



PTB – das nationale Metrologie-Institut mit wissenschaftlich-technischen Dienstleistungsaufgaben

PTB

News from the

Physikalisch-Technische Bundesanstalt

... the National Metrology Institute of Germany



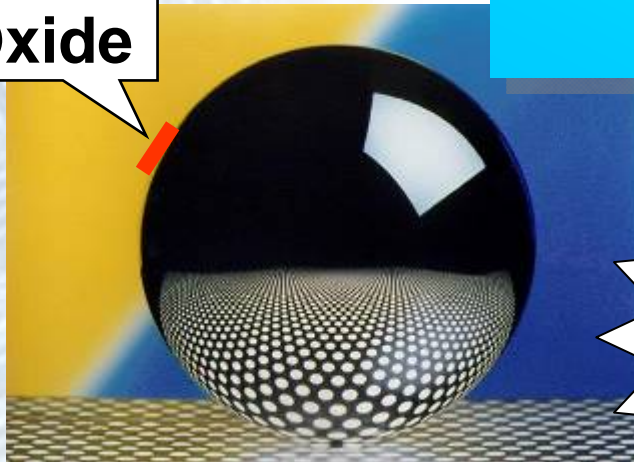
Federal Ministry
of Economics
and Technology

: 1 Avogadro constant



$$N_A = \frac{n \cdot M_{\text{mol}}}{\rho \cdot a^3}$$

Oxide



“Molar mass measurements”



1 International Avogadro Coordination

- Founded during the CIPM conference 1. October 2003:

- „Consortium for the realization of the new determination of the Avogadro constant“

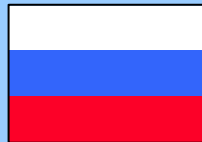
- Regulates the realization of the Avogadro constant and the ownership of the Avogadro constant

- Participants:

^{28}Si manufacturer:



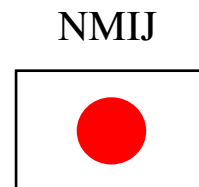
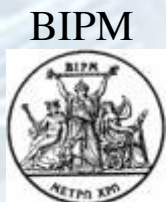
International Science and Technology Center, Moscow



STC Centrotech, St. Petersburg
IhpS RAS, Nishni Novgorod
JV Isoflex, Moscow



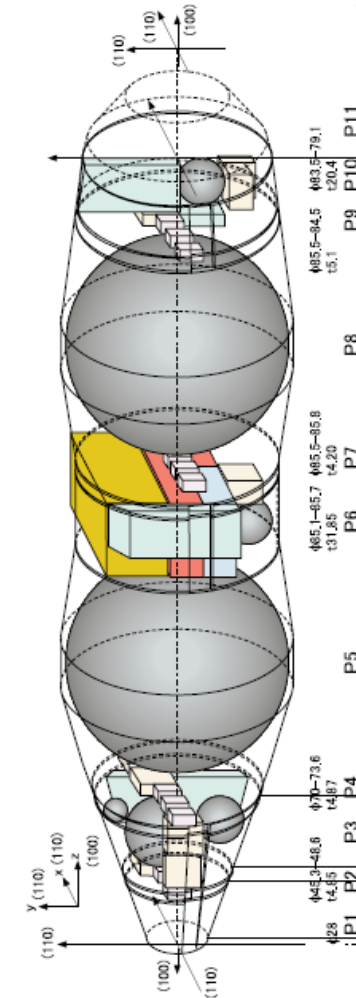
Institut für Kristallzüchtung IKZ, Berlin



