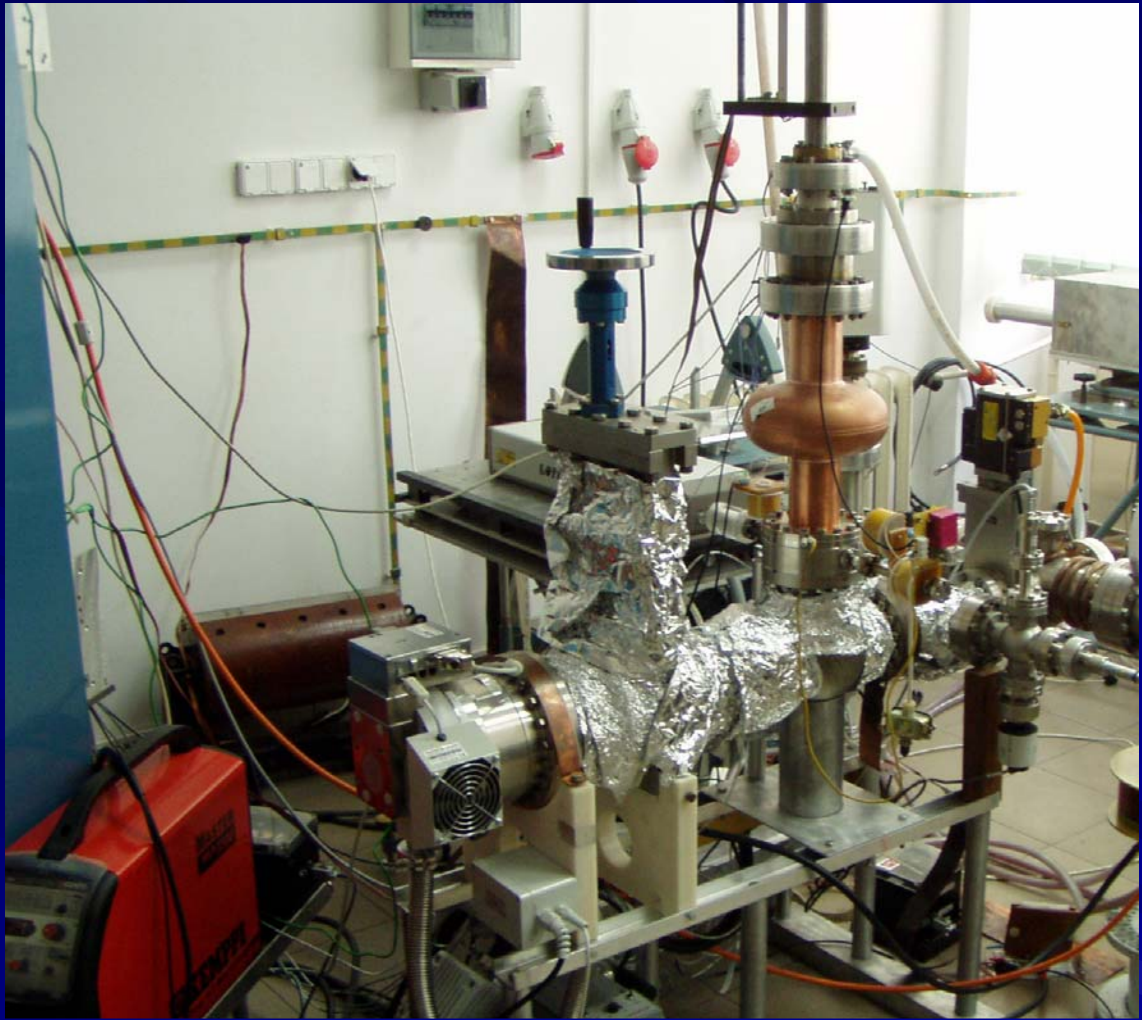
Coating a cavity by means of a high-vacuum linear-arc discharge



Principal scheme assumed in 2003.

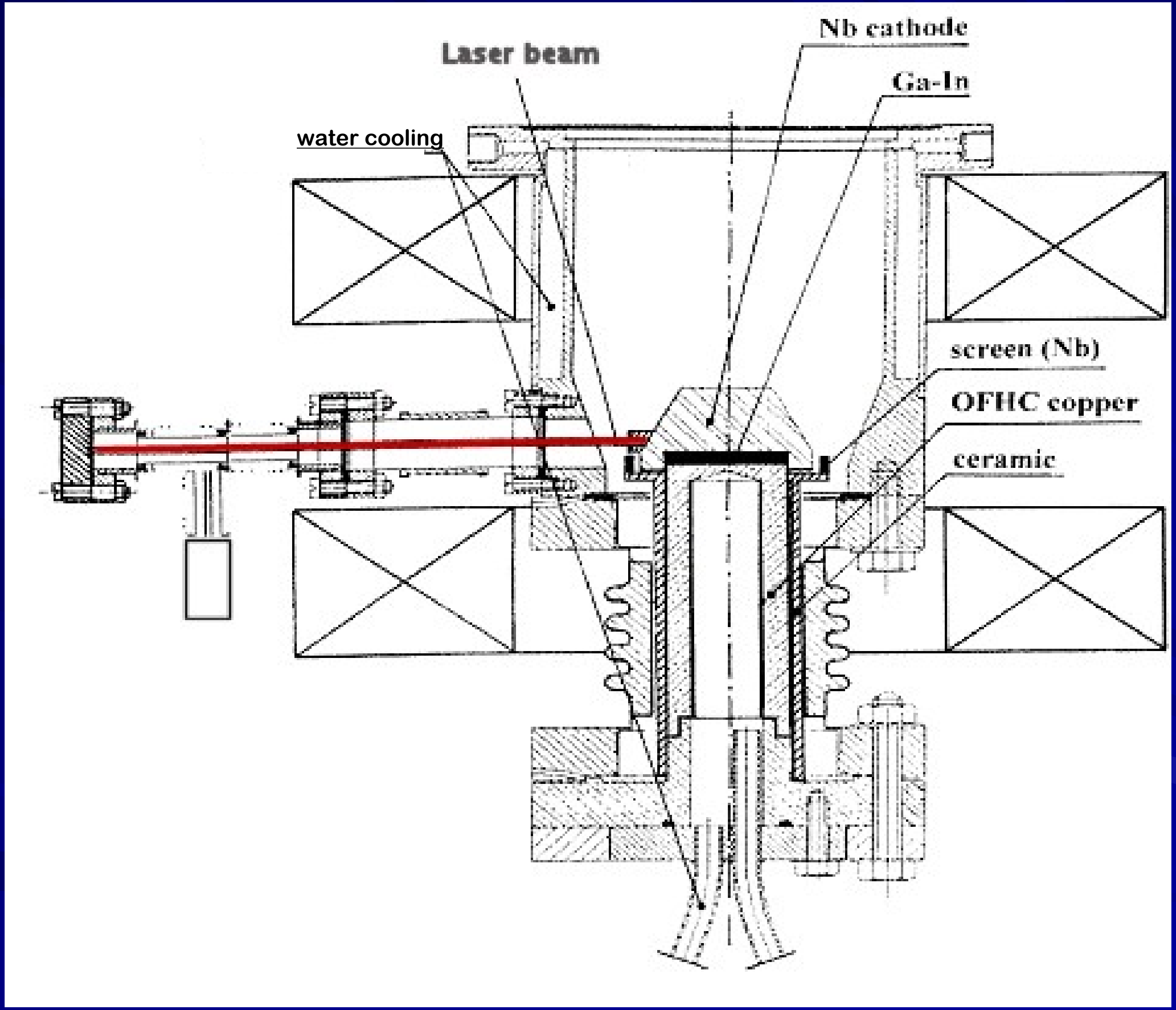


Detailed scheme elaborated in 2004.

