

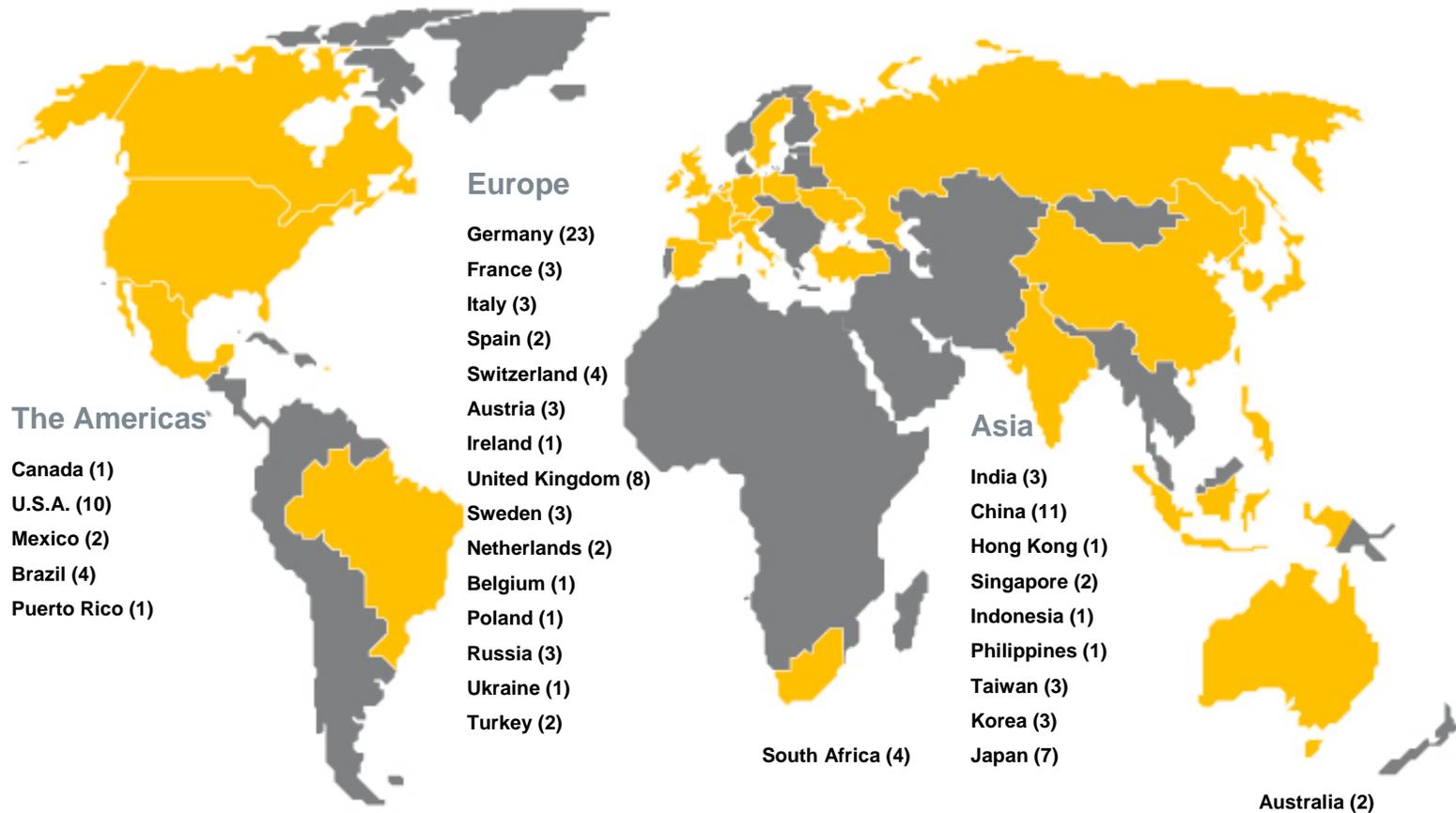
Single Crystal Niobium Workshop
October 30 – November 1, 2006



- **The Heraeus Group**
- **W.C.Heraeus**
- **Engineered Materials Division**
- **Business Unit Special Metals Technology**
- **Nb RRR**
- **poly... oligo... near single... single crystal**
- **where are we now, where can we go to ?**
- **available capacity for Nb RRR**

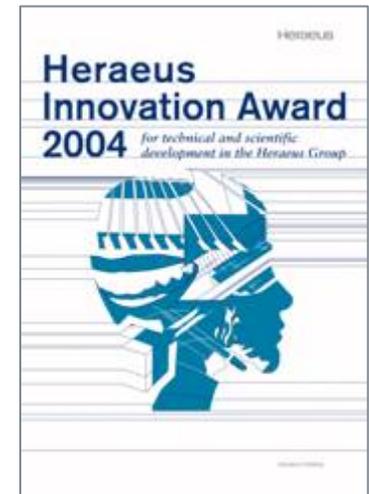
Global Presence

Heraeus is located at 116 sites worldwide



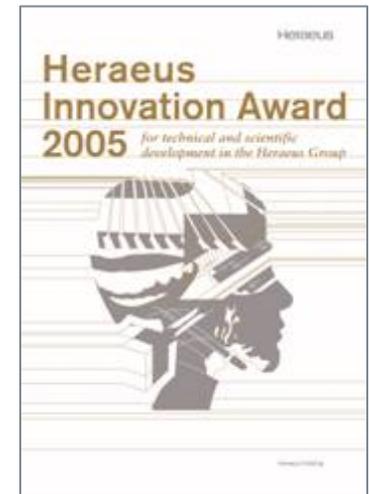
Ensuring the Future with Innovation

- **We capture markets of the future with innovative products and processes**
- **We contribute to technological progress with intelligent materials technology and technological innovations**
- **We develop and optimize customer-oriented and tailored products in close cooperation between various business segments**

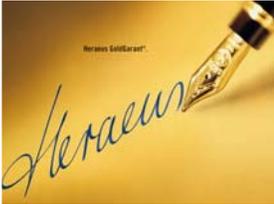
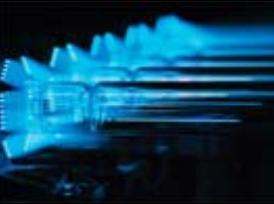


Ensuring the Future with Innovation

- **The Heraeus Innovation Prize pays tribute to outstanding innovative ideas and achievements of our company's researchers and developers**
- **R&D expenses in 2005: €54 million (5 % increase over previous year)**
- **Innovation rate of 22 %**
- **101 new patent registrations in 2005 = 13 % increase over previous year**
- **Heraeus now has more than 3,900 patents**



The Group Business Segments

W. C. Heraeus	Heraeus Kulzer	Heraeus Electro-Nite	Heraeus Quarzglas	Heraeus Tenevo	Heraeus Noblelight
					
Precious Metals Special Metals	Dental Health	Sensors	Quartz Glass	Synthetic Quartz Glass	Specialty Lighting Sources

Revenues in mio. € in financial year 2005

8,387	336	300	142	57	79
7,200*					

* Revenue Precious Metal Trading

Employees at year-end 2005

3,529	1,653	2,874	1,140	303	644
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W. C. Heraeus



