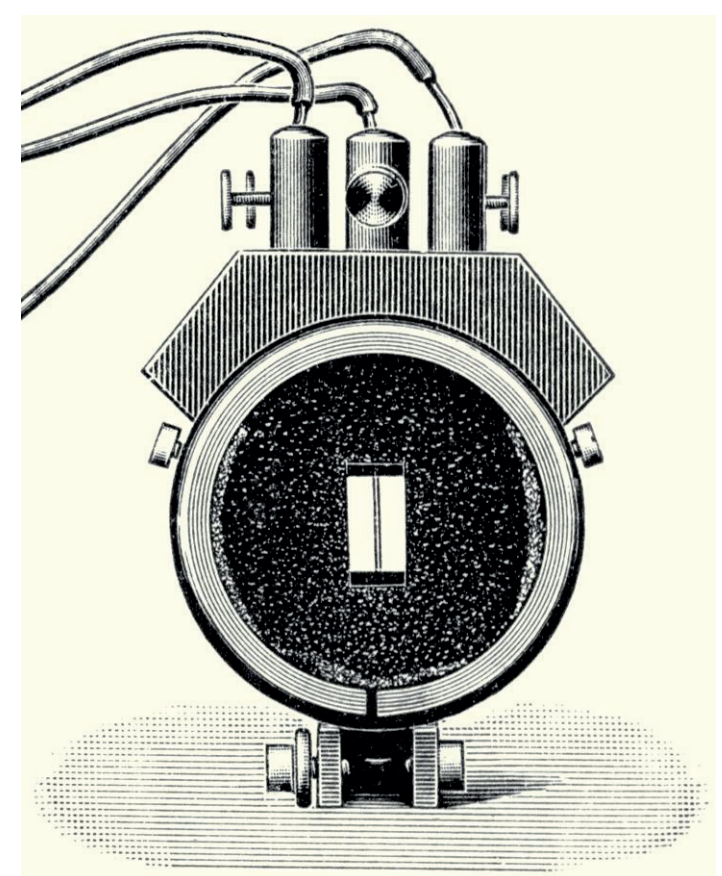


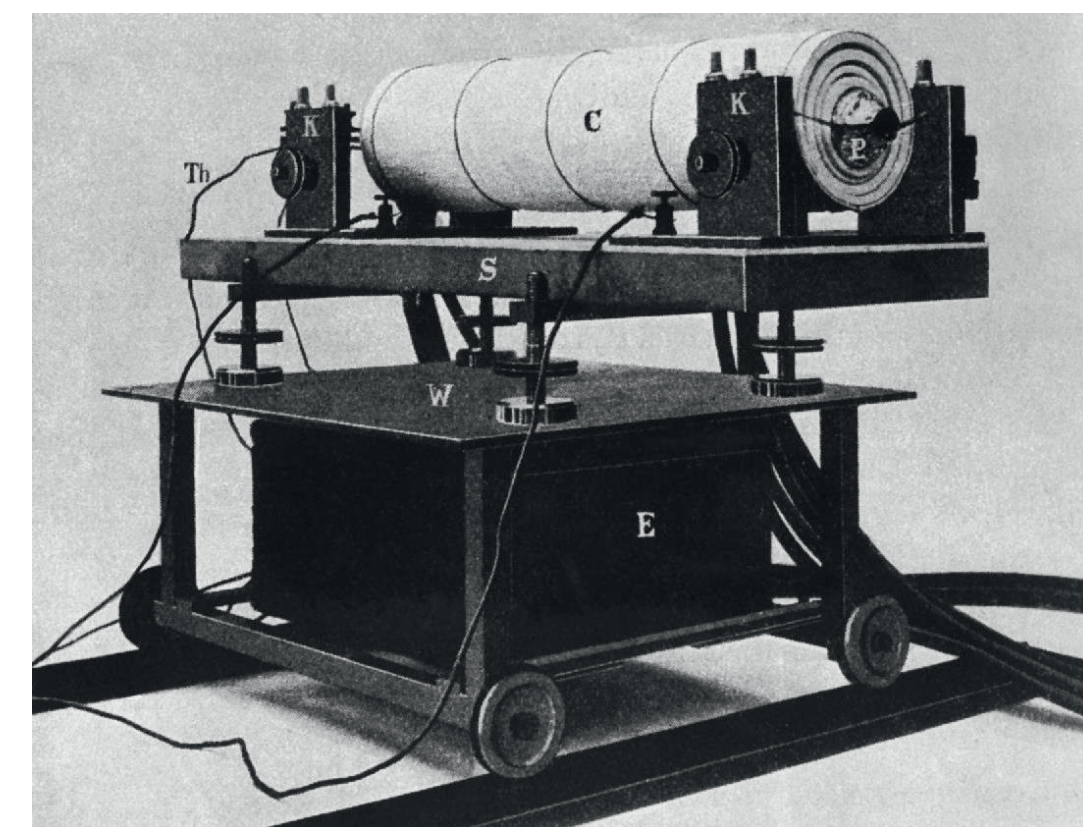
Radiation thermometry at PTB – A success story of the realisation of Planck's radiation law at the edge of feasibility