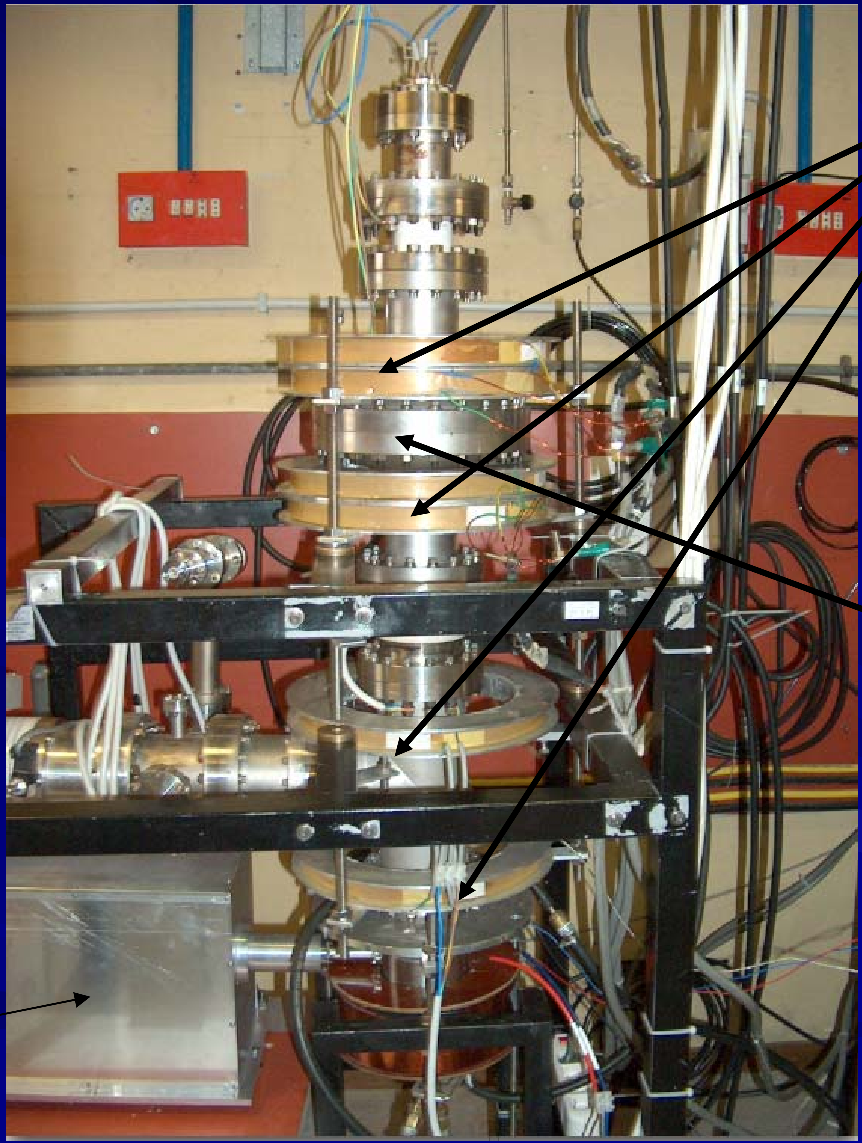


UHV system with a linear-arc during laboratory tests of the single-cavity coating (June 2005).

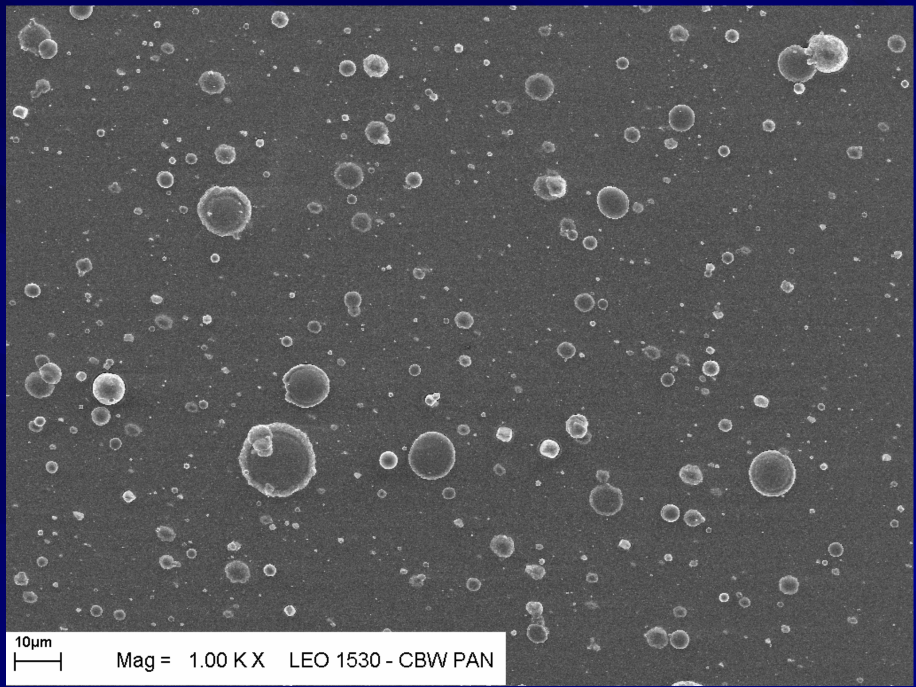
UHV planar cathode arc scheme



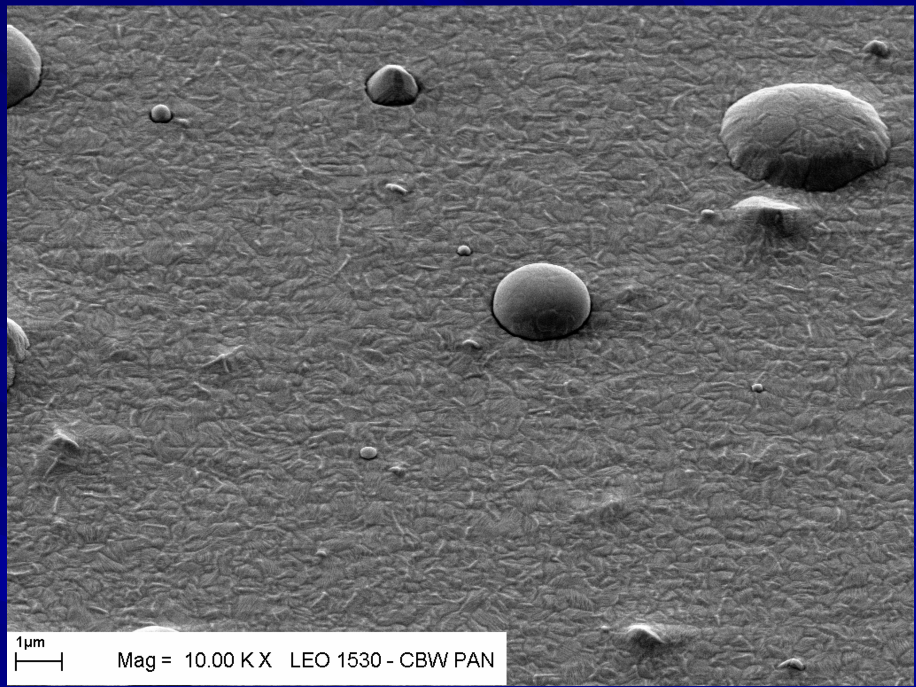
Unfiltered planar arc system to study single-cell cavity coating



Analysis of the coated sapphire samples

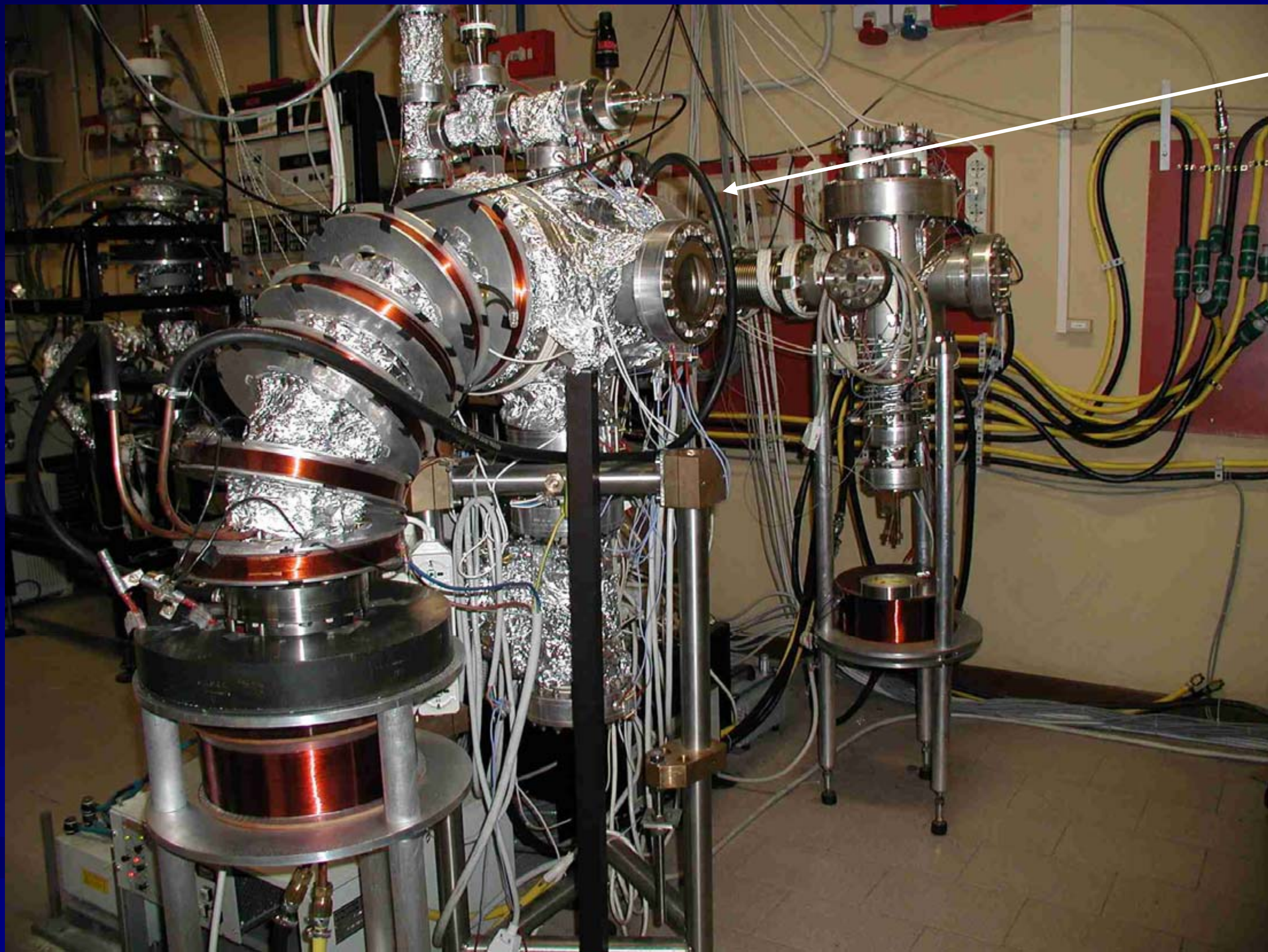


SEM picture showing a relatively large population of the deposited micro-droplets.