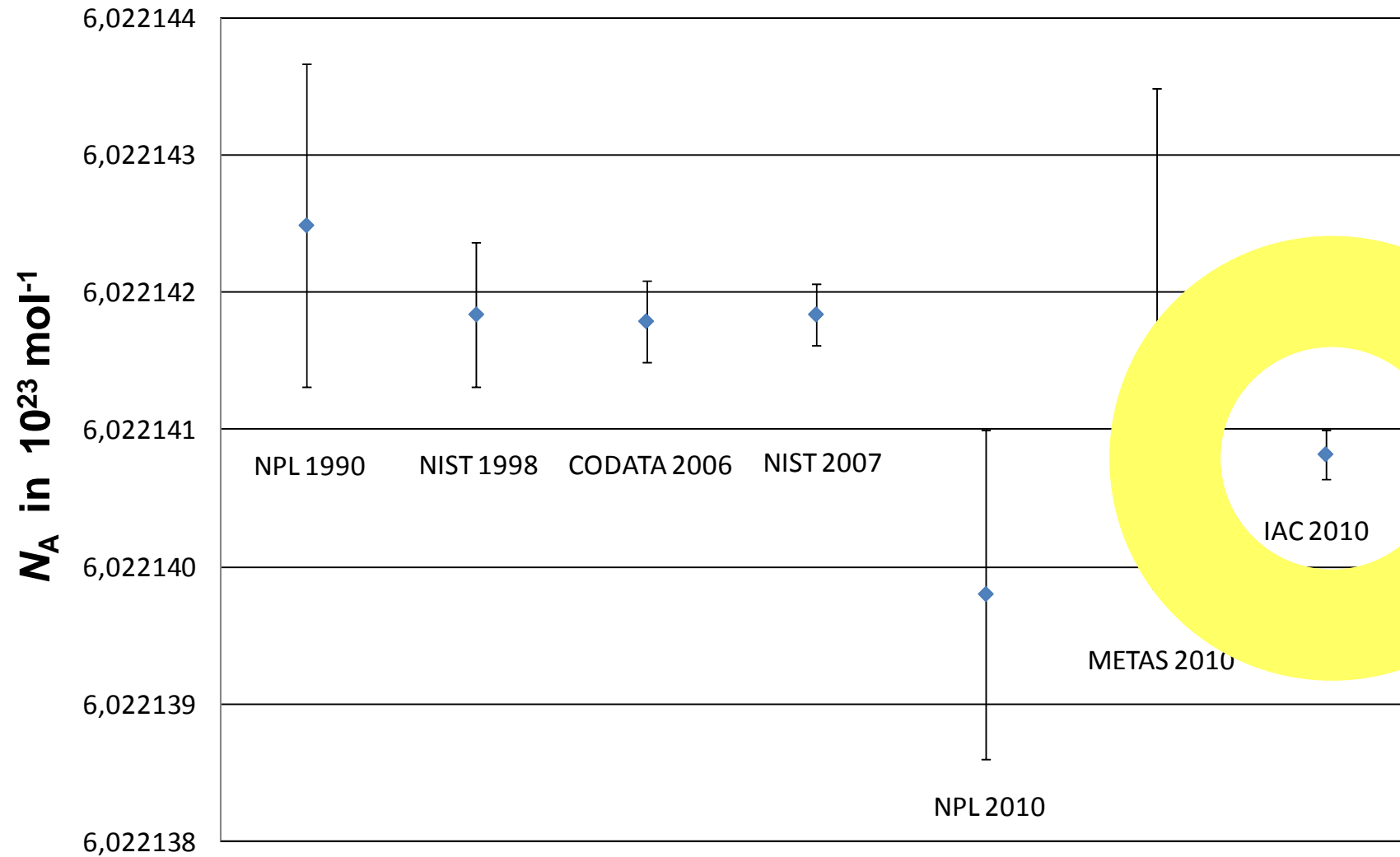
1 Avogadro Project

Status

- Publication in Phys. Rev. Lett.
- Special Issue of Metrologia:
„Dedicated to Peter Becker“
14 publications
- **Relative uncertainty achiev.: 3×10^{-8}**
- Largest remaining uncertainties:
Diameter of the spheres and
mass of surface layers



1 Avogadro's constant



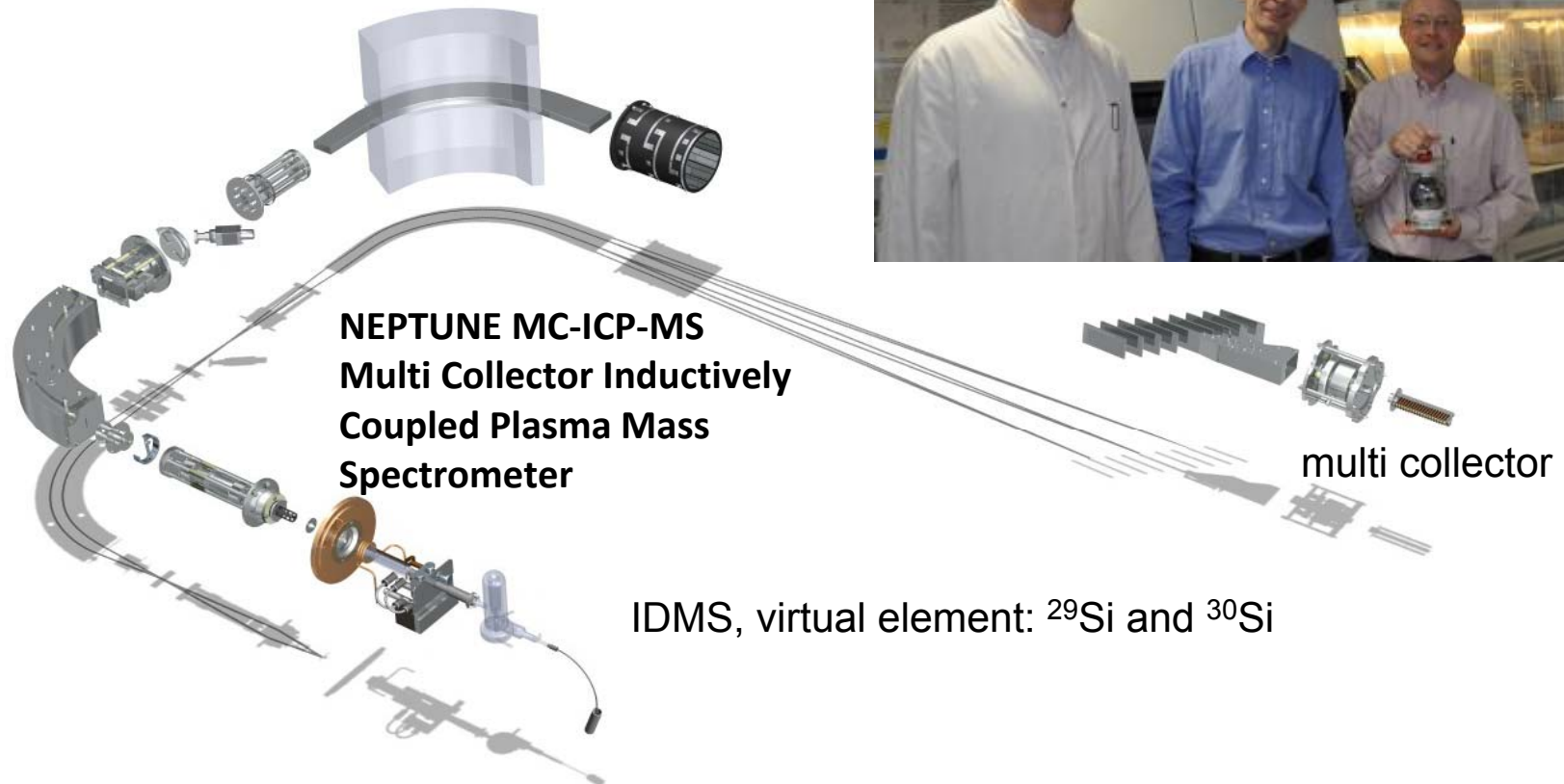
• 1 Avogadro Project

Particular improvements achieved:

- Isotopically enriched silicon (^{28}Si)
- Molar mass determination by IDMS at PTB
- Rel. uncertainty of molar mass below 1×10^{-8}
- Surface characterisation by ellipsometry, XPS, XRF, XRR
- More accurate lattice parameter



• The Key: Molar Mass: IDMS



$\text{Si}_{\text{crystal}} \rightarrow \text{aqueous sol.} \rightarrow \text{aerosol}$

IDMS (isotope dilution mass spectrometry)

• 1 Avogadro Project

Organisation of the Avogadro project

- **International Avogadro Coordination: expired**
- **iMERA-Plus Project T1 J1.2 NAh: ended in March**
- **CCM Working Group on the Avogadro Constant: Meeting on 9 and 10 May 2011, together with Chinese Avogadro project**
- **EMRP PRTs submitted, JRP jointly with European watt balances, for additional determination of the Planck constant and the redefinition/realisation of the kilogram, start 2012?**