History of Radiation Thermometry at PTB

The predecessor of PTB, the Physikalisch-Technische Reichsanstalt, was founded in 1887 as one of the world's first national metrology institutes. Just one year later scientists at the PTR started to work in the field of photometry.

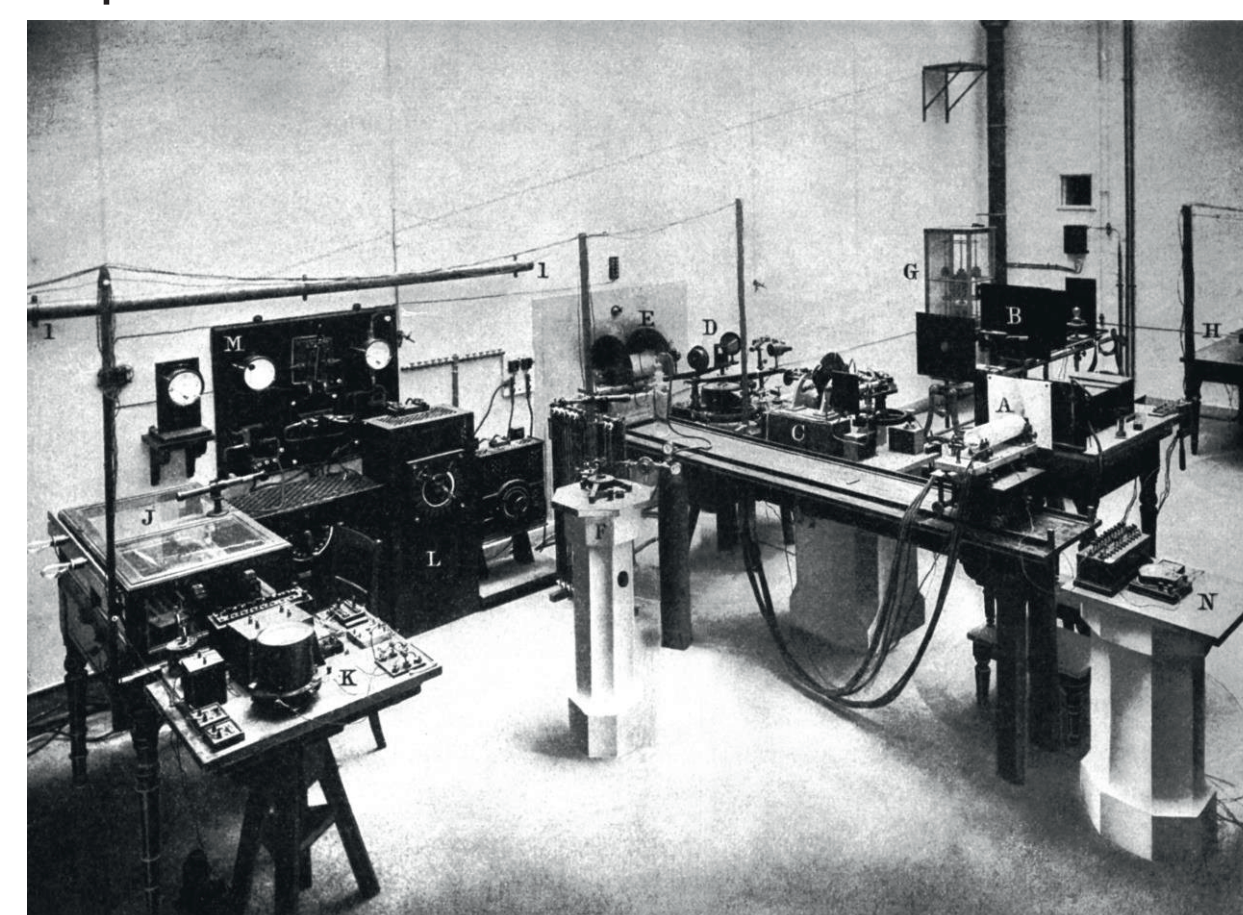


Linear bolometer (1899)
O. Lummer, E. Pringsheim, VhDPG 1, 23-41

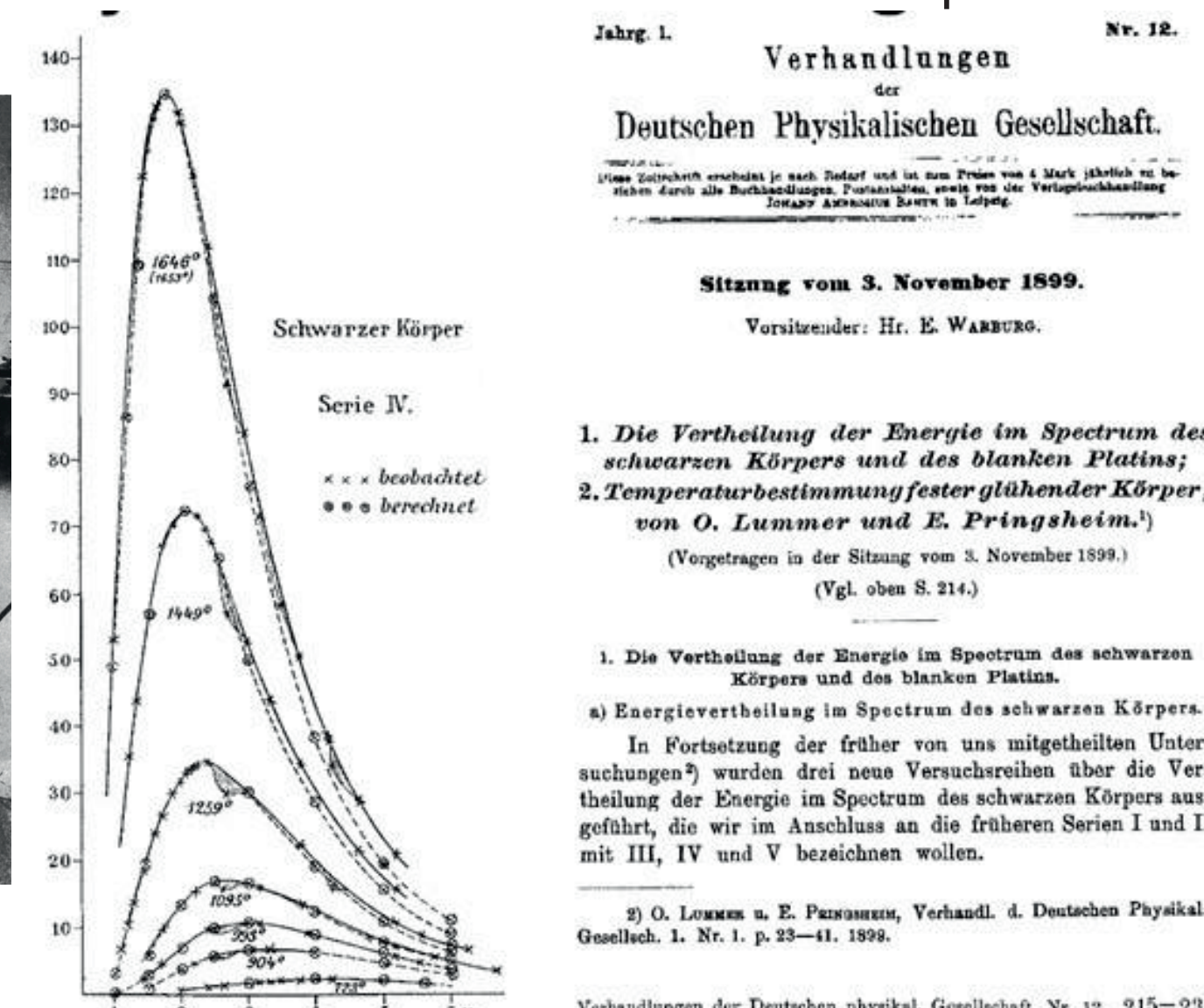


Lummer and Kurlbaum (1898) develop a "handy laboratory apparatus" for generating black radiation, the electrically annealed cavity radiator. VhDPG 17, 106-111