SEM picture showing the structure of the Nb-layer and shapes of the observed micro-droplets.

Prototype filtered arc system



sample holder on this side

1.7.2. Design and construction of a micro-droplet filter system

To reduce a number of the micro-droplets within the linear-arc facility a cylindrical magnetic filter was designed and constructed.

It consisted of a set of thin copper tubes distributed symmetrically around the cylindrical surface and joint at the ends by special connectors.

This construction enables an appropriate magnetizing-current and cooling-water flows to be realized.

2.2.3. Characterization of Nb-coated copper

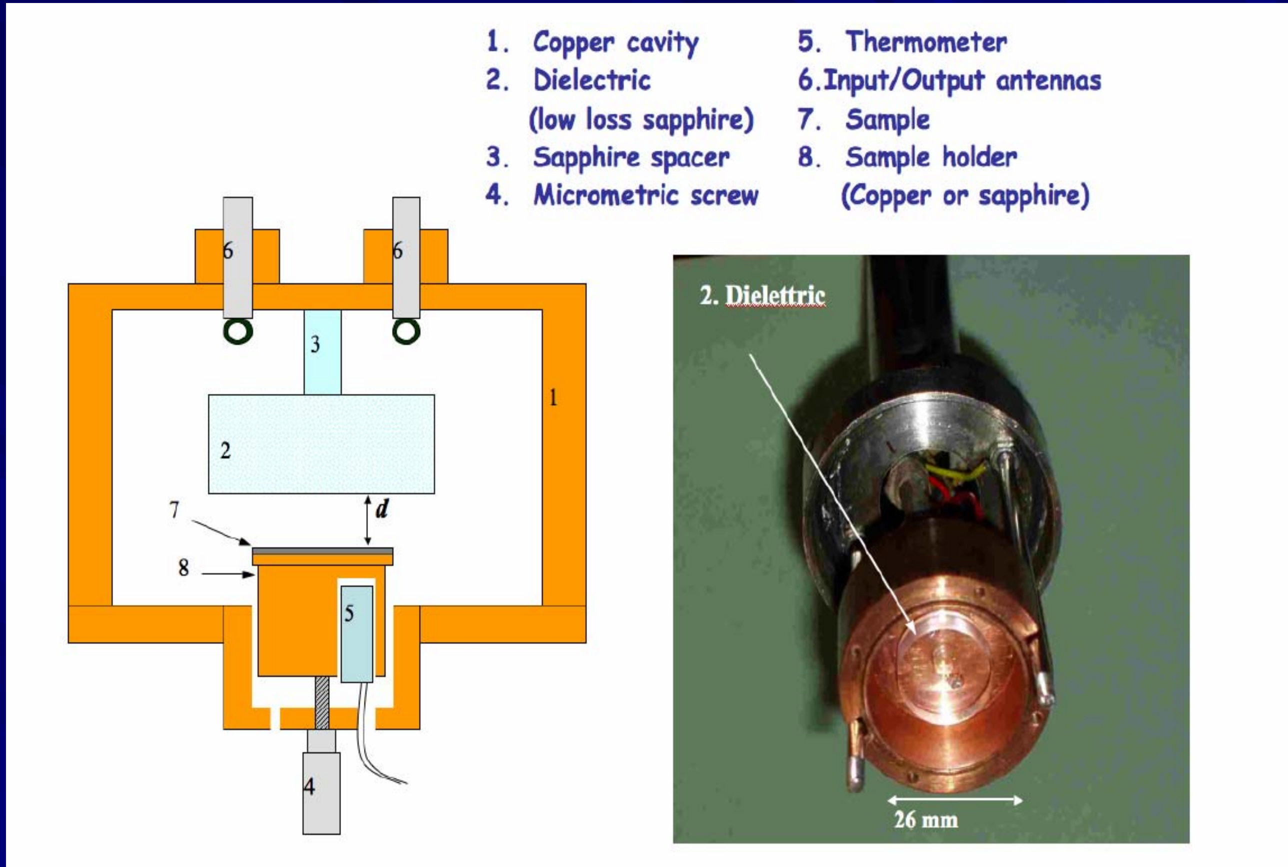
Large Nb-coated Cu sample prepared for RF measurements at Cornell .

First high field RF measurements, at 6 GHz were performed in Cornell of four filtered large Cu-substrates (Nb-coated at Rome), as described in our 2nd quarter report.

Results of a comparison of our samples with pure Nb bulk ones were presented at SRF2005 (by A. Romanenko and H. Padamsee, Proc. SRF2005 Inter. Workshop, Cornell, USA, July 2005 – in print).

The quality factor (Q) of the best sample was comparable within the errors to the present limit value of the host cavity (equal to ≈ $3x\ 10^8$). The sample sustained a magnetic field value of 300 Oe, possibly limited by the cavity quench.

2.2.2. Characterization of Nb-coated sapphire



Low field RF measurements have also been performed on small samples by our collaborators of INFN-Napoli. The film RF surface impedance $Z_s(T, H)$ has been measured as a function of temperature.

Status “Thin film Nb coating“

- Prototype installations of linear and planar arc coating are operational
- Droplett filters for both technologies are designed and tested
- First Rf measurements on thin film samples approach bulk performance
- Cavity coating will start early next year

WP5 Electro-polishing

- Main tasks in 2005
  - Treatment of 9-cell cavities
  - Start industrialization of EP
  - Explore automization of EP process
  - Validation / investigation of the principle EP parameters (single cells, samples)