• 1 Avogadro Project

Future as planned

- EMRP Project jointly with European watt balances
- Molar mass determinations at NIST, NRC, NIM, IMR
- Lattice parameter determination at PTB
- More accurate surface layer characterisation
- Sphere manufacturing: Unroundness < 10 nm
- New sphere interferometer
- New measurements with decontaminated spheres
- **Target: Uncertainty of $1 \times 10^{-8} N_A$**

• 2 Boltzmann Constant



Coordinator:

Physikalisch-Technische
Bundesanstalt



Partners:



Danish Fundamental
Metrology



Collaborators:

Universidad de Valladolid

UVa



EMRP

European Metrology Research Programme
► Programme of EURAMET



by :

acoustic gas therm.
(AGT)

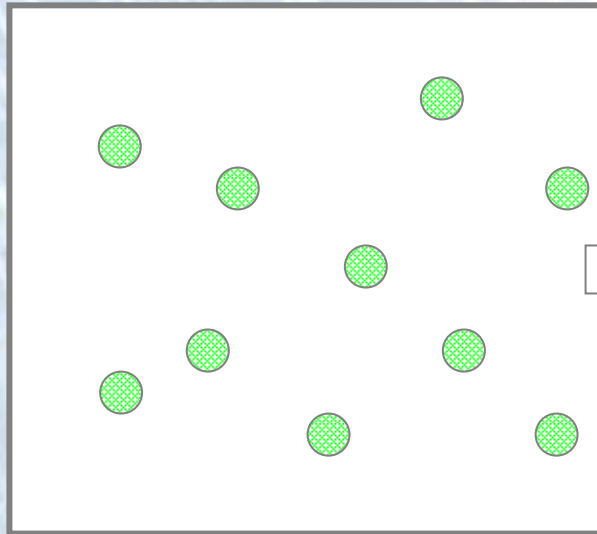
Doppler broadening
thermometry (DBT)

dielectric constant
gas thermometry
(DCGT)

EURAMET
European Association of National Metrology Institutes



2 Boltzmann Constant



system of “particles“

thermal energy E per degree
of freedom

thermodynamic temperature T

k = conversion factor

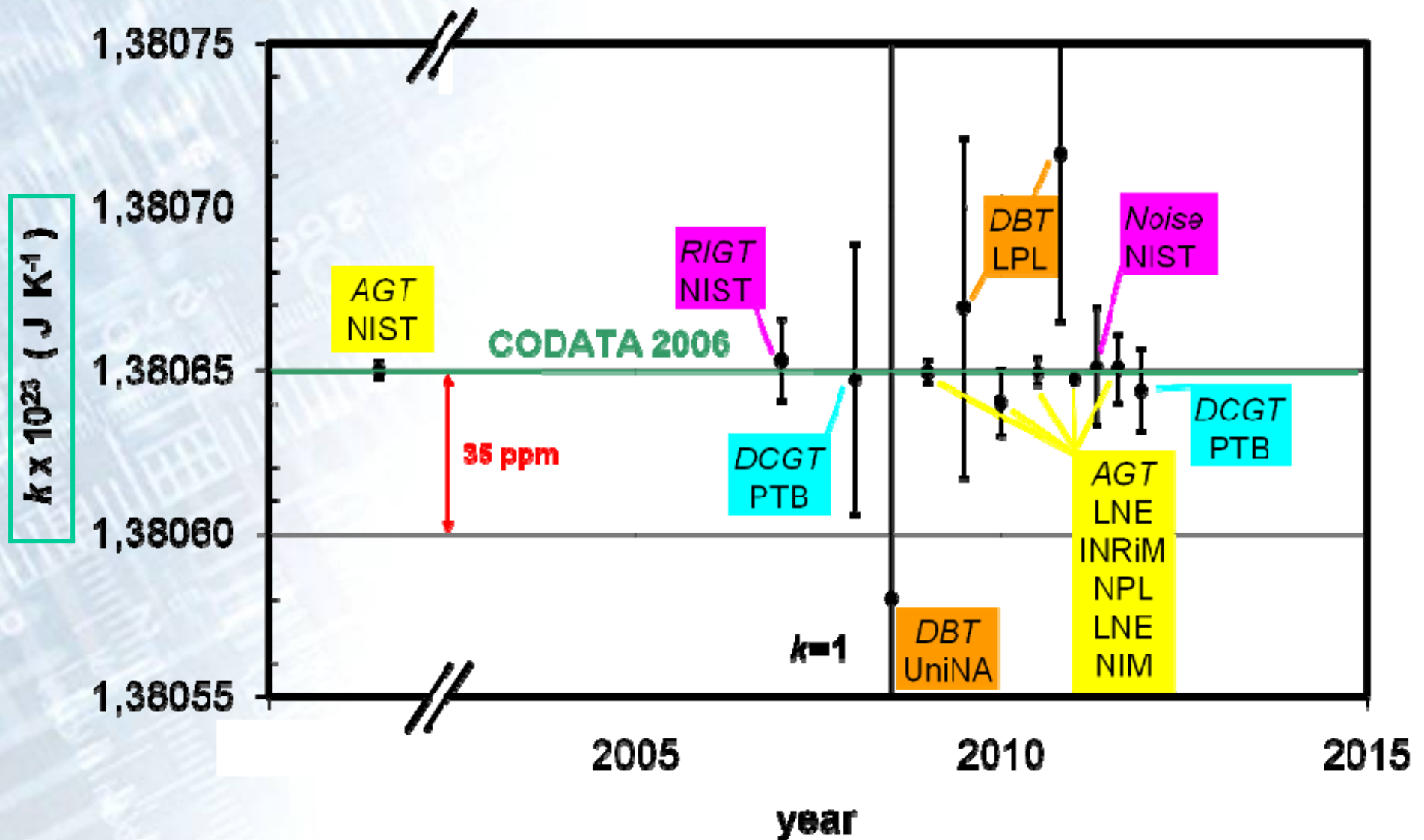
$$E = \frac{1}{2}kT$$

CODATA value of Boltzmann constant 2006:

$$k = R/N_A = 1.3806504 (24) \cdot 10^{-23} \text{ J/K} \quad u = 1.7 \cdot 10^{-6} \text{ *)}$$

