Physikalisch-Technische Bundesanstalt

… the National Metrology Institute of Germany

Bundesministerium für Wirtschaft und Energie

The Physikalisch-Technische Bundesanstalt, Germany's national metrology institute, is a scientific and technical higher federal authority falling within the competence of the Federal Ministry for Economic Affairs and Energy.

Fundamental Constants

Metrology

Metrology:

- Science and application of correct measurement
- Traceability of results to the SI through national standards
- Determination of results with verification of uncertainty

PTB:

- National Metrology Institute (NMI)
- Federal Ministry of Economics and Technology (BMWi)
- 170 Mio. € budget, plus third party funding
- Approx. 1300 permanent staff and 550 non-permanent staff including 110 PhD students
- 600 scientific papers per year

PTB locations

Braunschweig

Berlin-Charlottenburg

MLS and PTB-Labor at BESSY II
Berlin-Adlershof

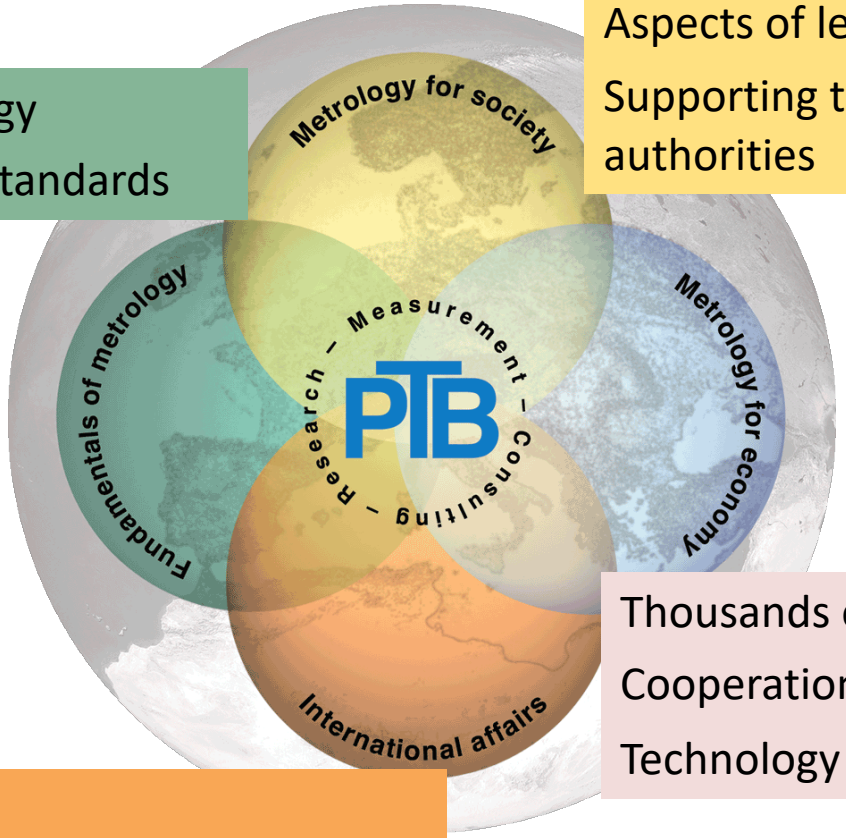
Fields of activity

Basic research for metrology

Improvement of national standards

Aspects of legal metrology

Supporting the verification authorities



Thousands of calibrations per year

Cooperation projects with industry

Technology transfer

Technical cooperation

International representation of Germany in metrology related issues

What characterizes PTB?

PTB is not *a typical government agency*:

- 60 % research / development
- 30 % calibration / services
- 10 % consulting / cooperation in bodies

PTB is not *a typical research institute*:

- Constitutional mandate – ensuring uniformity of metrology in Germany
- Cutting-edge research required as inherent part of PTB's duties
- Many tasks are mandated by law.