Principle EP arrangement

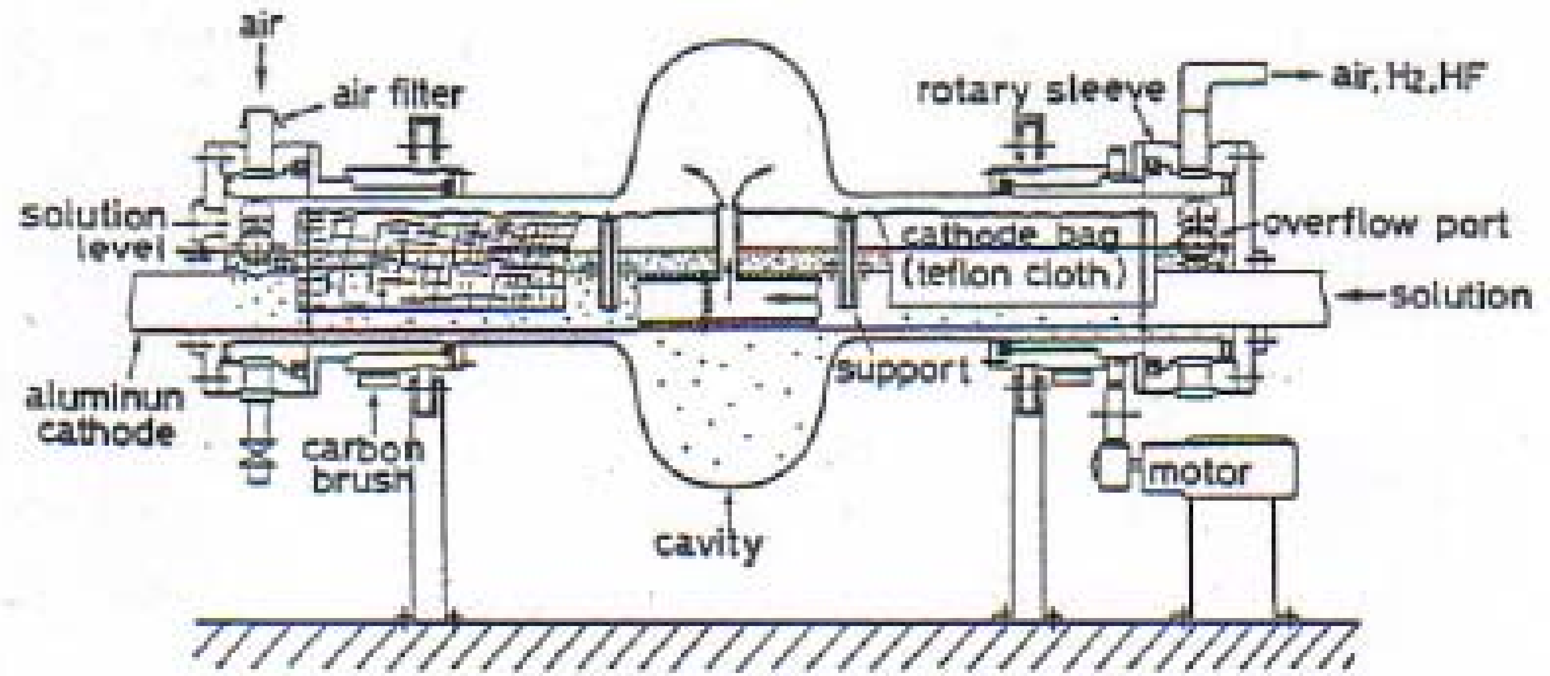
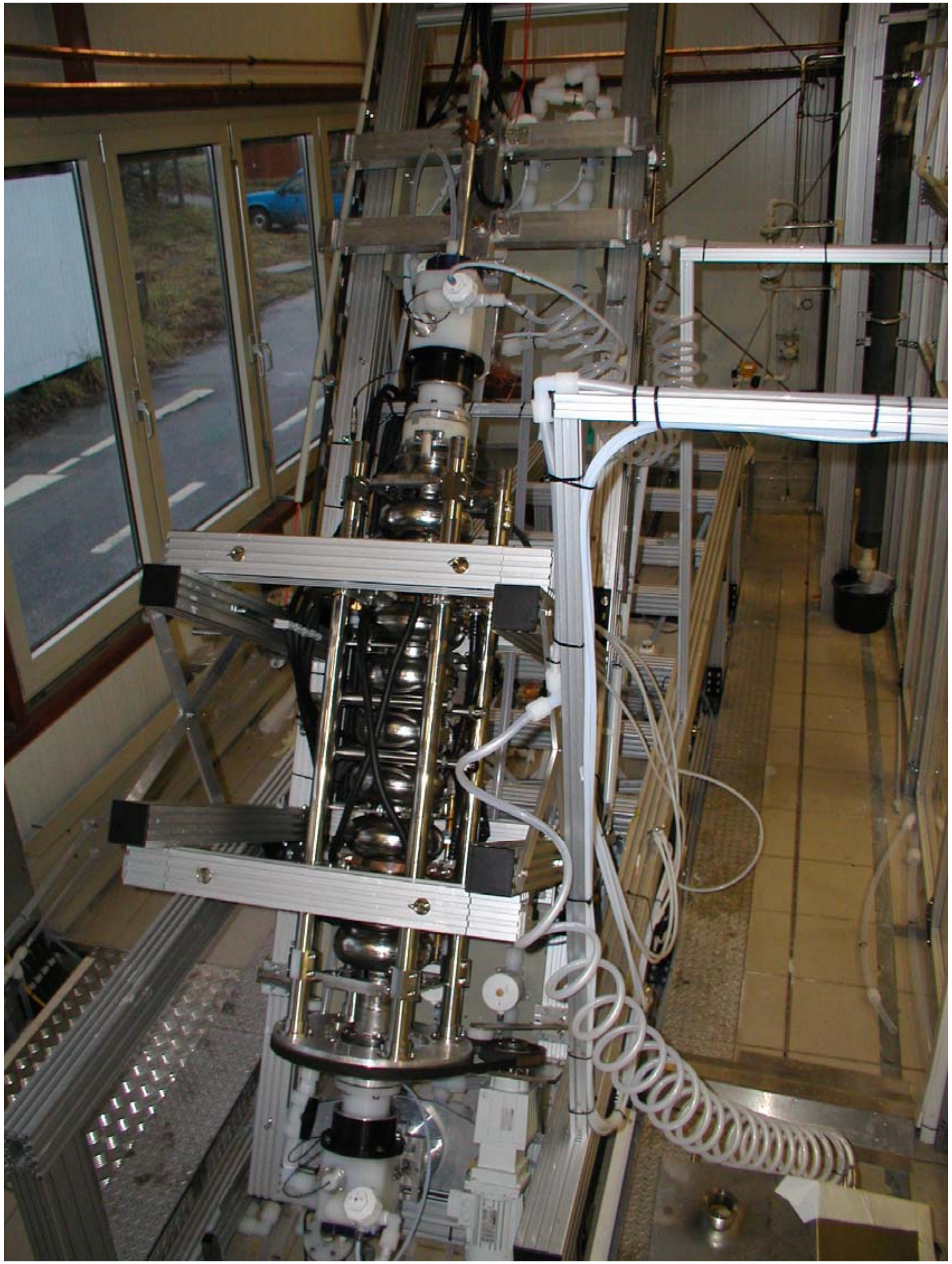


Figure 5: Horizontal rotated continuous electro-polishing.



Nine cell EP setup at DESY

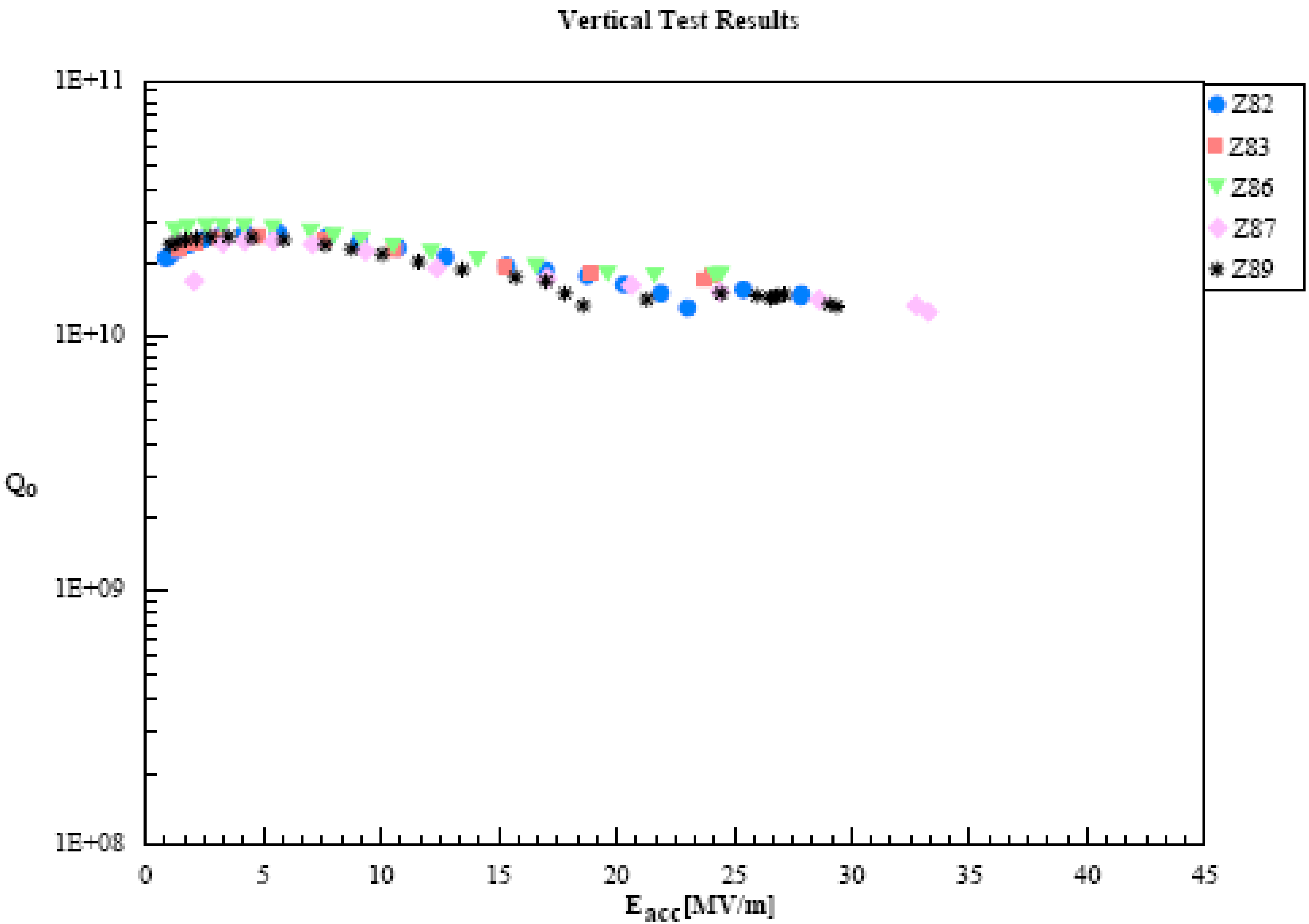
Activities in 05:

-12 complete EP cycles,

-about 20 additional short EP cycles

mainly with new 9-cell cavities from the ongoing production

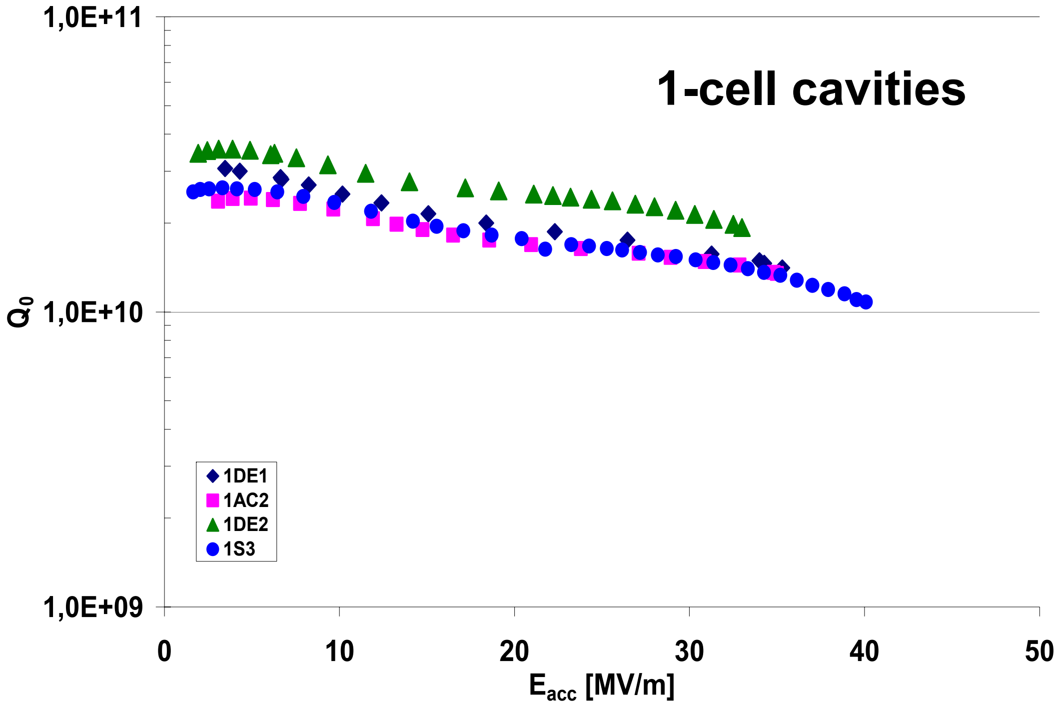
Performance of recent 9 cell EP cavities after first preparation