*) Rev. Mod. Phys. 80 2008, 633

2 Boltzmann Constant – Present State



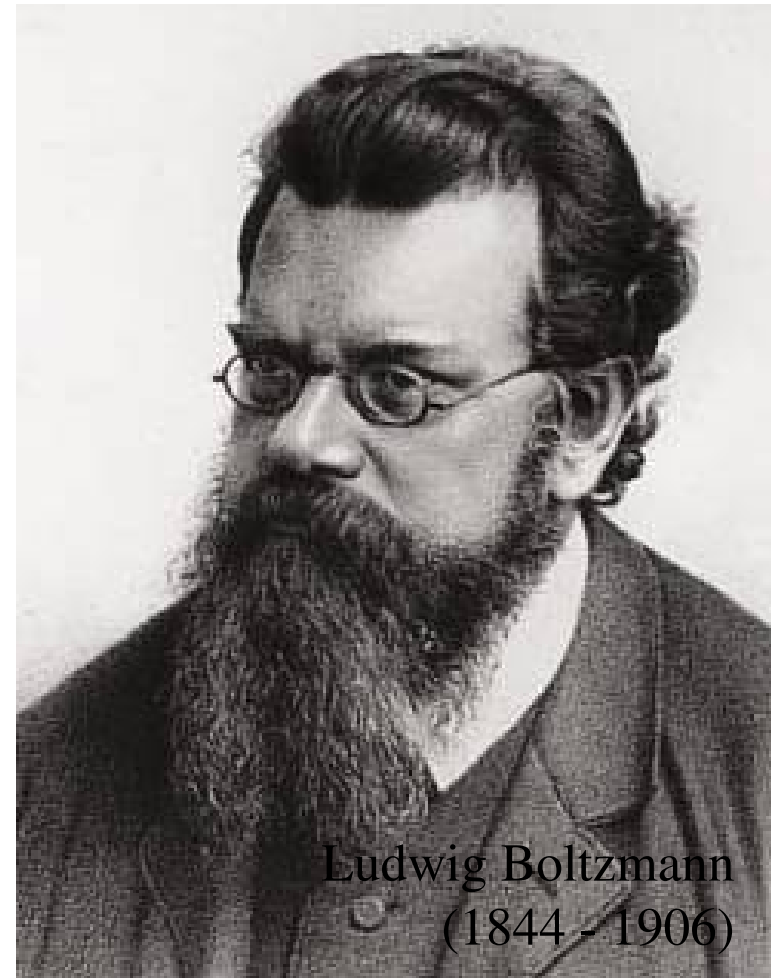
2 Impact of a New Kelvin Definition

Short term:

- the kelvin definition is independent of any material
- no favoured fixed point
- no favoured measurement method
- no error propagation from TPW
- thermodynamic measurements and ITS-90 are coexisting
- $<20\text{ K}$ and $>1300\text{ K}$ thermodynamics are superior

Long term:

- With improvement of primary thermometry thermodynamic measurements may replace ITS-90



Ludwig Boltzmann
(1844 - 1906)

• 3 The Second - Primary Clocks

- n 4 primary Cs clocks of PTB contribute to TAI
in total: 13 primary clocks in 7 institutes

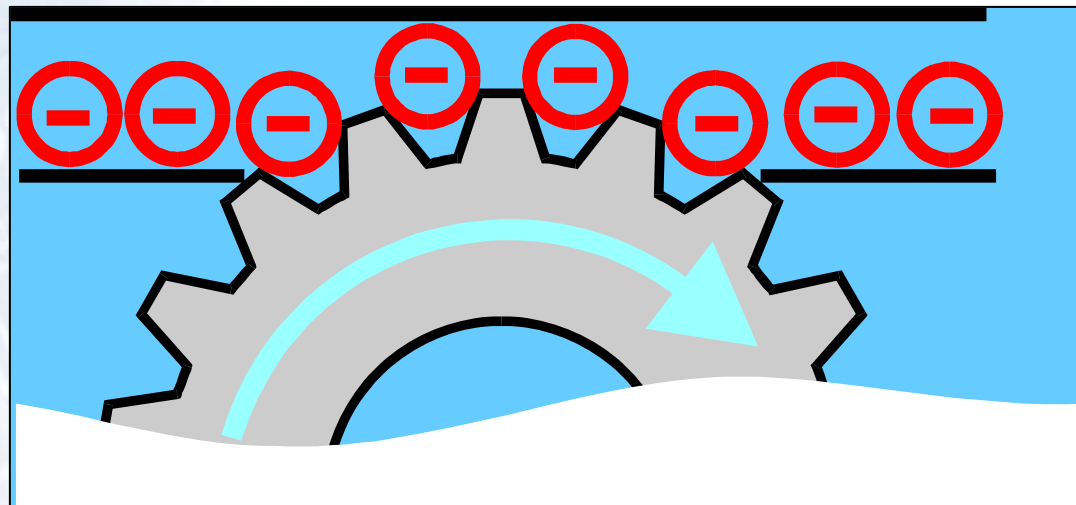
Progress of optical clocks at PTB:

- n First frequency measurement with PTB's Sr lattice clock
uncertainty of frequency standard is below 2×10^{-16}
transportable clock under construction
- n Yb⁺ singel Ion clock interrogates octupole transition
frequency ration of two Yb⁺ clock transitions is highly sensitive to
temporal variations of the fine structure constant α