Research in this field was driven by scientific questions that arose with the introduction of electric lighting. This work led to the development of the electrical substitution radiometer in 1892, and the application of **isothermal electrically heated shallow bodies** as radiation sources based on Kirchhoff's law in 1895. This type of blackbody could be operated at temperatures up to 1600 °C. Using the results obtained with these instruments, **Wien's radiation law** was formulated in 1895. However, precise spectral measurements by Rubens and Kurlbaum using the Reststrahlen method showed discrepancies between Wien's law and the results of the measurements. Based on these findings Max **Planck** formulated his famous radiation **law** in 1900. This law is not only seen as the foundation of quantum mechanics, but it is also still used to realise "temperature" radiation and to realise and disseminate radiometric and photometric quantities.



Laboratory for radiation thermometry at the PTR around 1900.



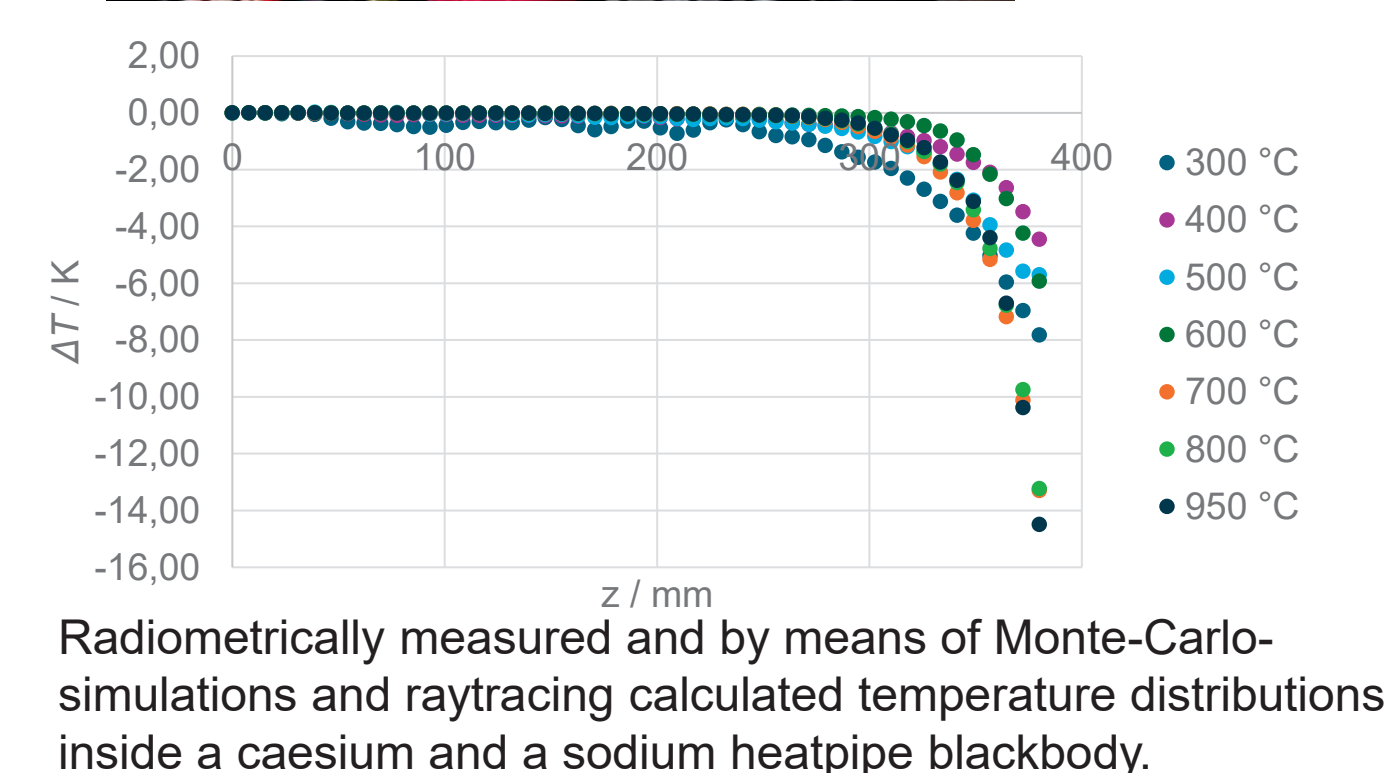
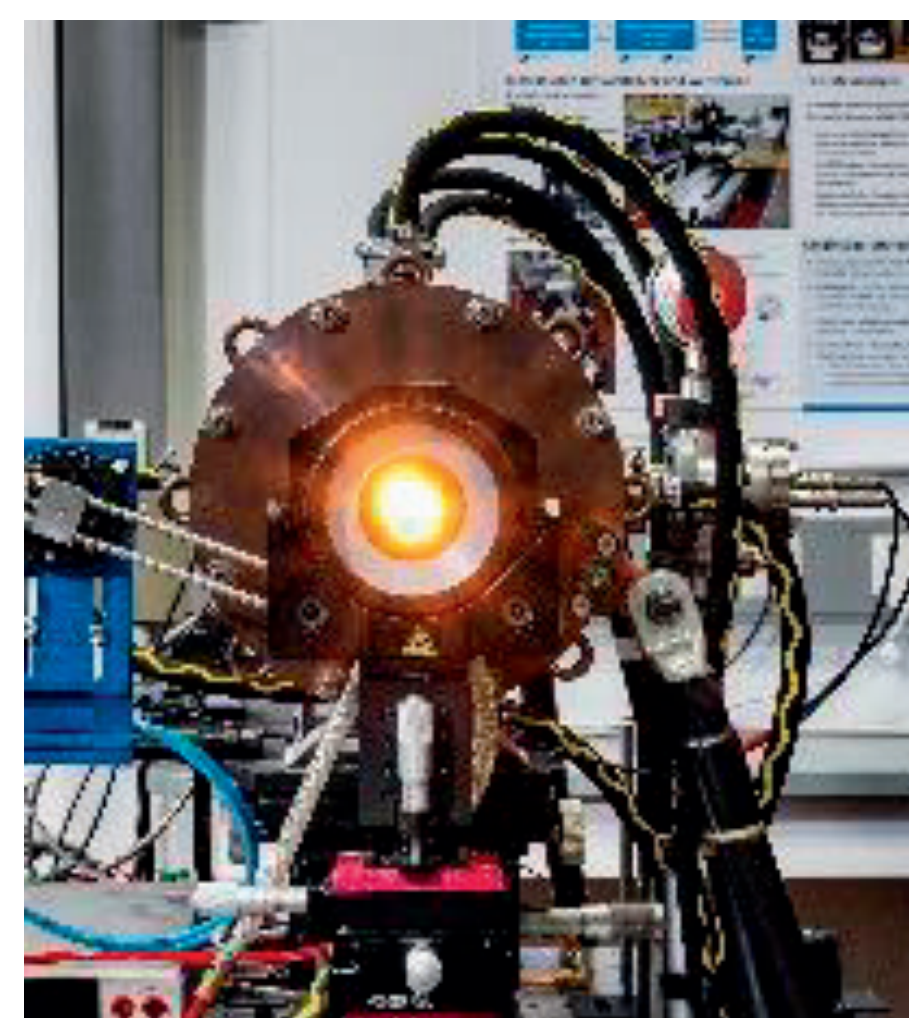
Today, based on Planck's law of radiation, PTB provides **full traceability** of non-contact temperature measurement to the International Temperature Scale (ITS-90) without gaps over a **temperature range** from **-170 °C to 3000 °C** and a **spectral range** from **200 nm to 200 μm**.