Experience with 9-cell cavity EP

- Electro-polishing mixture is bought from chemical company
- Constitution of mixture changes during storage and transportation, consequence to EP operation:
  - Excessive HF evaporation (severe safety problem)
  - Unstable EP process
- Chemical industry very active to solve the problem
- Sulfur contamination in EP circuit (and cavity?)
  - Observed after longer EP operation
  - Process under investigation (reason for large scatter of performance of EP cavities?)
  - Present action: regular cleaning cycles of EP system

Electro-polishing at Henkel Company



- Electro-polishing at Henkel produced very high gradient (up to 40 MV/m), high Qo cavities
- 1.3 GHz three-cell cavities can also be treated
- 9-cell EP needs some upgrade of infrastructure

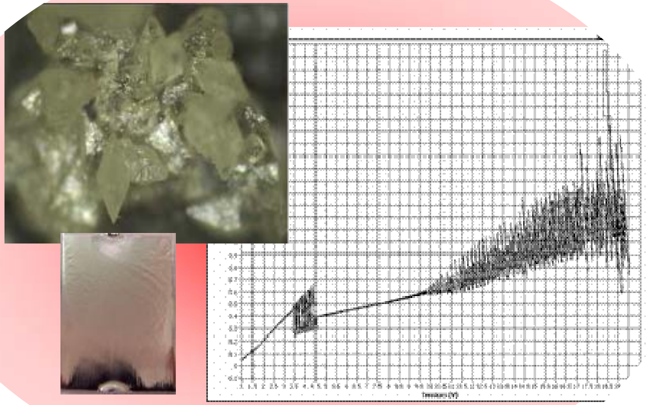
CARE-SRF : Work package 5-1 : Optimization of EP

Optimization of Electropolishing

Bench test for monocells

Samples studies : aging, impurities, cathode corrosion

Application to scale 1 (non trivial)



1rst results => present used conditions = not always optimal !
Sulfur fall out is reduced at high HF concentr.

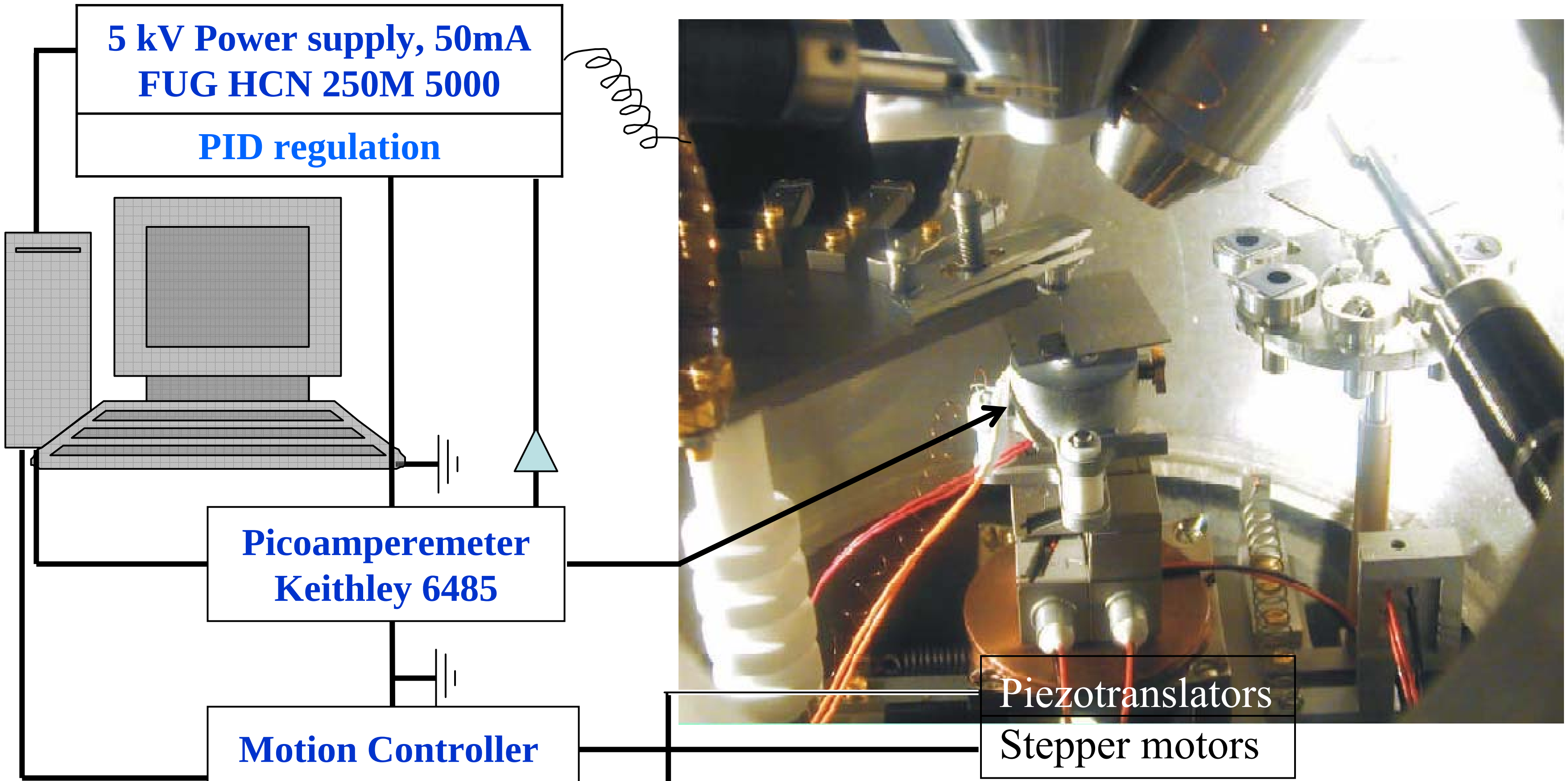
Status “Electro-polishing“

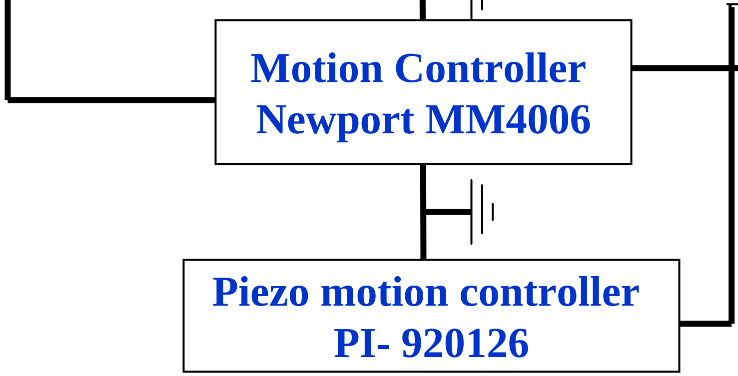
- Nine cell cavities show high gradients after EP
- However: large scatter of performance
  - Most likely due to non optimized EP paramters
  - Also quality problems with delivered acid mixture
- Systematic study of EP parameters in progress
- EP processing in industry started

WP6 Material research

- DC scanning of samples for identification of field emitters
- Magnetometry as simple method to investigate EP electrode configuration
- Squid scanning of Nb material
  - Higher sensitivity than present normal conducting eddy current scanning