W. C. Heraeus

- One of the top names in the industrial precious metals and special metals business
- The division processes the precious metals gold, silver, platinum and other platinum group metals as well as the special metals tantalum or niobium primarily to produce industrial products for the automotive, semiconductor, electronics, and medical industries
- Leading position in international precious metals trading

W. C. Heraeus

Divisions

- Chemicals Division
- Contact Materials Division
- **Engineered Materials Division**
- Medical Components Division
- Thick Film Materials Division
- Thin Film Materials Division
- Trading Division

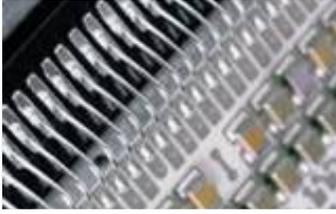
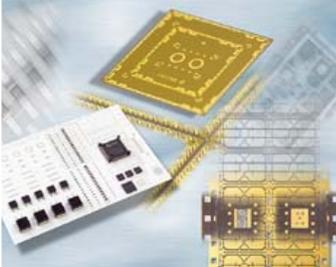
Key Markets

- Automotive technology
- Chemical industry
- Tile, glass and ceramics industry
- Semiconductor and electronics industry
- Light technology
- Aerospace industry
- Medical technology and lab industry
- Measurement and control technology
- Petrochemistry and environment
- Pharmaceuticals
- X-ray technology
- Jewelry industry
- Writing utensils industry
- Telecommunications industry

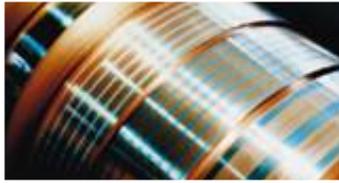
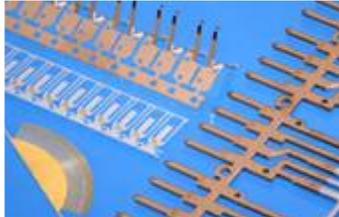
W. C. Heraeus – Top Products

Product	Application	
<p>Pt/Pd/Rh-coated catalytic converters for emissions (Chemicals Division)</p>	<ul style="list-style-type: none"> Reduction of hydrocarbons and nitrogen oxides in small motors, for example in chain-saws, brush cutters, blowers and lawn mowers 	
<p>Precious metal compounds and homogeneous catalysts (Chemicals Division)</p>	<ul style="list-style-type: none"> Homogeneous catalysts for the synthesis of silicones, liquid crystals, pharmaceutical intermediates and petrochemicals. Solutions for the coating of catalyst supports and for electroplating. 	
<p>Pharmaceutical agents (Chemicals Division)</p>	<ul style="list-style-type: none"> Highly active pharmaceutical anti-tumor agents based on platinum (e.g. carboplatin, cisplatin, dacarbazine, irinotecan, rubicine, oxaliplatin) 	
<p>Recovery of precious metals (primary and secondary materials) (Chemicals Division)</p>	<ul style="list-style-type: none"> Recovery of precious metals (Pt, Pd, Rh, Ir, Ru, Os, Au, Ag and Re) from primary and secondary sources (e.g. primary concentrates, catalysts, alloys, residues) 	

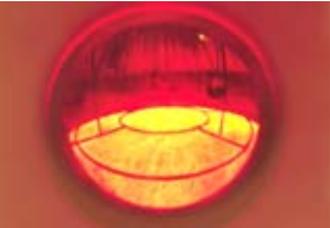
W. C. Heraeus – Top Products

Product	Application	
<p>Bonding wires (Contact Materials Division)</p>	<ul style="list-style-type: none"> ▪ Bonding wires made of gold, copper and aluminum with diameters into the μm range for the electrically conductive connection of semiconductor components 	
<p>Soldering pastes and SMT adhesives (Contact Materials Division)</p>	<ul style="list-style-type: none"> ▪ For assembly of electronic components onto printed circuit boards and other substrates 	
<p>Conductive- and non-conductive adhesives, solder pastes and ultra fine solder powders (Contact Materials Division)</p>	<ul style="list-style-type: none"> ▪ For semiconductor- and packaging-applications, such as Die Attach, Wafer Bumping, System in Package, Flip Chip and Ball-Attach 	

W. C. Heraeus – Top Products

Product	Application	
<p>Roll clad strips (Engineered Materials Division)</p>	<ul style="list-style-type: none"> Strips with bondable surfaces as conductors of electrical signals in subassemblies for automotive and industrial electronics 	
<p>Precision parts for the automotive industry (Engineered Materials Division)</p>	<ul style="list-style-type: none"> Plated precision stamped parts and etched parts, micro-contact parts and multi-wire wipers for automotive applications 	
<p>Flexible substrates (Engineered Materials Division)</p>	<ul style="list-style-type: none"> Flexible substrates, stamped, laminated and electroplated as carriers for semi-conductors, diodes and electronical parts 	

W. C. Heraeus – Top Products

Product	Application	
<p>Metal plastic parts (Engineered Materials Division)</p>	<ul style="list-style-type: none"> ▪ Bondable hybrid housings as complex sub-assemblies with electrical components (e.g. for controlling electrical power steering for the VW Golf V) 	
<p>Precious metal catalyst gauzes (Engineered Materials Division)</p>	<ul style="list-style-type: none"> ▪ Computer designed knitted gauzes made of platinum alloys for the synthesis of nitric acid and the reduction of N₂O (laughing gas) 	
<p>Precision parts for light technology (Engineered Materials Division)</p>	<ul style="list-style-type: none"> ▪ Pins, extruded parts and wires made of niobium and niobium-alloys for e.g. high-pressure sodium lamps, CCFL (Cold Cathode Fluorescent Lamp) and metal-halide lamps 	

W. C. Heraeus – Top Products

Product	Application	
<p>Micro-precision parts (Medical Components Division)</p>	<ul style="list-style-type: none"> Coated fixation, ring and head electrodes for muscle and nerve stimulation made of platinum alloys and titanium 	
<p>Housings (Medical Components Division)</p>	<ul style="list-style-type: none"> Housings for drug pumps, pacemakers and capacitors made of titanium, titanium alloys, stainless steel and aluminum 	
<p>Coils and assemblies (Medical Components Division)</p>	<ul style="list-style-type: none"> Pacemaker leads and micro-invasive catheters require a number of conductor, drive and flex coils. Microcoils are for instance used for brain aneurysm treatment. 	
<p>Stylets and centerless ground parts (Medical Components Division)</p>	<ul style="list-style-type: none"> Metal based corewires, stylets (straight, J-shape, steerable) and special guide wires enable mini-invasive procedures 	

W. C. Heraeus – Top Products

Product	Application	
<p>Thick film pastes and LTCC materials (Thick Film Materials Division)</p>	<ul style="list-style-type: none"> For electronic circuits, e.g. in automotive electronics, telecommunication devices, passive components, solar and fuel cell technology 	
<p>Precious metal preparations for decoration (Thick Film Materials Division)</p>	<ul style="list-style-type: none"> Metallo-organic compounds of gold, platinum, palladium, silver and other auxiliary materials for fine 0.1 μm metal decorations on ceramic and glass mostly applied by screen printing 	
<p>Resin pastes (Thick Film Materials Division)</p>	<ul style="list-style-type: none"> Metallo-organic pastes for screen printing used for the production of 0.1 up to 0.6 μm conductive precious metal layers on aluminum oxide substrates or glass. Typical applications: sensors, thermal printheads, flat panels 	