Current Calibration Capabilities

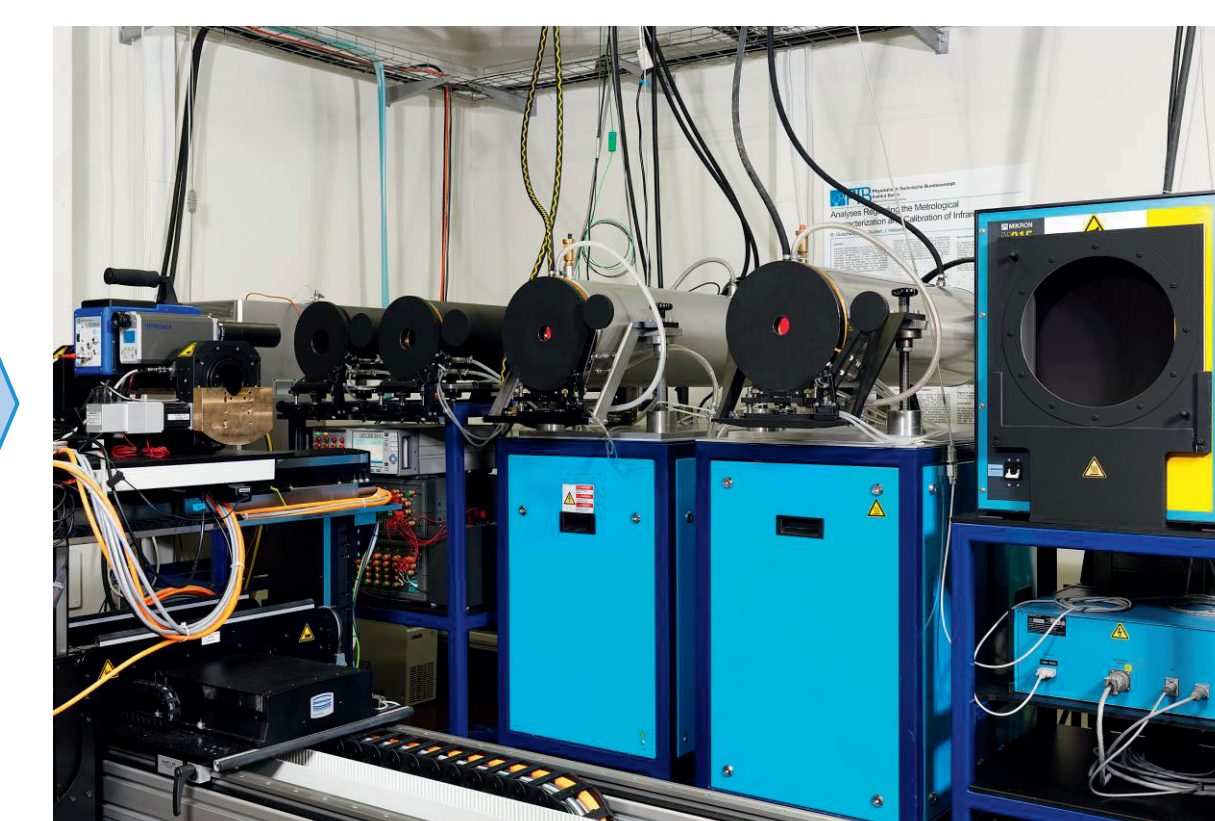


The **Reduced Background Calibration Facility** is operated for remote sensing and earth observation applications. In this facility, radiation temperatures down to **-170 °C** can be achieved and the environmental conditions can be precisely tailored to meet the requirements of ground-, air-, and spaceborne applications.

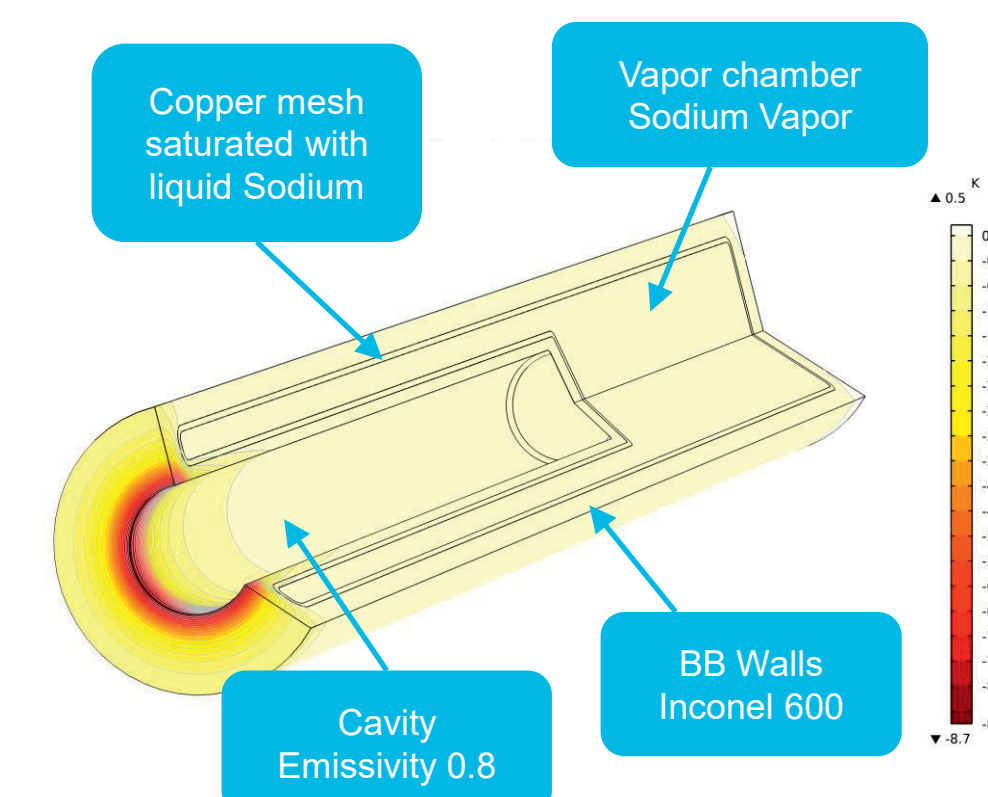
In the temperature range from **-60 °C up to 962 °C**, **heatpipe blackbody**-based calibration facilities are operated that allow for measurements with the lowest uncertainties over the full temperature range.