Lab VIEW Automated FESM

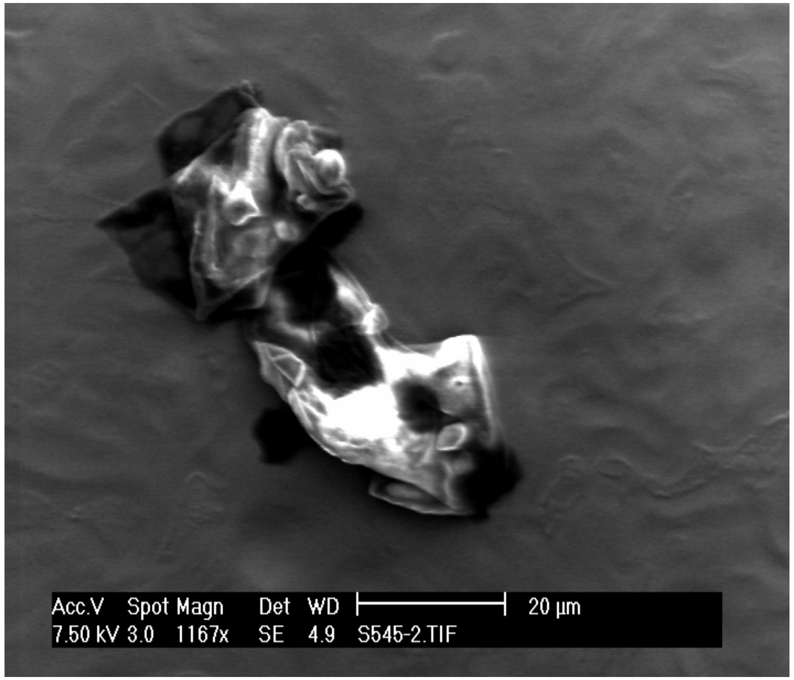


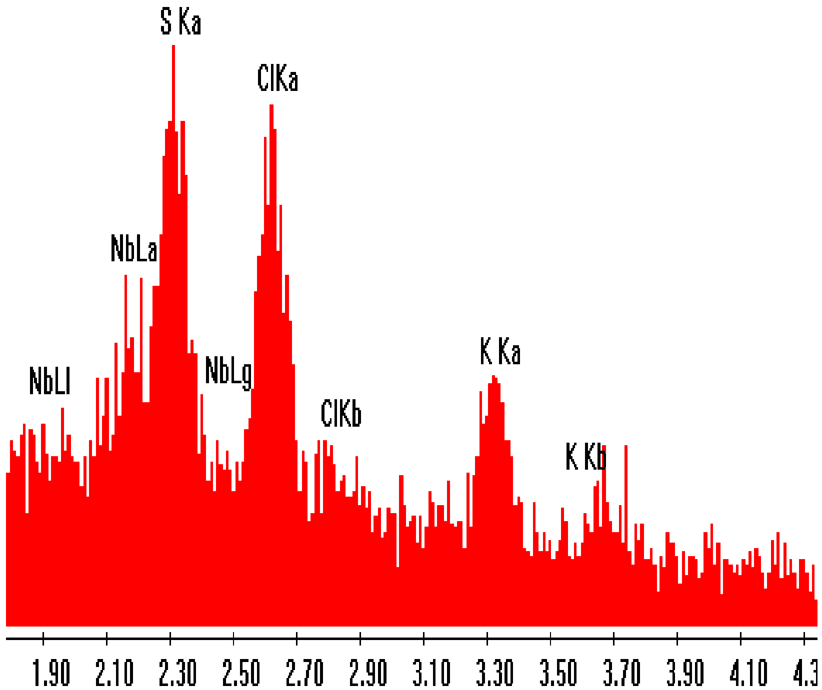


- **Scanning speed doubled**
- **Large area scans possible now**

  $\Rightarrow$ **Better statistics**

SEM and EDX Analysis of Emitter # 4*



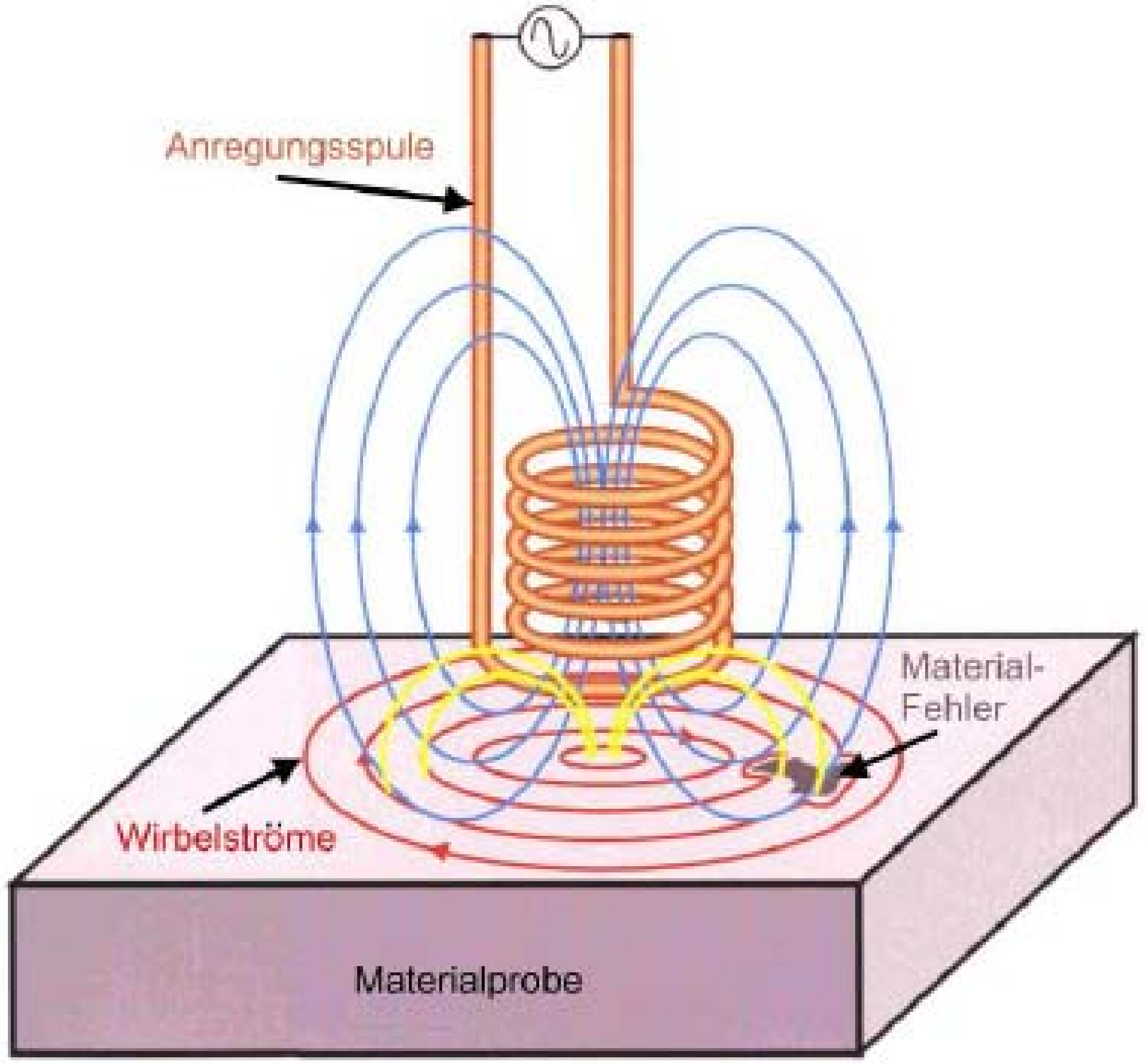


> 50 µm large crystalline particle

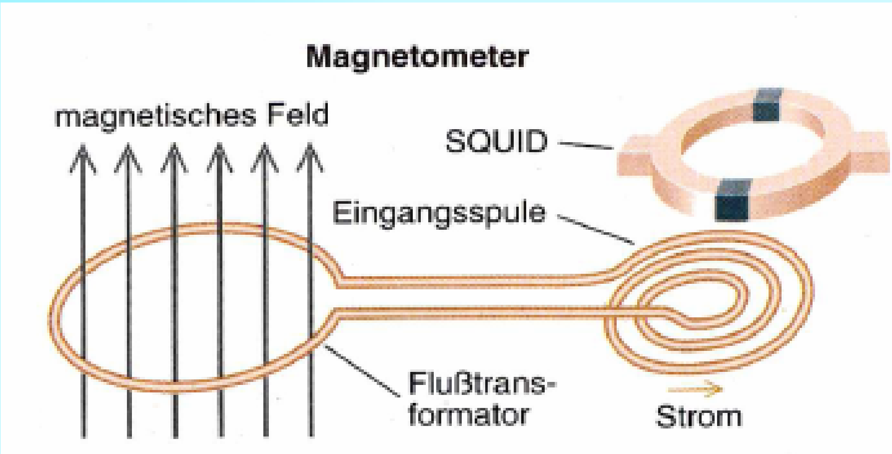
EDX spectrum: S, Cl, K contents

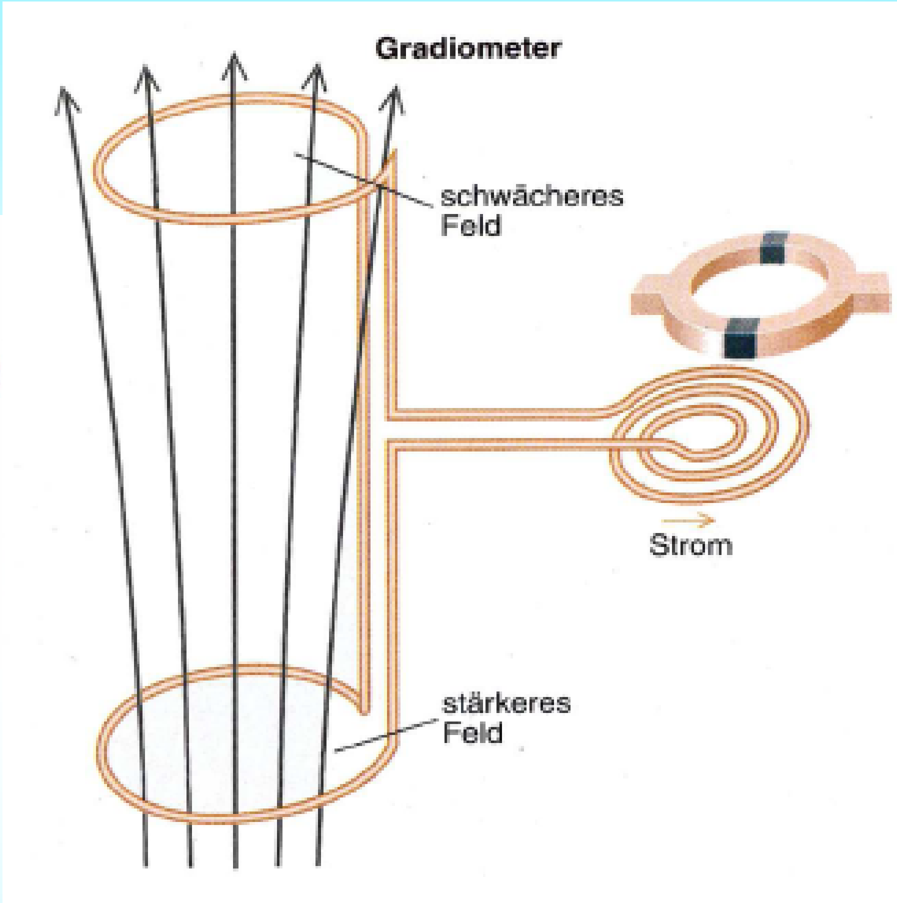
Most probably a dust particle or some remanent from chemical bath (EP) or from insufficient high pressure water rinsing

Bergische Universität Wuppertal



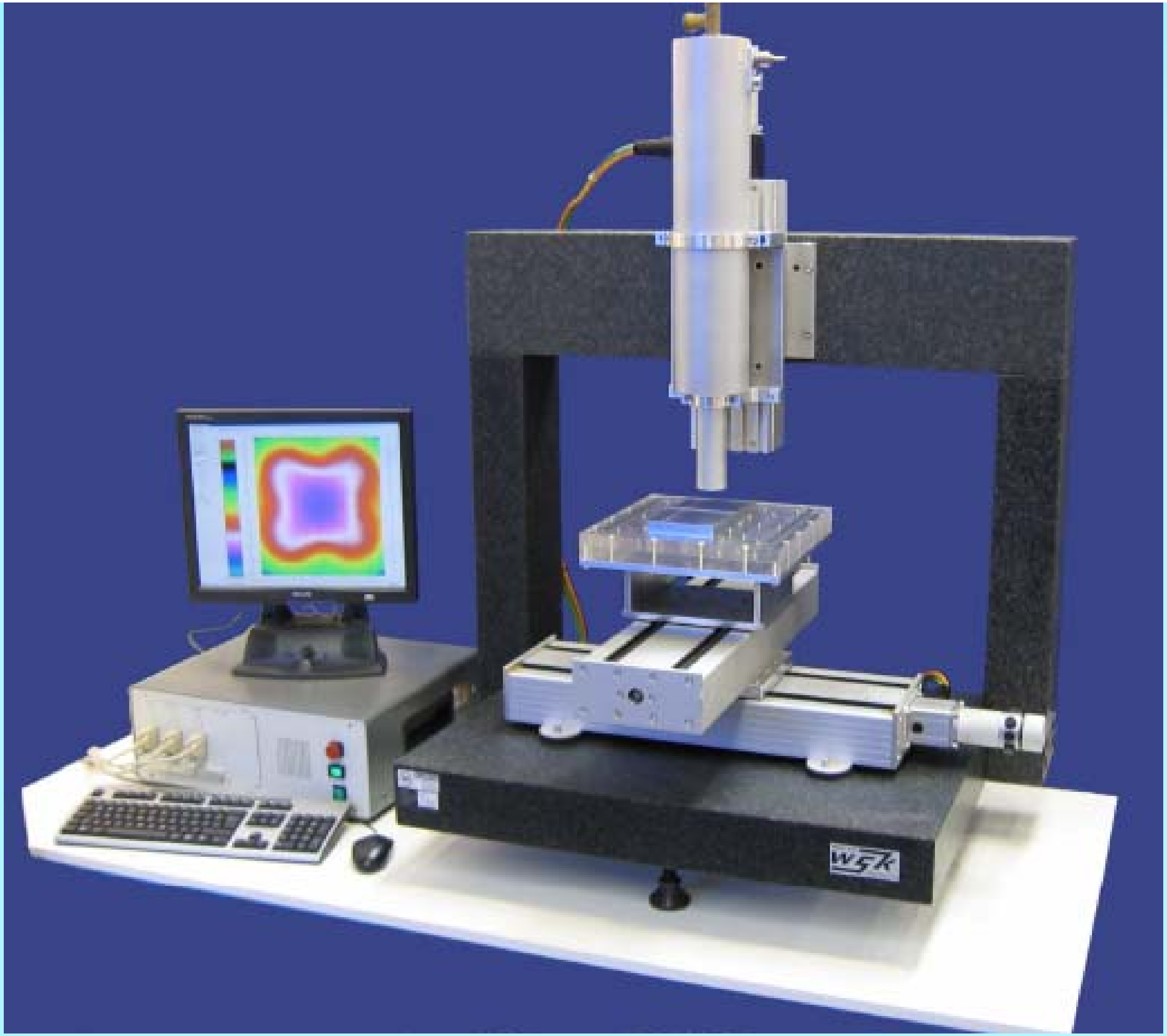
Eddy current principle





Principle of SQUID magnetometer or SQUID gradiometer system

Cryostat