PTB forms an essential part of the scientific and technical infrastructure of Germany

International Cooperation

Harmonizing metrology, removing trade barriers

- **Worldwide Metrology**

  Cooperation with metrology institutes, international comparisons
  CIPM-MRA, OIML-MAA, WTO-TBT

- **Large-scale Projects**

  e.g. EMRP/EMPIR, Galileo

- **Collaboration in international committees**

  Meter Convention,
  legal metrology,
  standardisation bodies

- **Technical Cooperation**

  Support of developing and threshold countries (49 projects in 81 countries)

PTB Organisation Chart

Presidential Board

Presidential Staff

Press and Information Office

Certification centre

QUEST-Institute at PTB

Mechanics and Acoustics

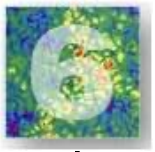
Electricity

Chemical Physics and Explosion Protection

Optics

Scientific-technical Cross-sectional Tasks

Precision Engineering



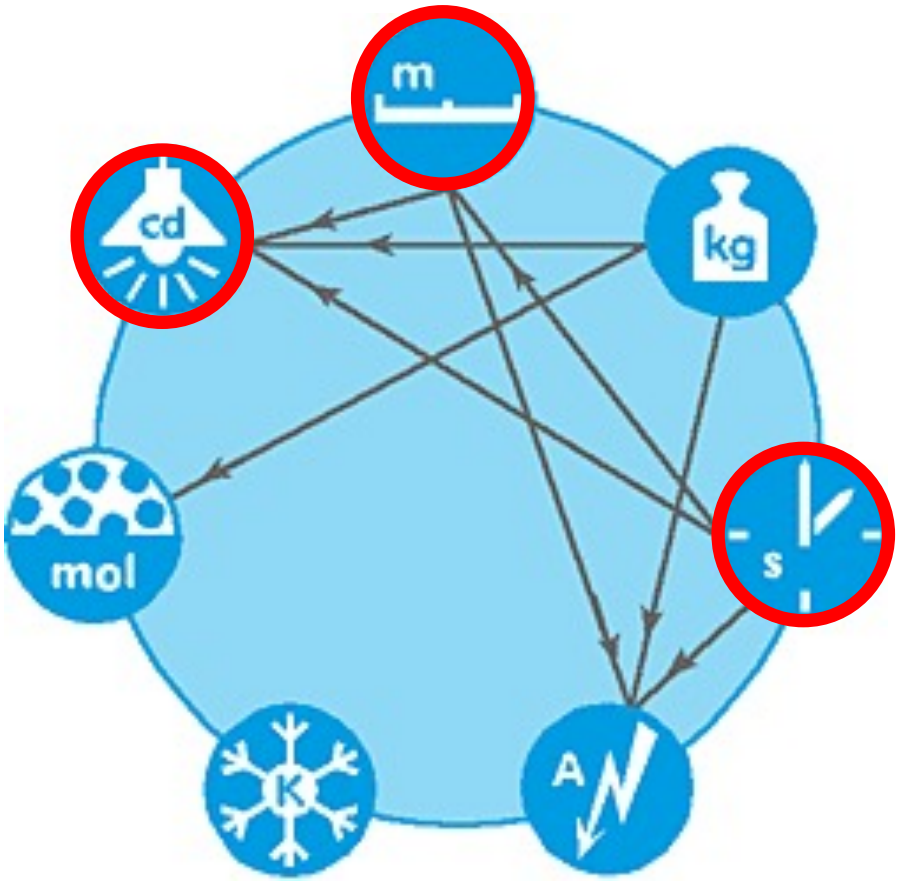
Ionizing Radiation

Temperature and Synchrotron Radiation

Medical Physics and Metrological Information Technology

Administrative Services

SI-Units



- **Research**
  Fundamental research in the field of metrology, e.g.
  - SI units traceable to fundamental constants and constants of nature
  - Quantum effects for the realization of the units
- **Primary standards**
  - Development
- **Secondary and transfer standards**
  - Dissemination of units

Working Group 4.52 Solar Cells

Tasks

Characterization and calibration of solar cells, photometers and (filtered) radiometers in uniform radiation fields within the wavelength range from 210 nm to 4.0 µm.