W. C. Heraeus – Top Products

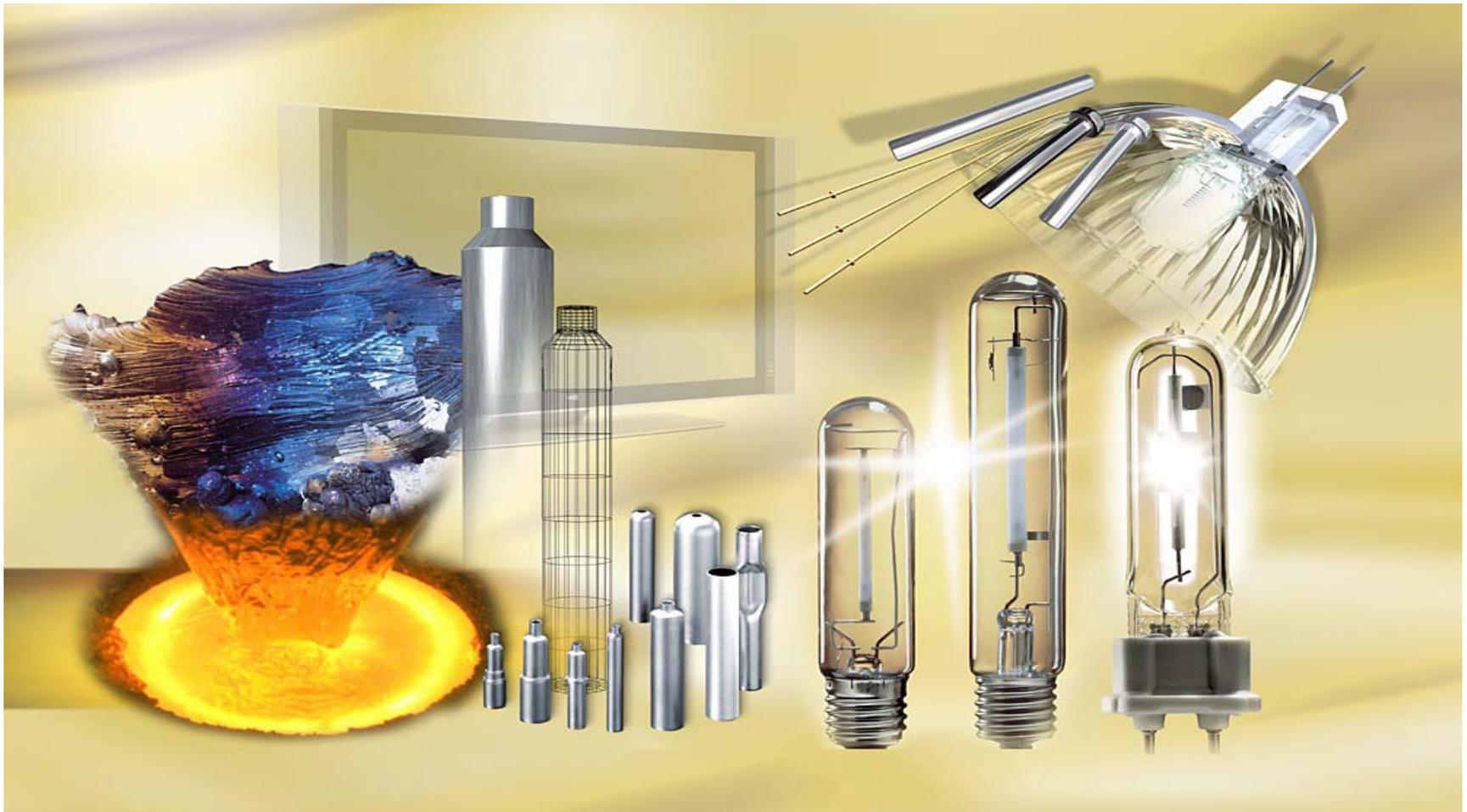
Product	Application	
<p>Sputtering targets for large area coating (Thin Film Materials Division)</p>	<ul style="list-style-type: none"> ▪ Heat insulating, anti-reflective and reflective functional coatings for architectural glass, automotive glass, mirrors, photovoltaics, etc. 	
<p>Sputtering targets for electronic applications (Thin Film Materials Division)</p>	<ul style="list-style-type: none"> ▪ Functional coatings for electronic components ▪ Transparent and conductive coatings for display applications 	
<p>Sputtering targets for magnetic data storage (Thin Film Materials Division)</p>	<ul style="list-style-type: none"> ▪ Functional coatings for magnetic data storage (hard disks for PCs, laptops, servers), read/write heads for hard disk drives 	

Organization Structure

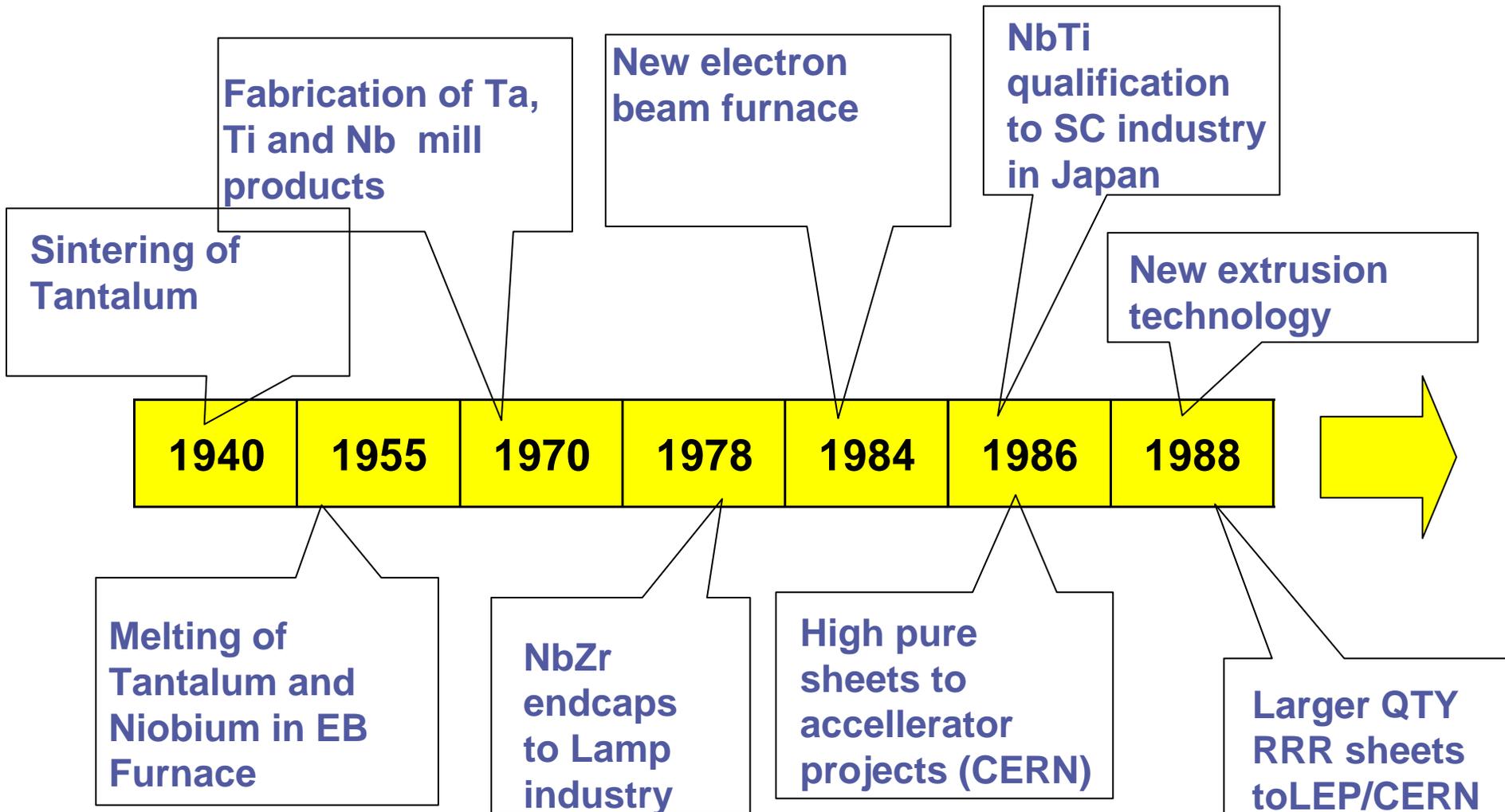
W. C. Heraeus GmbH													
Chemicals CHD		Contact Materials CMD		Engineered Materials EMD		Medical Components MCD		Thick Film Materials TFD		Thin Film Materials TMD		Trading TRD	
													