with the
SQUID
amplifying
electronics

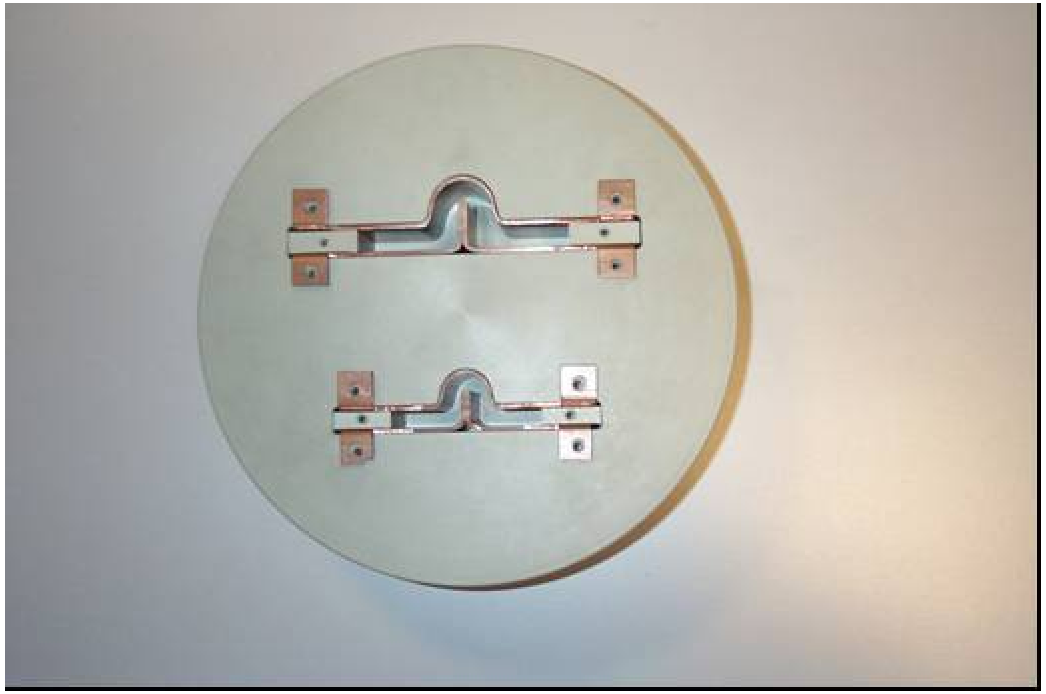


SQUID-based scanning system developed at company WSK

Status "Material research"

- Improved apparatus for DC scanning of samples is operational
  - regular QA measurements have started
- Magnetometry is applied to investigate EP electrode configuration
- Squid scanning of Nb material
  - **First prototype from industry is operational**


JRA1 annual meeting, Legnaro, Oct.05

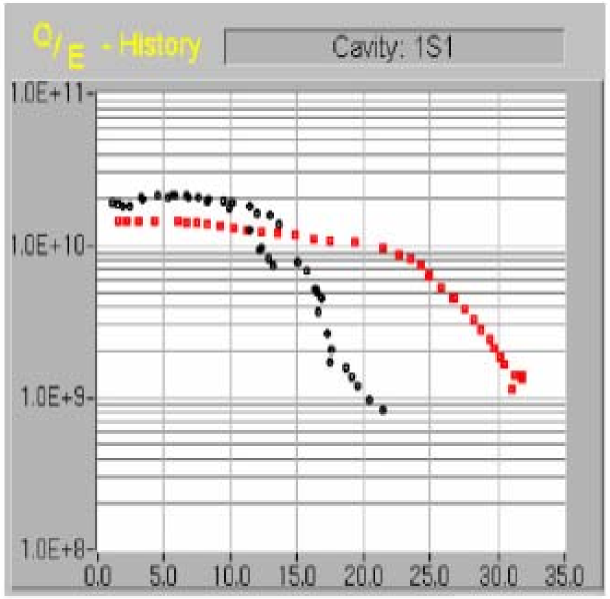


The cavity shaped electrolytic cell is a moke up of the EP process

- The scanning fluxgate head determines the current distribution between inner electrode and outer wall
- Hereby the relative removal rate by electro-polishing can be calculated