Fields of work

- Measurement techniques for photovoltaics (DSR- and LaserDSR-setup)
- Calibration of reference solar cells under user defined test conditions
- Calibration of large area photometers and (filtered) radiometers

Research

- Improvement of measurement procedures for solar cells and large area detectors
- Convergence of indoor and outdoor measurements
- Advanced calibration methods for solar modules
- Laboratory calibration of Multijunction space solar cells with lowest uncertainties

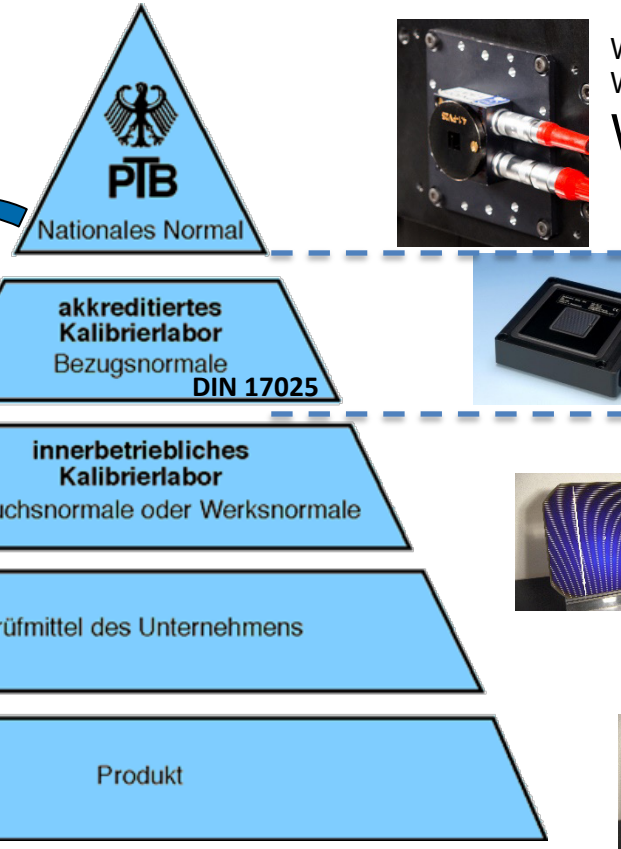
Projects

- Third-party projects with industrial partners
- European projects about Energy Rating (coordination) ,
  Space solar cell calibration
- Sun spectrum measurement with highest resolution for ozone column determination

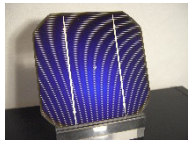
Traceability Photovoltaics

spectral methods

Sun-simulators



WG 7.33
WG 5.34
WG 4.52



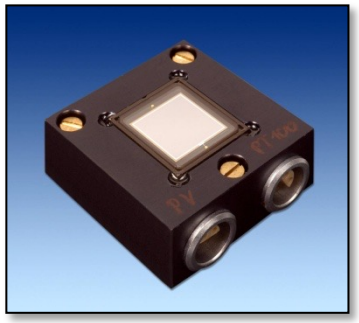
U_{rel} (%) (k=2)