• 4 The Ampere

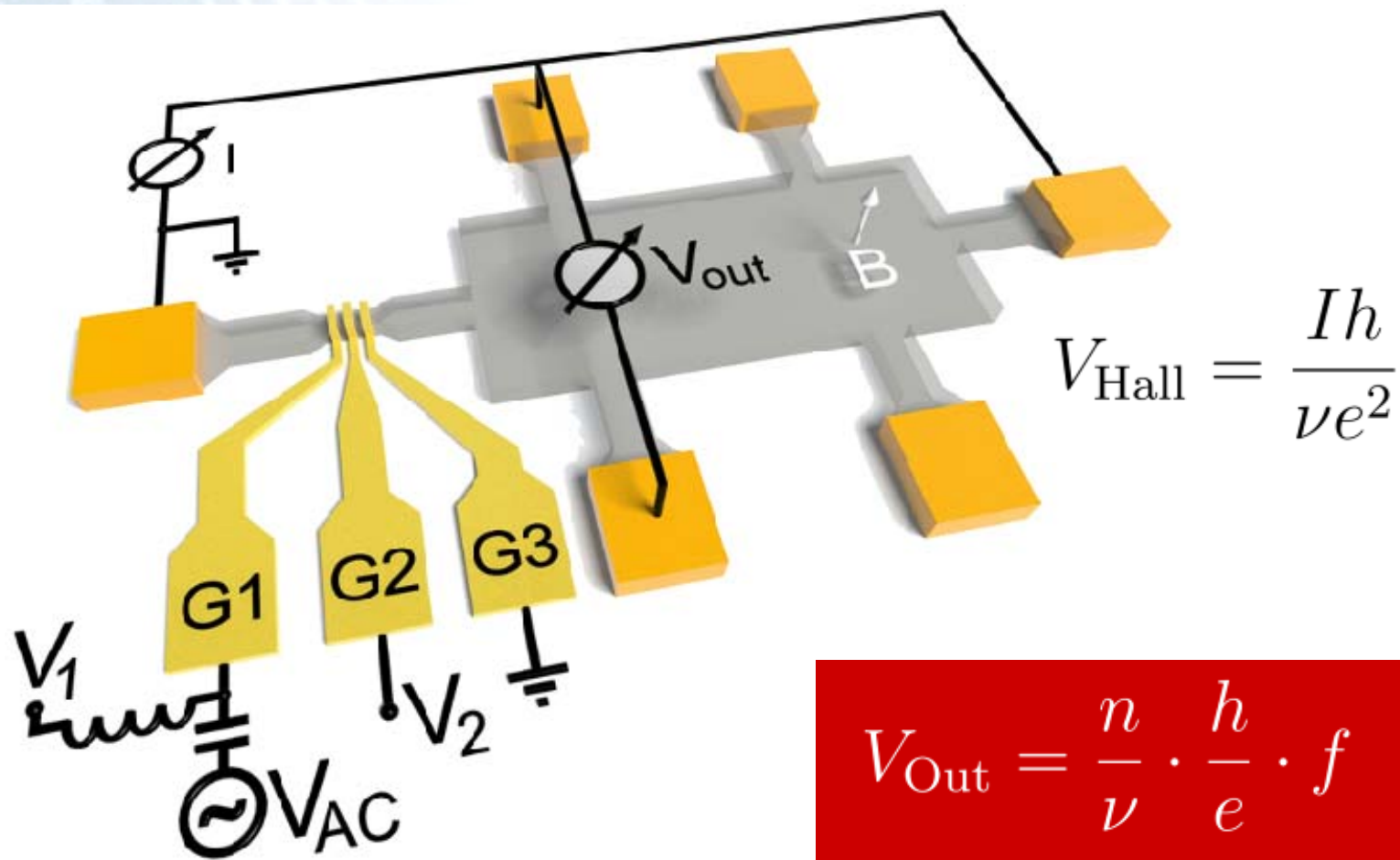
Key: Single-electron transport:



$$I_{\text{SET}} = n \cdot e \cdot f$$

$$I_{\text{SET}} = 100 \text{ pA at } 1 \text{ GHz}$$

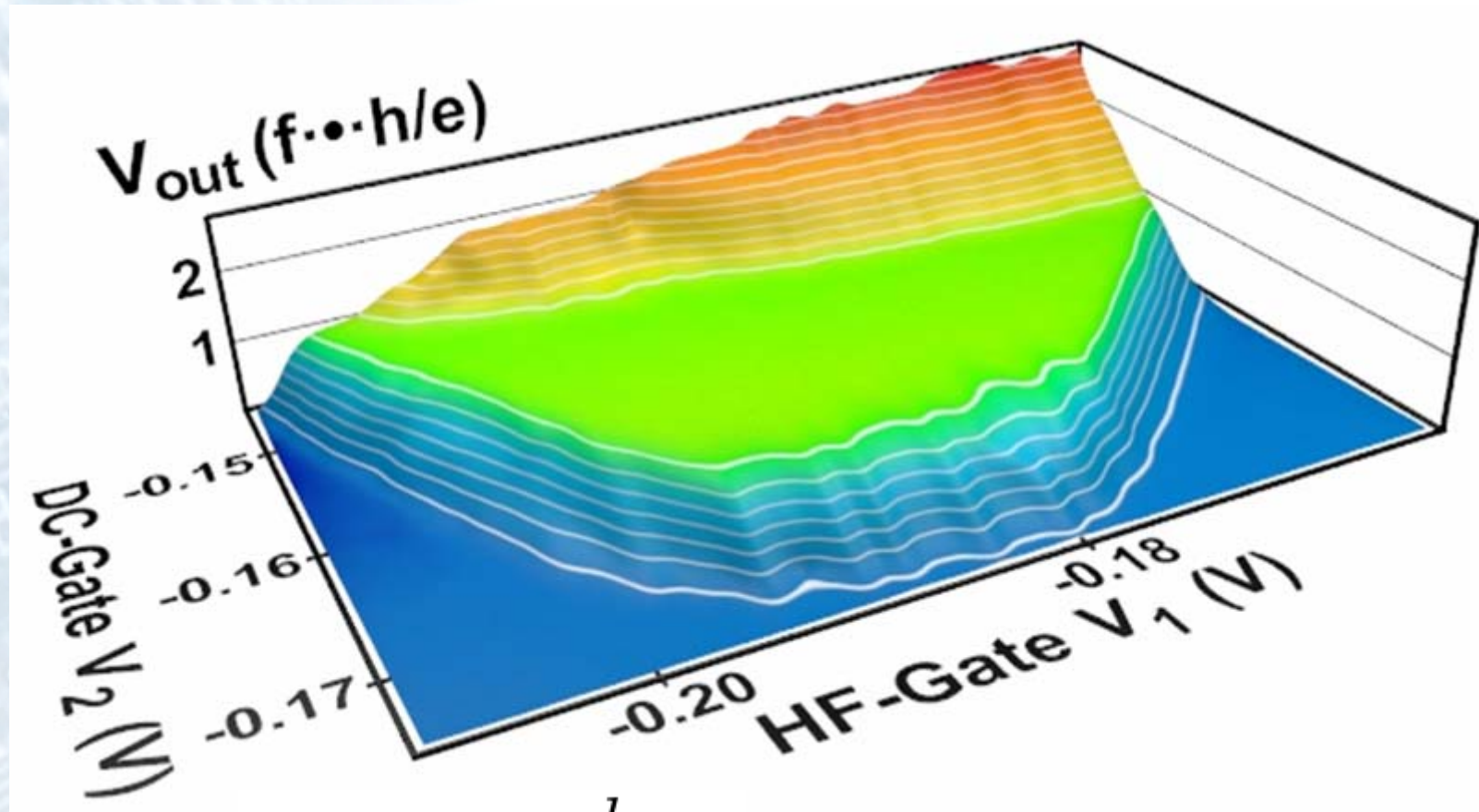
4 The Ampere



$$I_{SET} = n \cdot e \cdot f$$

• 4 The Ampere

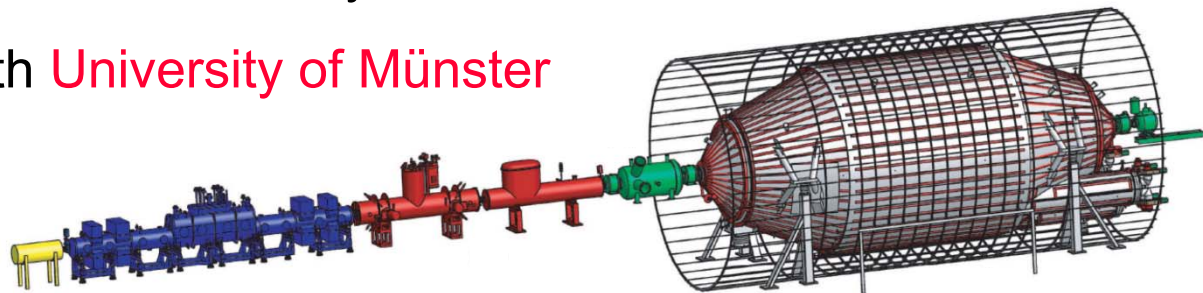
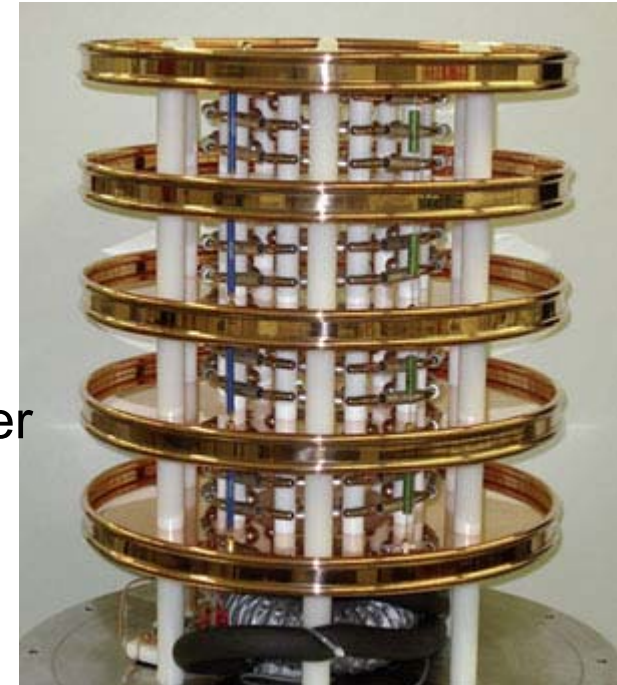
Alternative closure of the Quantum-Metrological Triangle



$$V_{\text{Out}} = \frac{n}{\nu} \cdot \frac{h}{e} \cdot f \quad \nu = 1, n = 1, f = 675 \text{ MHz}$$