Catalysts -CA	Bonding Wires -BW	Metal Plastic Technology -MP	Active Devices -AD	Ceramic Colours -CC	Electronics -ELC	Semifinished Jewellery -SJ							
Chemical Products -CP	Surface Mount -SM	Precious Metal Techology -PM	Vascular Devices -VD	Thick Film -TH	Large Area Coating -LAC								
Pharma -PH		Precision Technology -PT			Magnetic Data Storage -MDS								
Recycling -RC		Semifinished Products -SE											
		Special Metals Technology -ST											



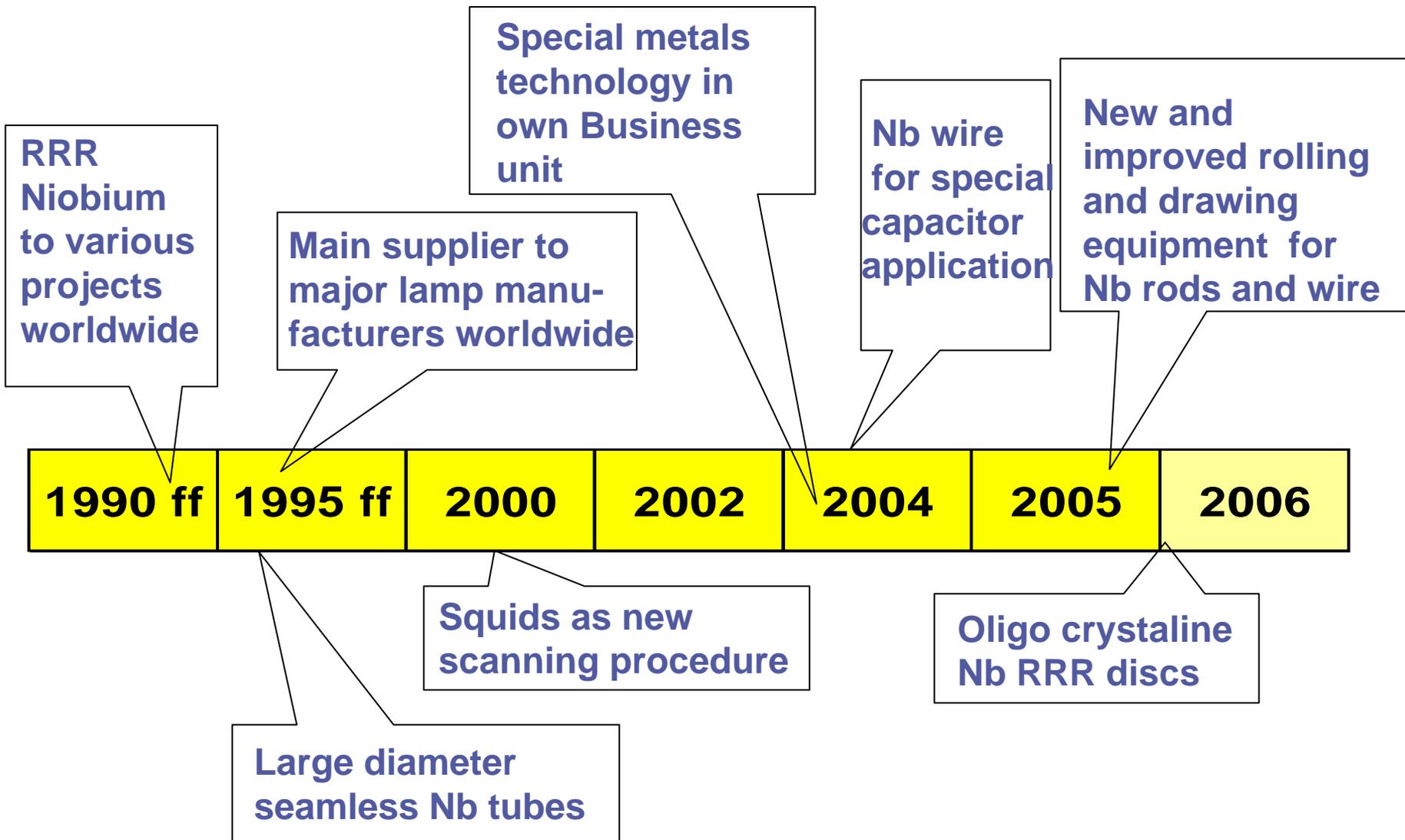
W. C. Heraeus / EMD-ST



Milestones in Special Metals Technology



Milestones in Special Metals Technology



Niobium and Niobium-Zirkonium 1% application

- **Lamp industry - General lighting(endcaps, wire, pins)**
- **Lamp industry CCFL for flat panels**
- **Capacitor (wire)**
- **Accelerator projects (discs; rods; tubes, housings)**
- **SC industry (rods, tubes)**

EMD-ST / Products for Lighting Applications

- **Niobium - 1 % Zirconium Endcaps**
(Application: High Pressure Sodium Vapour Lamps)



- **Niobium - 1 % Zirconium Tubes**
(Application: High Pressure Sodium Vapour Lamps)



- **Niobium - 1 % Zirconium Wire and Pins**
(Application: Metal Halide Lamps)



EMD-ST / Products for Lighting Application

- **Platinum - Tungsten 90/10 Strip**



- **Platinum wire and strip**
(Application Welding support)



- **Stamping part with In – Coating**
(Application: Energy Saving lamps as Amalgam Depot)



EMD-ST / Products for Lighting Application

- **Coatings of Mo Foil and Pins**
(Application Halogen Lamps)