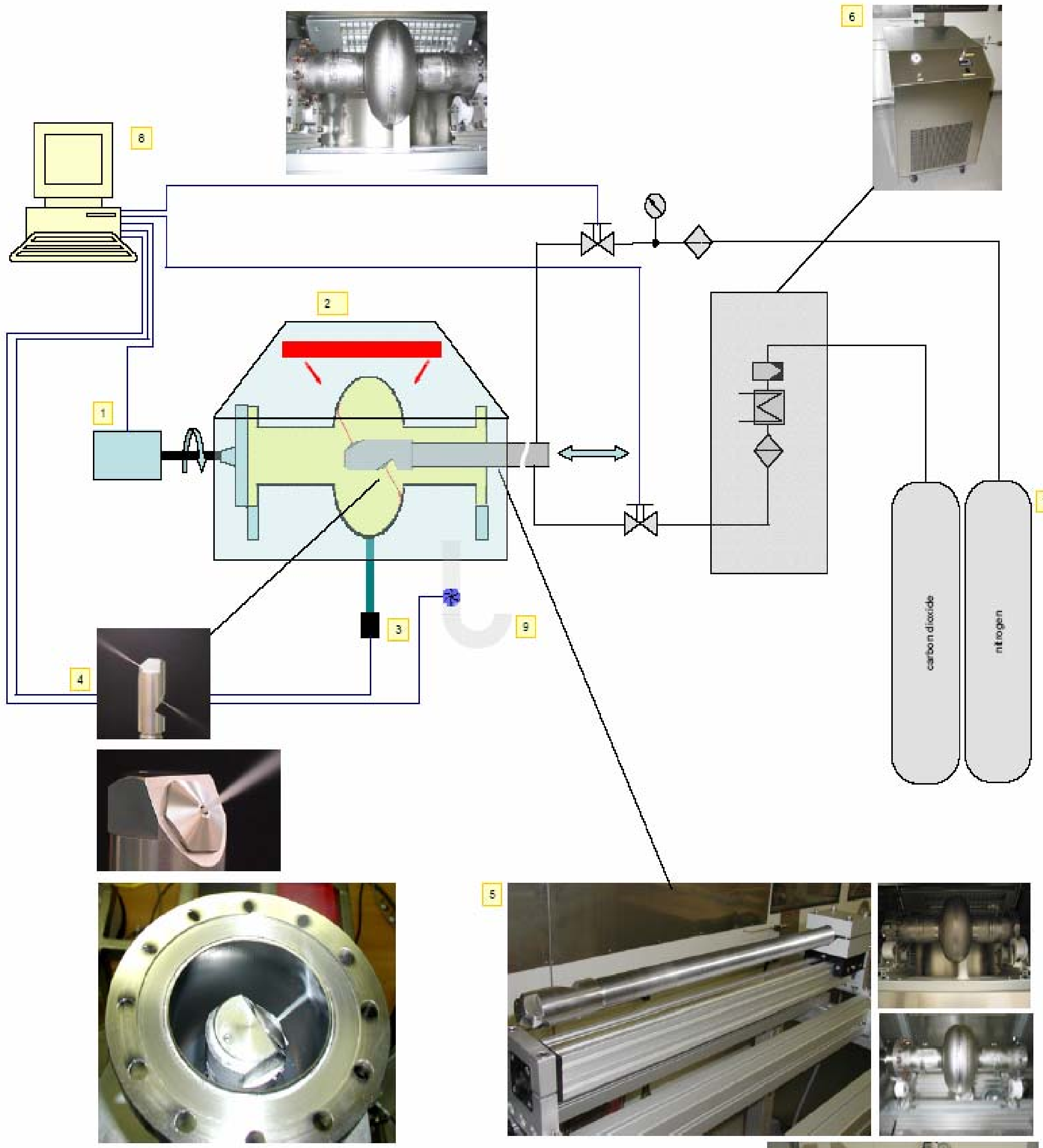
The scanning flux gate apparatus

Horizontal Dry-Ice Cleaning Setup

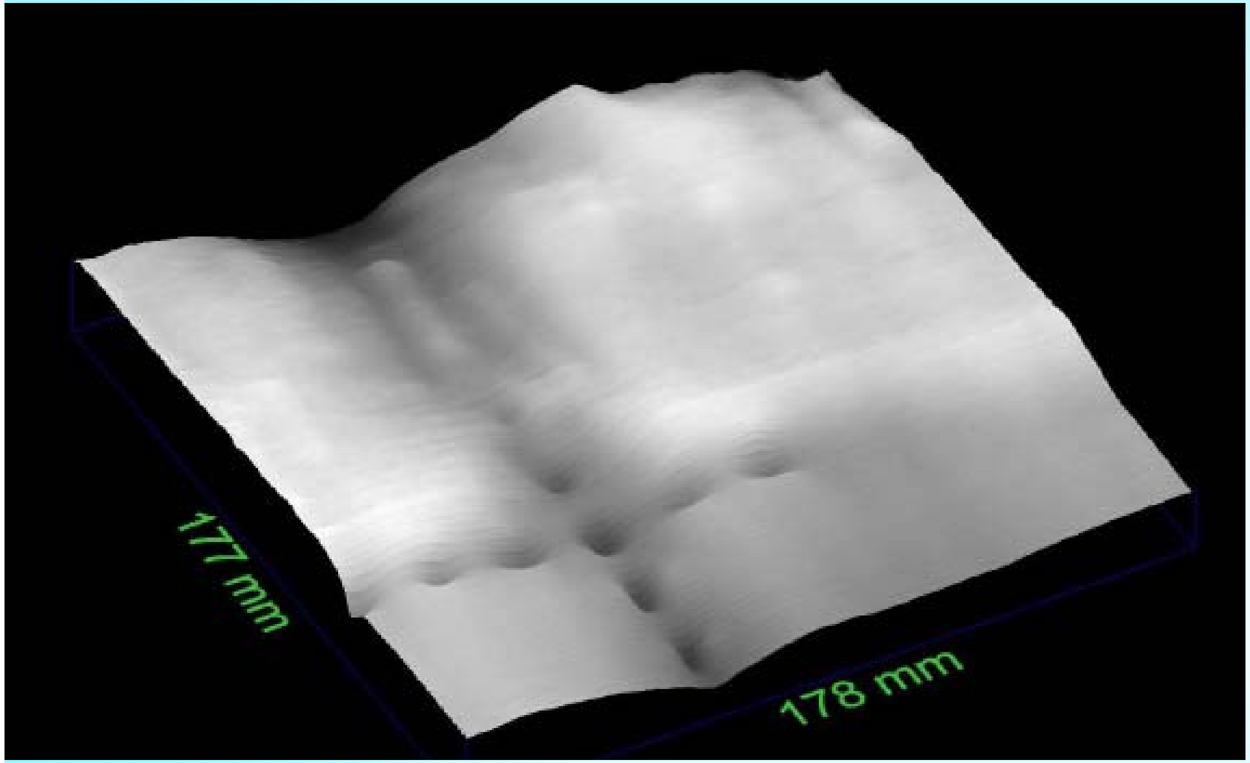


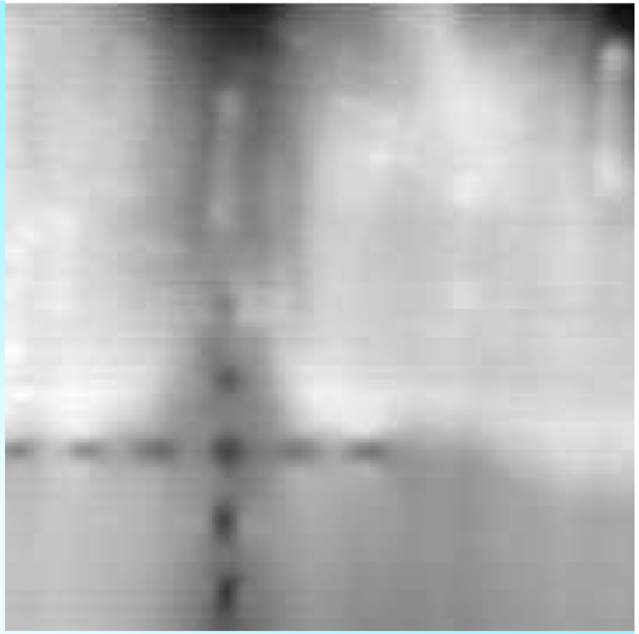
■ Test result after first DIC process

■ Test result after improved DIC. Cavity stored under air for several months, no HPR before DIC



Explanation:
1: motor; **2**: IR-Heater; **3**: IR-Temp.sensor; **4**: nozzle system; **5**: horizontal nozzle; **6**: liqiufier:
7: Gases; **8**: motion control,Interlock,Temp.; **9**: exhaust of CO_2 and N_2





3D image of Nb test sheet with artificial Ta defects by SQUID scanning