Supporting the Determination of the Neutrino Mass

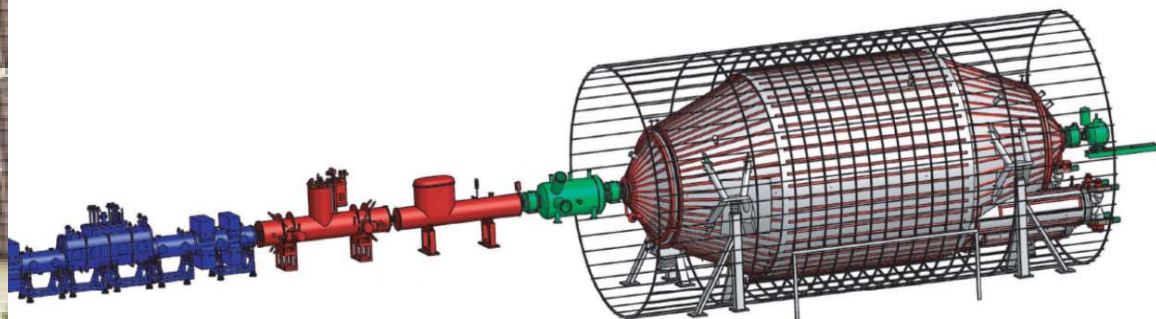
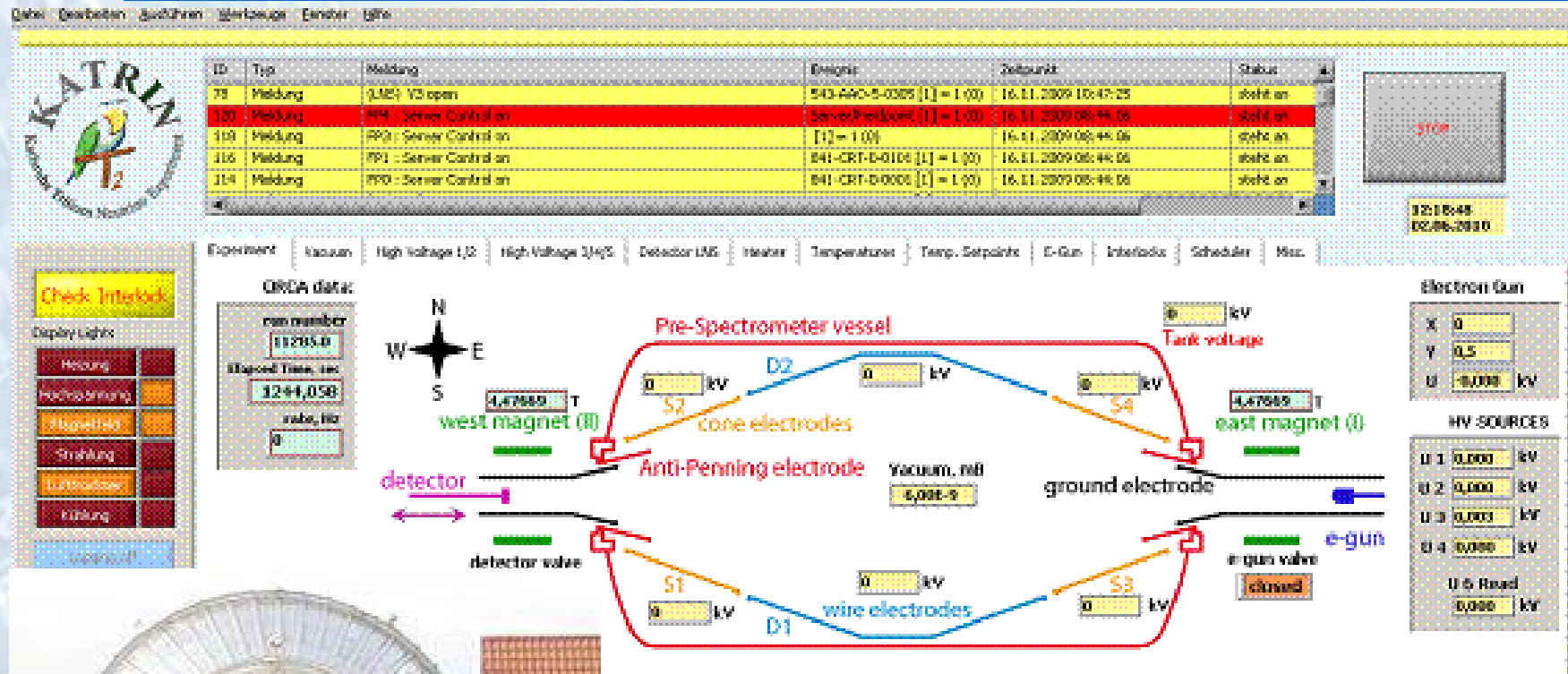
- n Neutrino mass determination by measuring the end point energy of the Tritium- β -decay
- n Development of a 18 kV-DC-Voltage-Divider for **KATRIN-Experiment** of KIT, Karlsruhe, Germany
- n Achieved uncertainty $2 \mu\text{V/V}$ undercuts requested uncertainty
- n Collaboration with **University of Münster**



KATRIN: Karlsruhe-Tritium-Neutrino-Experiment

doi:10.1088/1742-6596/203/1/012097

5 Precision Instruments for Basic Research

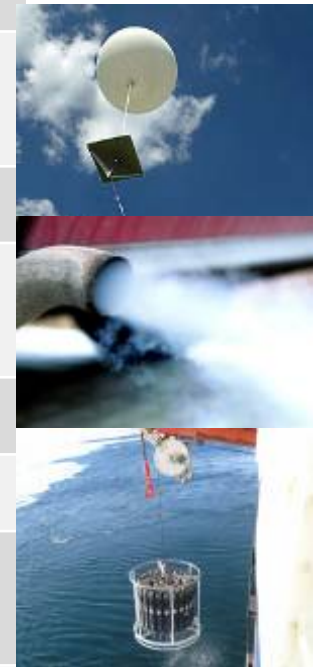


doi:10.1088/1742-6596/203/1/012097

9 funded projects

- Metrology for chemical pollutants in air
- Emerging requirements for measuring pollutants from automotive exhaust emissions (PTB)
- Traceability for surface spectral ultraviolet radiation
- Traceable radiometry for remote measurement of climate parameters
- Metrology for oceanic salinity and acidification (PTB)
- Spectral reference data for atmospheric monitoring (PTB)
- Metrology for pressure, temperature, humidity and airspeed in the atmosphere
- Traceable measurements for monitoring critical pollutions under the European Water Framework Directive (WFD-2000/60/EC) (BAM)
- Metrology for radioactive waste management

(PTB/BAM Coordinator: K.-D. Sommer)



17 funded projects

High temperature metrology for industrial applications ($>1000\text{ }^{\circ}\text{C}$)

Electromagnetic Characterization of Materials for Industrial Applications up to Microwave Frequencies

High pressure metrology for industrial applications (PTB)

Ionizing Radiation Metrology for Metallurgical Industry

Dynamic mechanical properties and long-term deformation behaviour of viscous materials

Metrology for Industrial Quantum Communication Technologies

Metrology for the manufacturing of thin films

Metrology for Advanced Industrial Magnetics (PTB)

Traceable Dynamic Measurement of Mechanical Quantities (PTB)



17 funded projects

Optical and tactile metrology for absolute form characterization (PTB)

Metrology to Assess the Durability and Function of Engineered Surfaces

Vacuum metrology for production environments (PTB)

Thermal design and time-dependent dimensional drift behaviour of sensors, materials and structures (PTB)

New generation of frequency standards for industry

Traceable quantitative surface chemical analysis for industrial applications

Metrology for ultrafast electronics and high-speed communications (PTB)

Metrology of small structures for the manufacturing of electronic and optical devices (PTB)
(PTB Coordinator: R. Schwartz)



8 Deutsche Akkreditierungsstelle GmbH **(8 German Accreditation Office LTD.)**

Division 5 | Metrology

REGULATION (EC) No 765/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 9 July 2008

setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93

Scope:

- ➡ All kinds of CABs:
Calibration and testing laboratories, certification bodies, etc. related to the New Approach directives
- ➡ Explicitly excluded:
Products related to food law, medicinal products, blood, tissue and cells
- ➡ Accreditation in both the regulated and voluntary area is covered