- **Electrode Caps for CCFL Backlights**

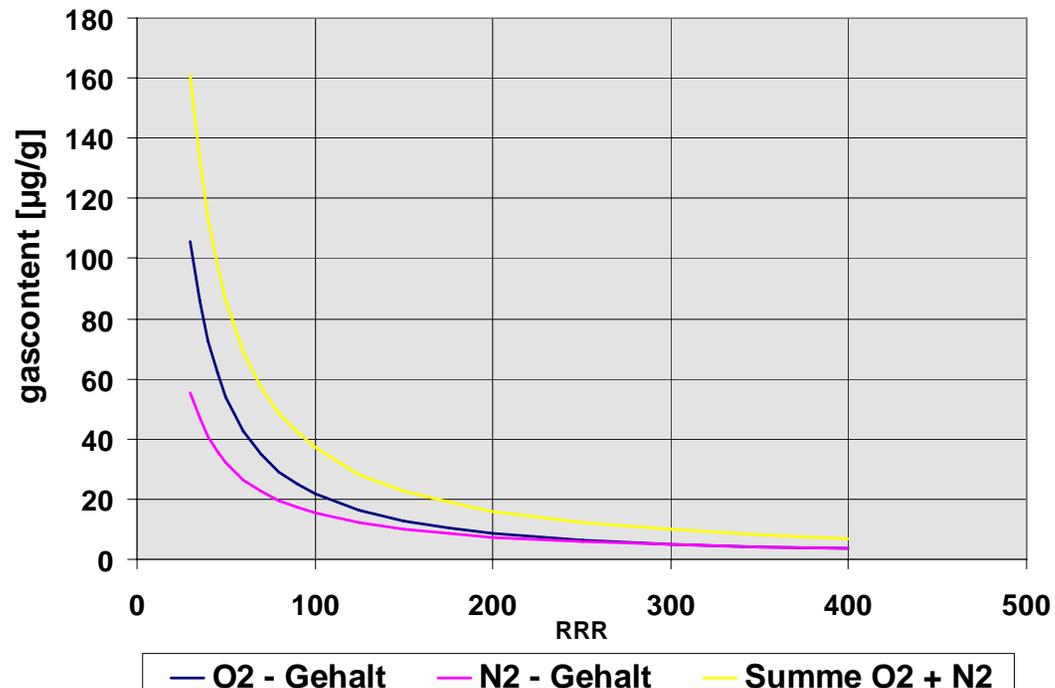


— Nb RRR 1,3 GHz Cavity DESY

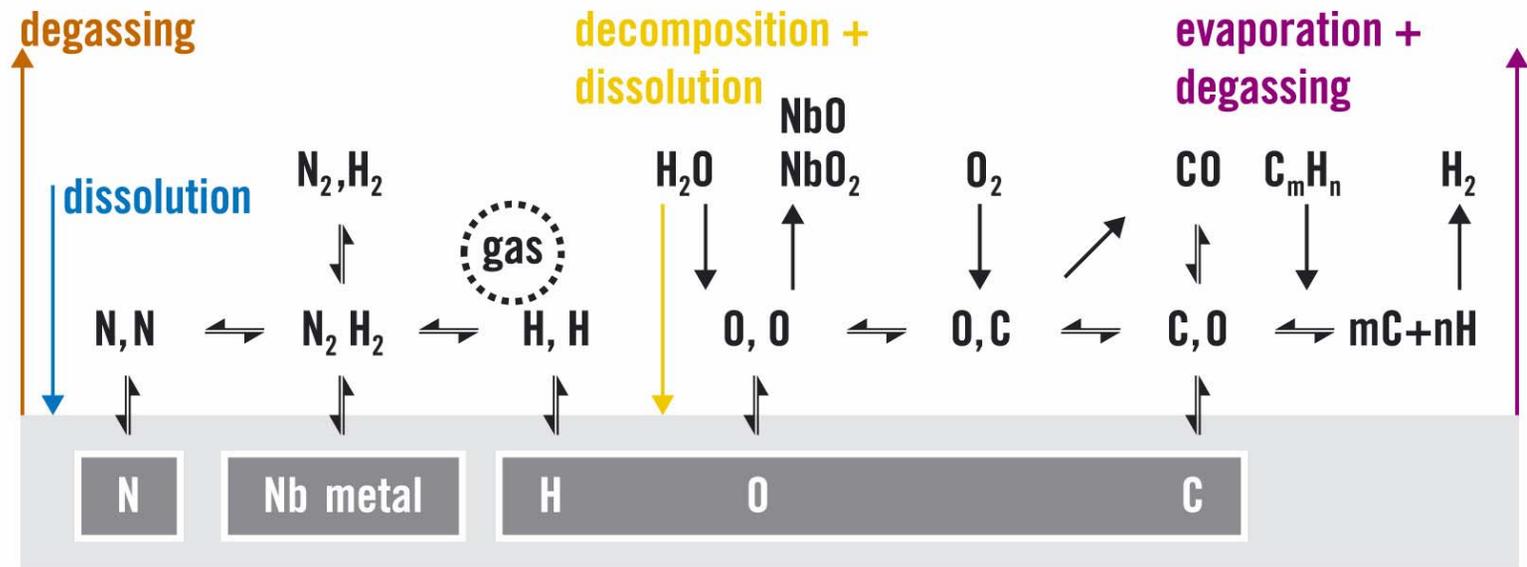


Nb refining for reaching high RRR values

**RRR for Niobium
in correlation to gascontent O2 - N2**



Nb refining for reaching high RRR values