These facilities are **well characterised** and understood by means of **thermal modelling** of the temperature distributions inside and outside the radiation sources. The optical properties of these radiation sources are obtained from a **combination of radiometric measurements** of their thermal properties to support the thermal modelling results and simulation of their effective emissivities for different measurement conditions by **raytracing** and **Monte-Carlo simulations** based on **precise emissivity measurements** of all wall materials.

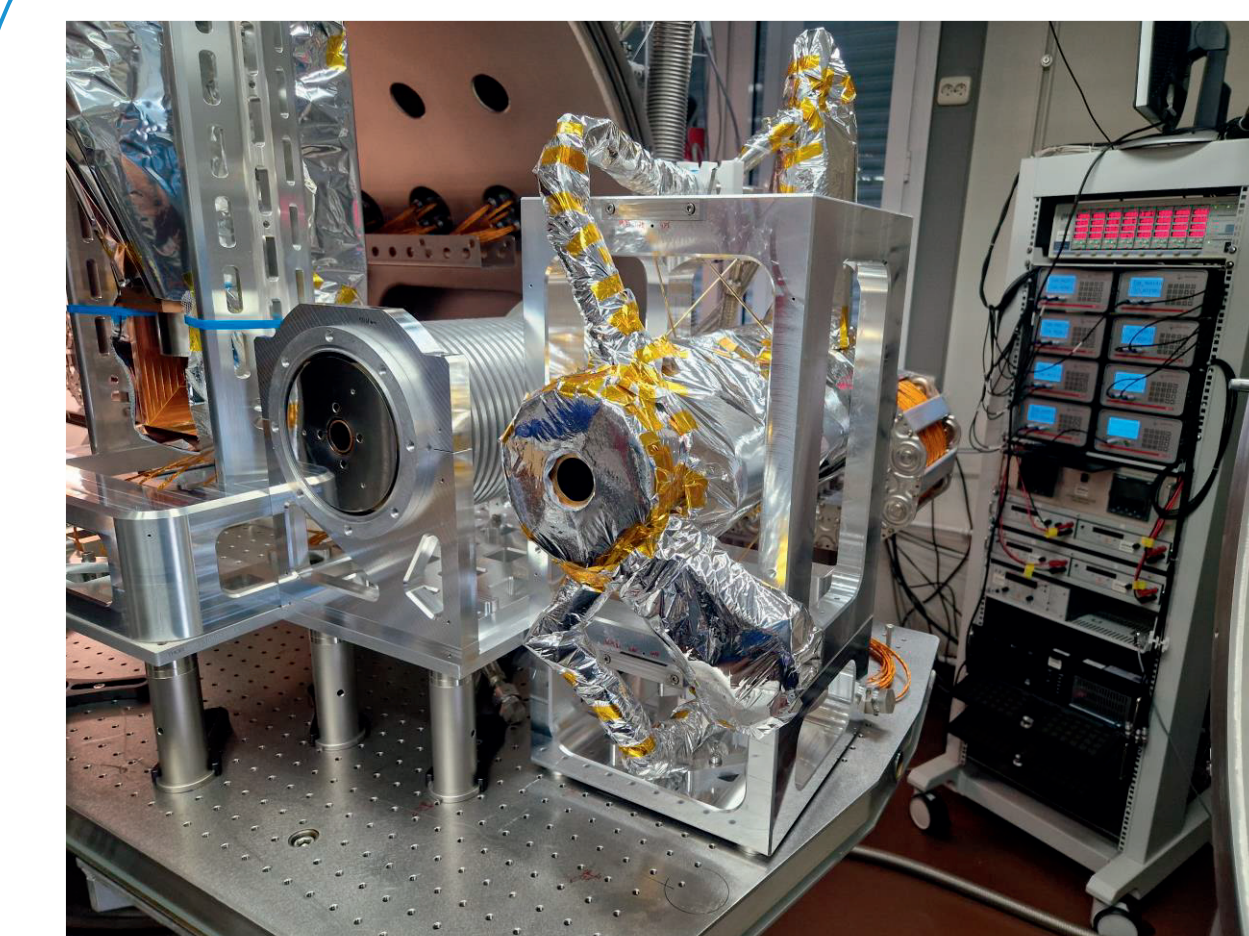


Temperatures **above 962 °C** are realised and disseminated by high-temperature **blackbodies** and several high-temperature **fixed-points**.



FEM-simulation of the temperature distribution inside a sodium heatpipe blackbody at 1000 K. FEM-results and radiometric results agree well within their combined uncertainties.

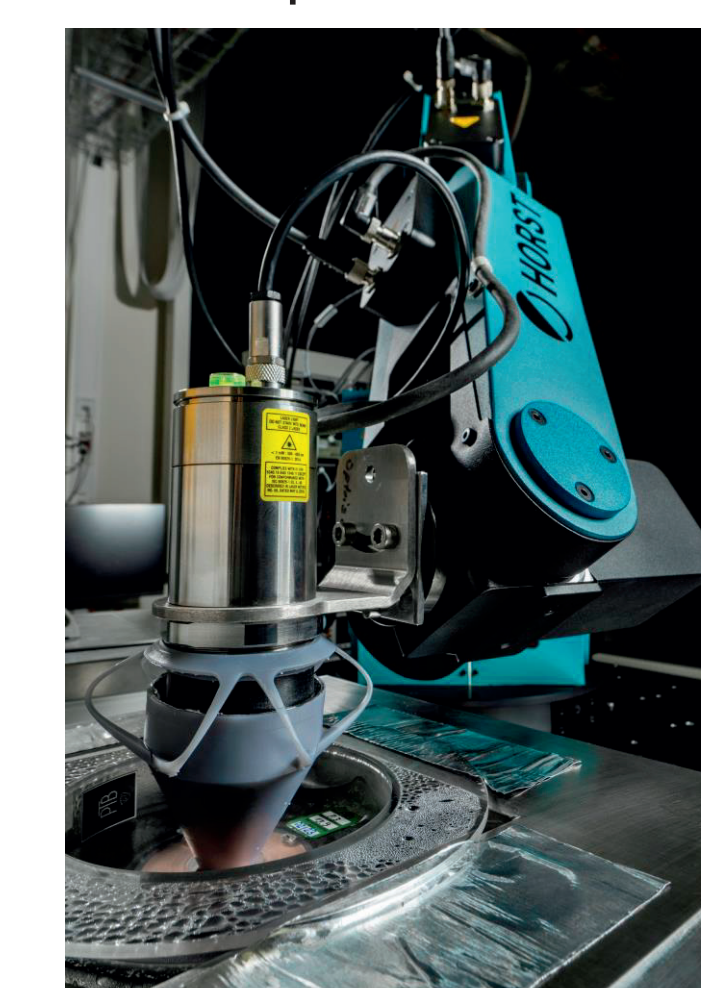
Recent and Current Challenges in Radiation Thermometry



The new **variable temperature blackbody** of the Reduced Background Calibration Facility can be operated from **-80 °C up to 80 °C** with combined standard uncertainties $u(k=1) \leq 15$ mK.

Recent and current challenges in radiation thermometry are diverse and include:

- The development of **high-temperature fixed-points** for temperatures **above** the freezing point of **copper**
- The development of **user-specific methods** for traceable industrial high-temperature radiation thermometry, e.g. for aerospace industry, metal manufacturing, and additive manufacturing
- **Digitalization** and automation in thermometry
- Thermometry for **health applications** and pandemic prevention
- ...
- The provision of traceability for **remote sensing** and **Earth observation** applications such as the monitoring of **Essential Climate Variables (ECVs)**, which require an unrivalled low level of uncertainty.



Fully automated calibration facility for tympanic thermometer blackbodies and automatic compilation of **Digital Calibration Certificates (DCC)**

Using Planck's law of thermal radiation, the **thermodynamic temperature** of blackbody cavity radiators can be determined by applying **radiation detectors absolutely calibrated for their spectral sensitivity**