Deutsche Akkreditierungsstelle GmbH

- What has been achieved? **GmbH Foundation**

- Private limited liability company (GmbH)
- Merger of a number of private accreditation companies (TGA / DAP / DACH) to DGA GmbH in September 2009
- Foundation of DAkkS (at first 100% Federal corporation) in October 2009
- **Transfer of DKD into DAkkS on 17 December 2009**
- Merger of DAkkS and DGA GmbH on 23 December 2009
 - Corporation partners: 2/3 Federal Republic of Germany and 1/3 Federation of German Industries (BDI)
- 2 General managers

DAkkS provides accreditation in the following fields:

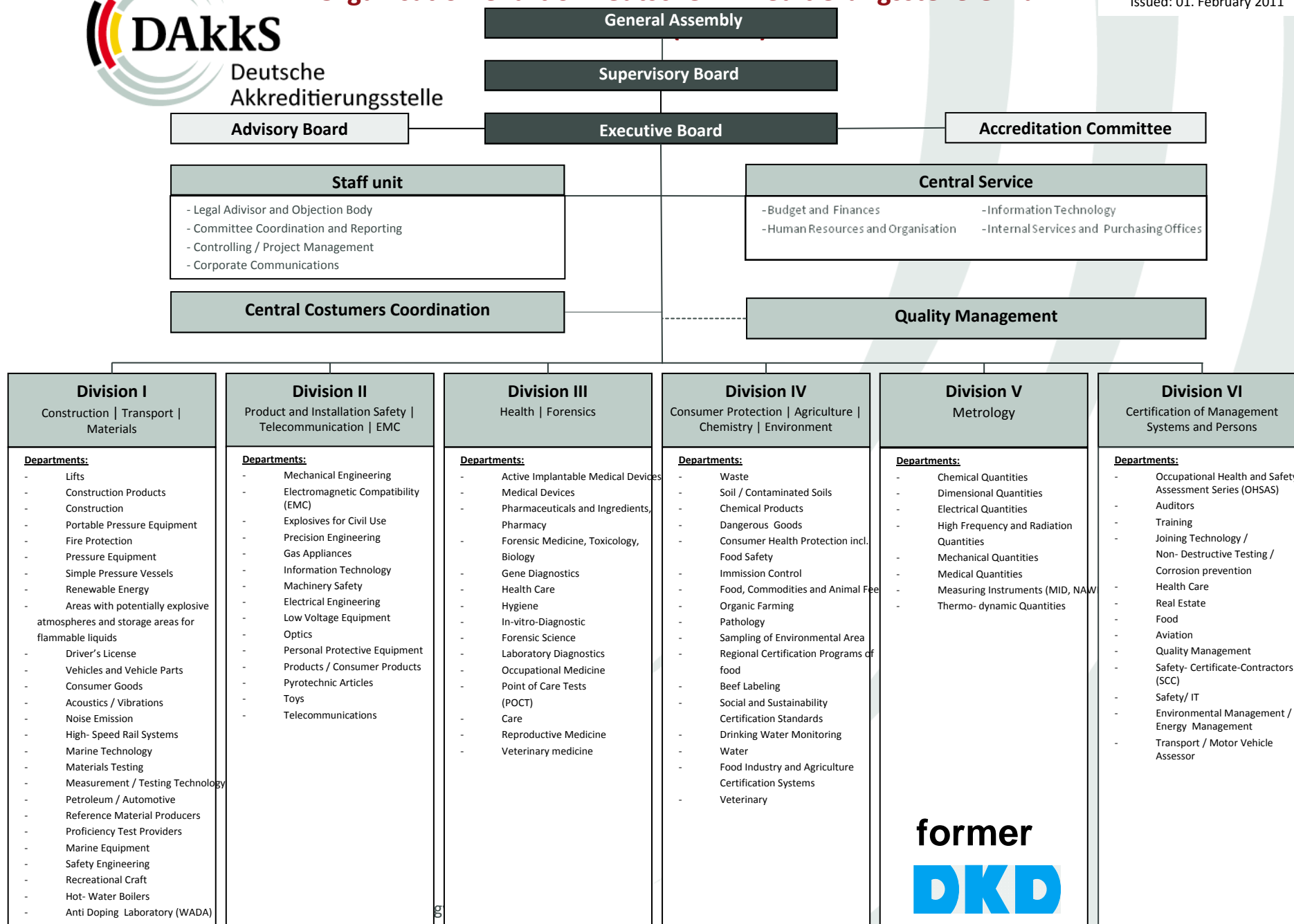
- Calibration laboratories
- Testing laboratories
- Medical laboratories
- Inspection bodies
- Certification of products
- Certification of management systems
- Certification of persons
- RM producers
- PT providers



Deutsche
Akkreditierungsstelle

Organisation Chart of Deutsche Akkreditierungsstelle GmbH

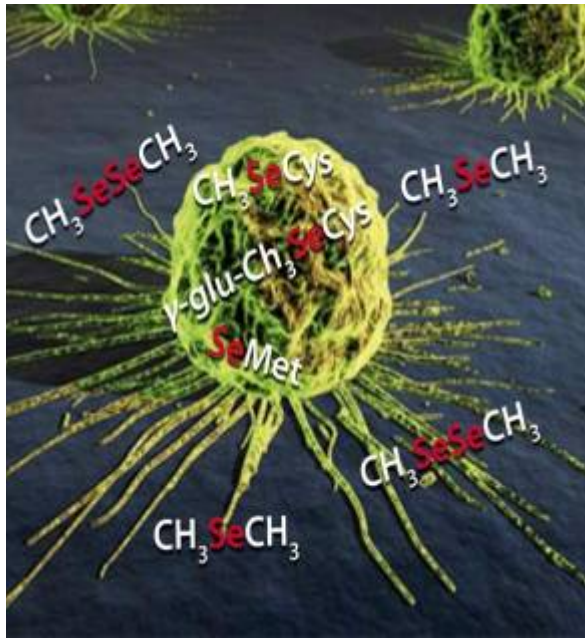
Document 42.1. SD 003
Issued: 01. February 2011



Main Tasks of Division 5

- Accreditation in the field of Calibration and Metrology
- Assessment of notified bodies in accordance with MID (2004/22/EC) and NAWID (2009/23/EC), notifications are performed by the BMWi

**Continuation of the work started by DKD,
Cooperation with PTB (the NMI of Germany)**



Thank you !