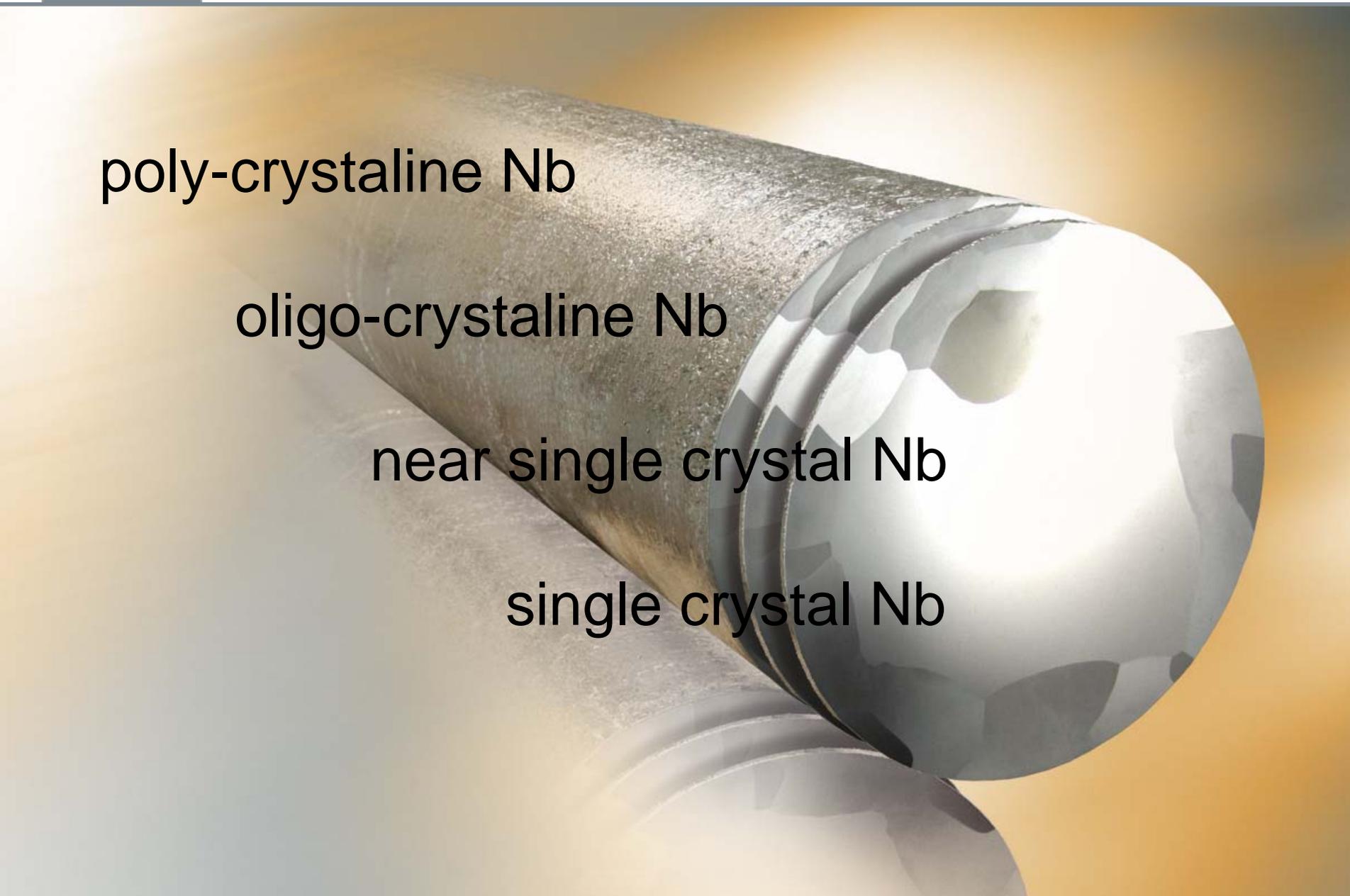


poly-crystalline Nb

oligo-crystalline Nb

near single crystal Nb

single crystal Nb

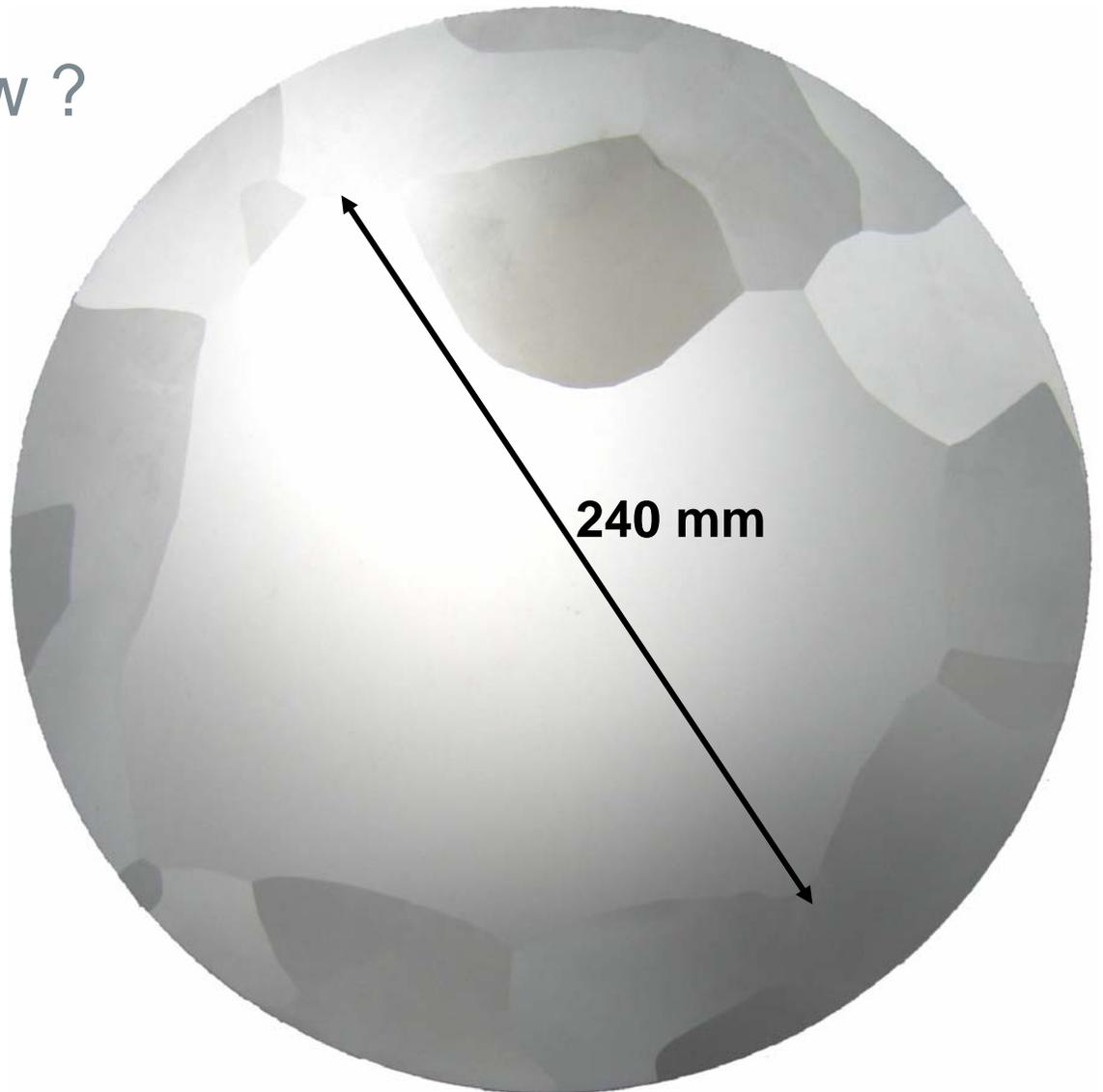


poly...oligo...near single...single crystal Nb

- **where are we now ?**
- **where can we go to ?**
- **what work is to do ?**
- **available capacity for Nb RRR**

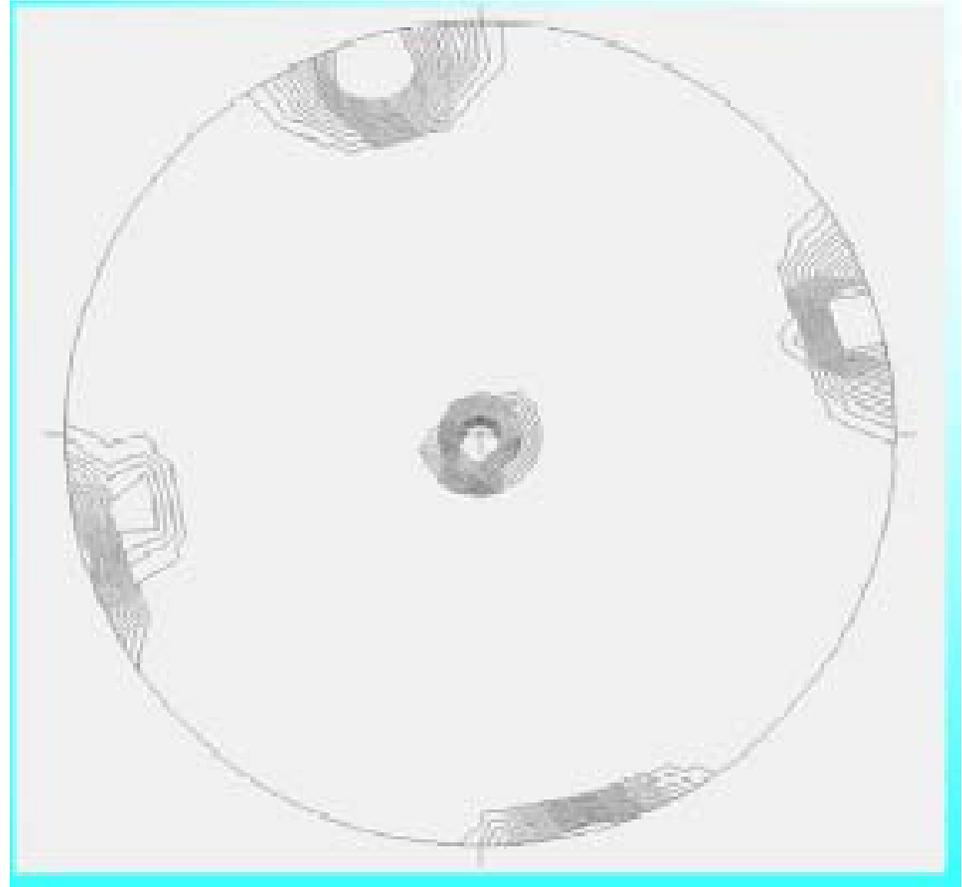
where are we now ?

yes !!



where are we now ?

- **the core crystal is a near ideal crystal**



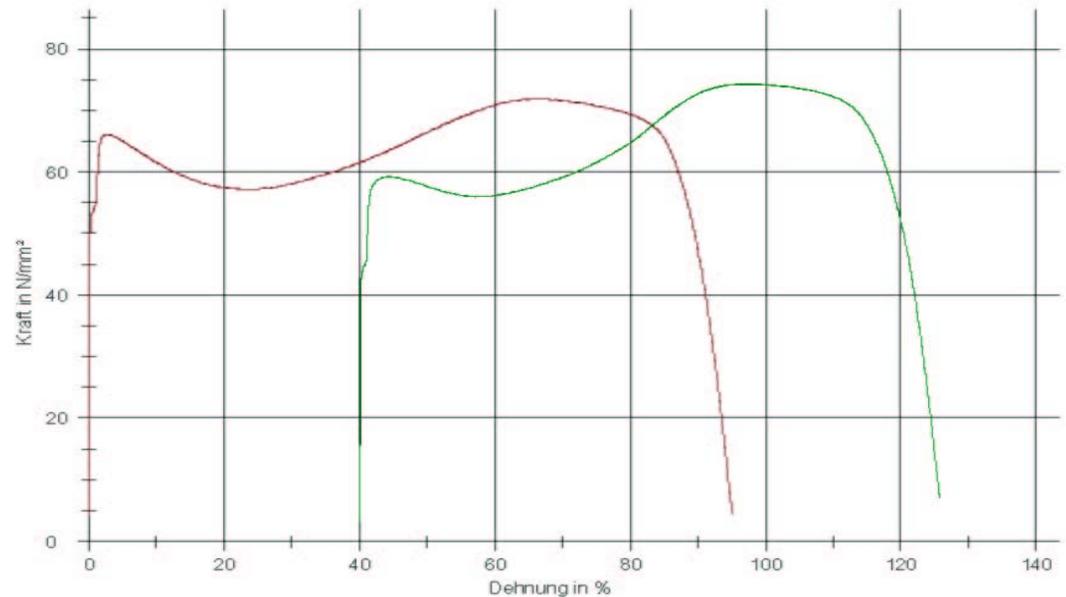
where are we now ?

- **excellent mechanical properties**
- elongation > 85 %**

Ergebnisse:

Nr	Probe	b0 mm	a0 mm	Rp 0.2 N/mm ²	Rm N/mm ²	A 30mm %
1	Mitte Ingotscheibe	7,95	2,56	52,6	71,9	95,0
2	radial am Rand Ingotscheibe	8,15	2,88	43,0	74,3	85,7

Seriengrafik:



where are we now ?

— with the direct cutting thickness tolerances of 0,06 mm and better are reachable

Disc No	nom. Thickn.	Actual Thickness							min	max	delta
		1	2	3	4	5	6	7			
1		3,24	3,11	3,21	3,1	2,41	2,77	3,19	2,41	3,24	0,83
2	2,86	2,85	2,83	2,87	2,86	2,82	2,81	2,81	2,81	2,87	0,06
3	2,86	2,84	2,83	2,84	2,84	2,83	2,81	2,83	2,81	2,84	0,03
4	2,86	2,88	2,86	2,84	2,85	2,85	2,85	2,85	2,84	2,88	0,04
5	2,86	2,85	2,86	2,87	2,88	2,87	2,85	2,88	2,85	2,88	0,03
6	2,86	2,88	2,86	2,84	2,83	2,83	2,87	2,87	2,83	2,88	0,05
7	2,86	2,83	2,84	2,89	2,86	2,84	2,83	2,83	2,83	2,89	0,06
8	2,86	2,86	2,84	2,87	2,86	2,86	2,87	2,86	2,84	2,87	0,03
9	2,86	2,88	2,85	2,84	2,84	2,85	2,86	2,86	2,84	2,88	0,04
10	2,86	2,85	2,85	2,87	2,86	2,82	2,84	2,84	2,82	2,87	0,05
11	2,86	2,84	2,86	2,82	2,83	2,84	2,84	2,85	2,82	2,86	0,04
12	2,86	2,82	2,83	2,84	2,85	2,82	2,81	2,84	2,81	2,85	0,04
13	2,86	2,88	2,87	2,88	2,86	2,89	2,89	2,88	2,86	2,89	0,03
14	2,86	2,89	2,88	2,90	2,92	2,86	2,87	2,88	2,86	2,92	0,06
15	2,86	2,8	2,83	2,79	2,82	2,83	2,82	2,83	2,79	2,83	0,04
16	2,86	2,87	2,85	2,88	2,89	2,85	2,88	2,86	2,85	2,89	0,04
17	2,86	2,83	2,84	2,84	2,84	2,84	2,85	2,86	2,83	2,86	0,03
18	2,86	2,87	2,88	2,85	2,86	2,87	2,86	2,88	2,85	2,88	0,03
19	2,86	2,86	2,84	2,84	2,85	2,84	2,86	2,85	2,84	2,86	0,02
20	2,86	2,87	2,85	2,85	2,85	2,84	2,85	2,84	2,84	2,87	0,03

where are we now ?

- **Cavities out of that oligo crystalline Nb are showing high field performance**

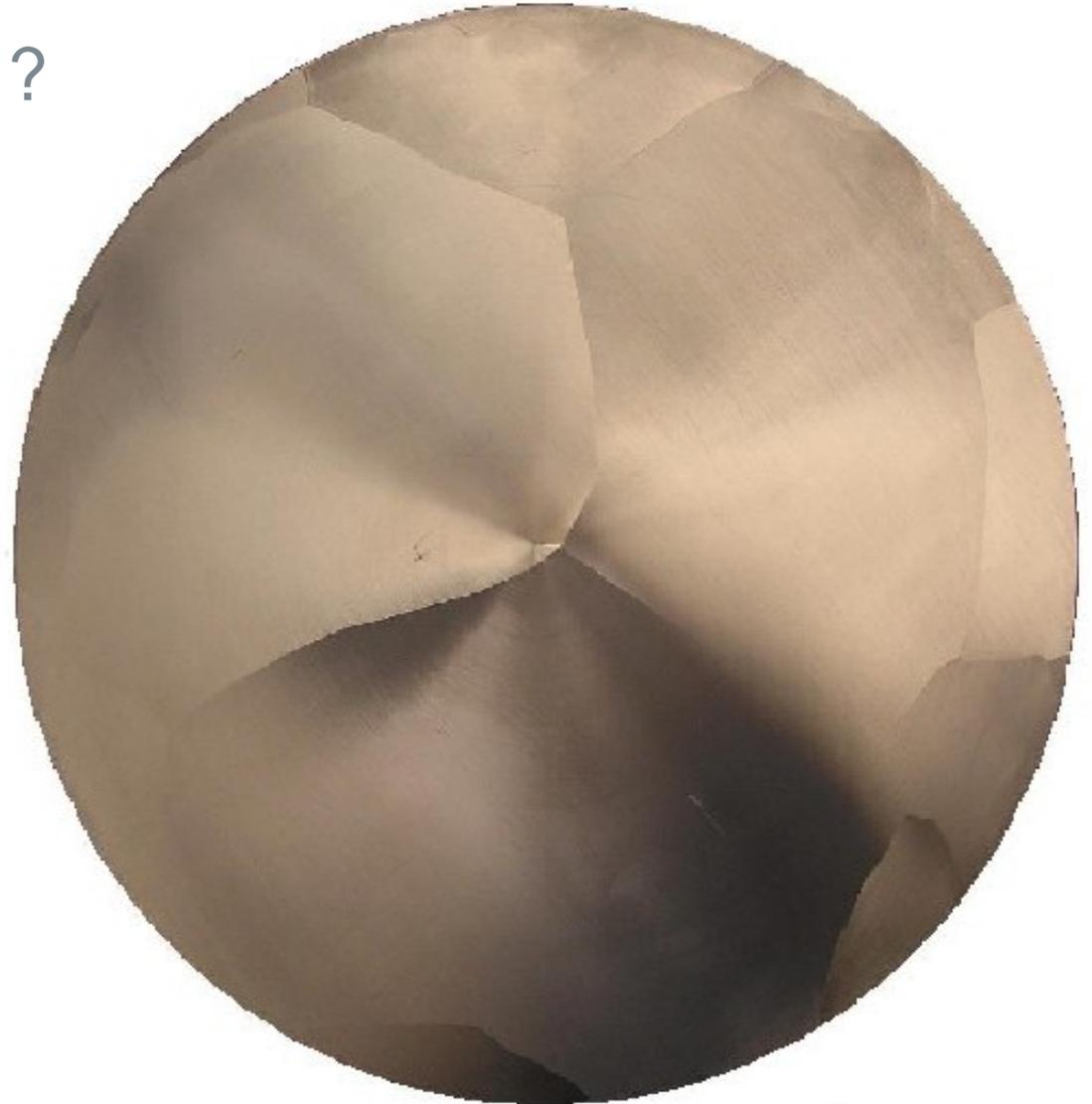
9 cells are testet

→ Dr.Singer



where are we now ?

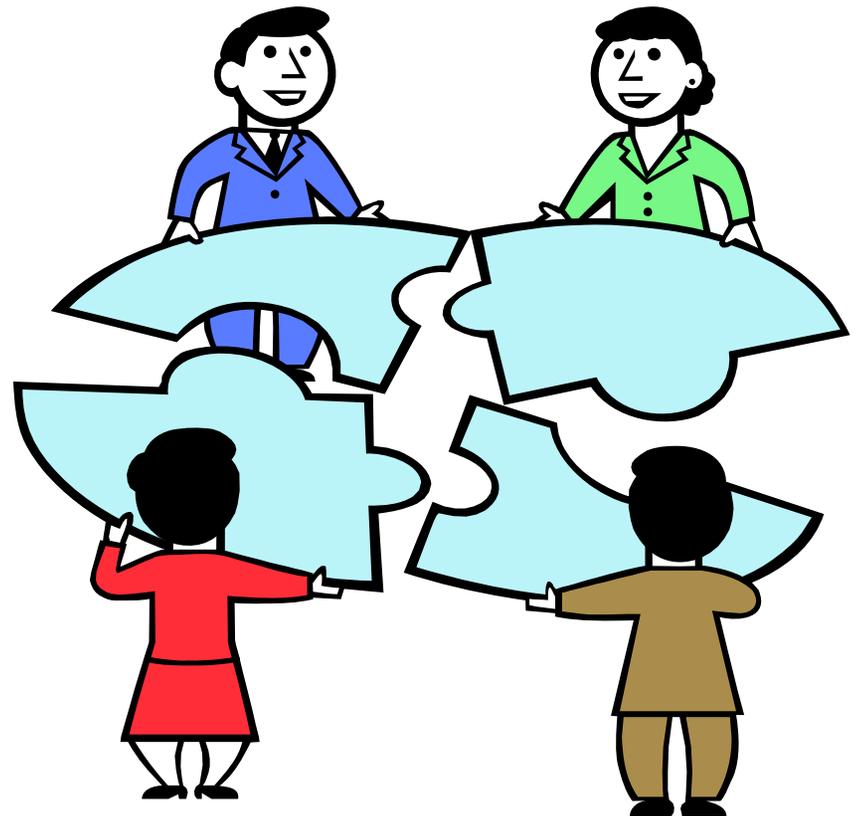
but ??



where can we go to ? what work is to do ?

— **single crystal niobium workshop**

—



- Electron beam melting furnace
- **Manufacturer: LH / ALD**
- **EB Power: 600 kW**
2 EB – Guns KSR 600
- **Pump rating: 2 x 50 000 l.s-1**
- **Vacuum in the chamber**
 - **down to 10 E-6 mbar**
- **two Ingot chambers**
- **max Ingot-diameter: 312 mm**
- **max Ingot-length: 2200 mm**
- **max Ingot weight: 1400 kg**



what capacities would be available
if we will be successful ?

- **Nb RRR melting capacity at Heraeus**
 - ~ 40 to 50 t/a
 - with existing furnace and product portfolio

- **Cutting capacity at Heraeus**
 - ~ 13000 to 15000 discs/a
 - = discs for ~ 800 cavities/a
 - depending on investments to be multiplied

Single Crystal Niobium Workshop
October 30 – November 1, 2006

Thank you for your attention !!