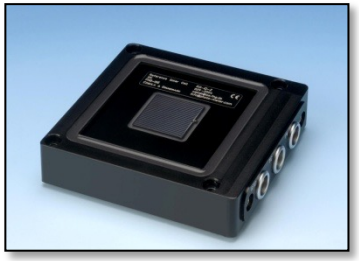
0.4 % – 0.6 %

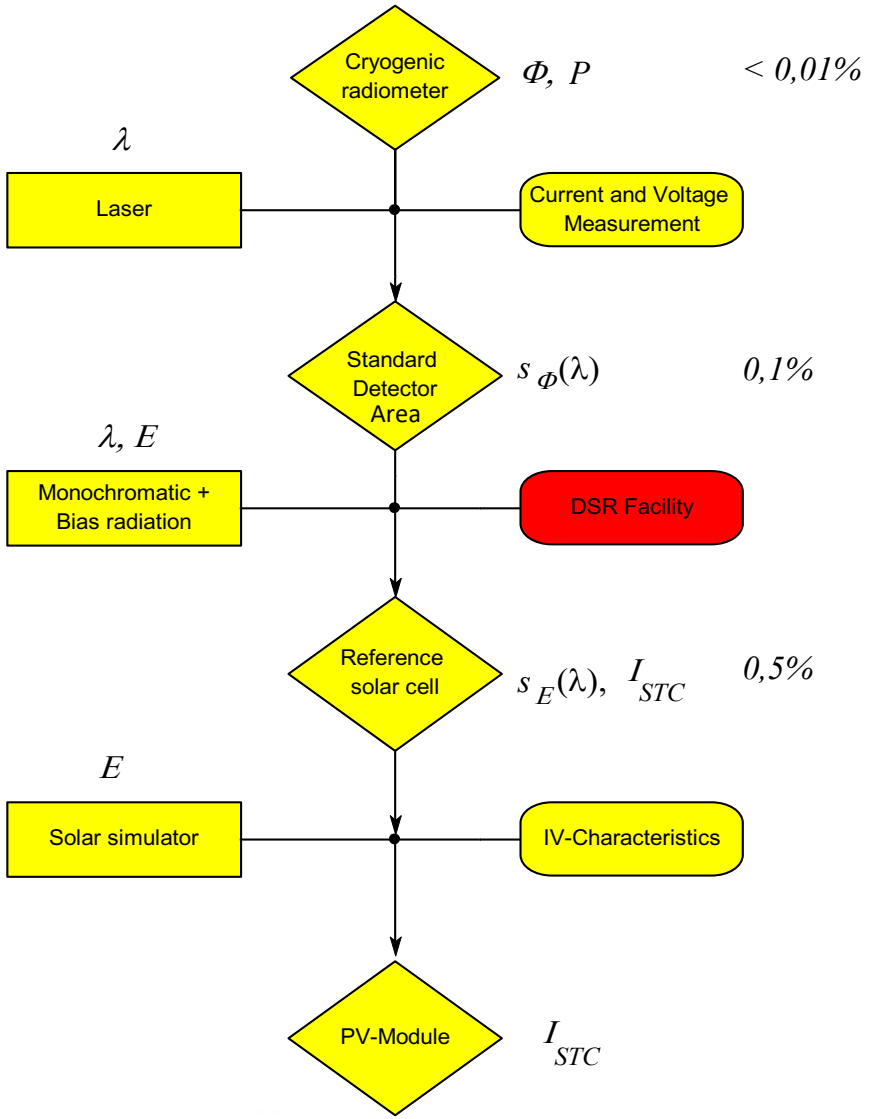
1.7 % - 3 %

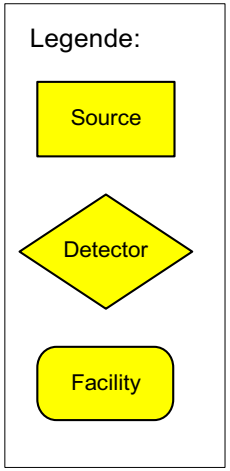
3 % – 5 %

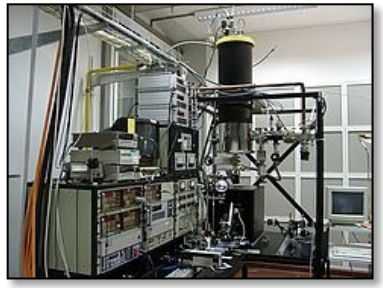
PV calibration Chain

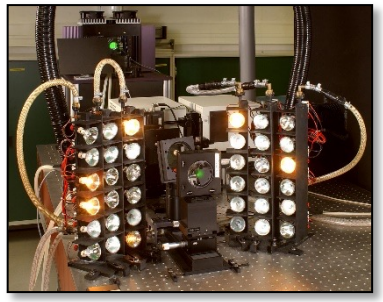




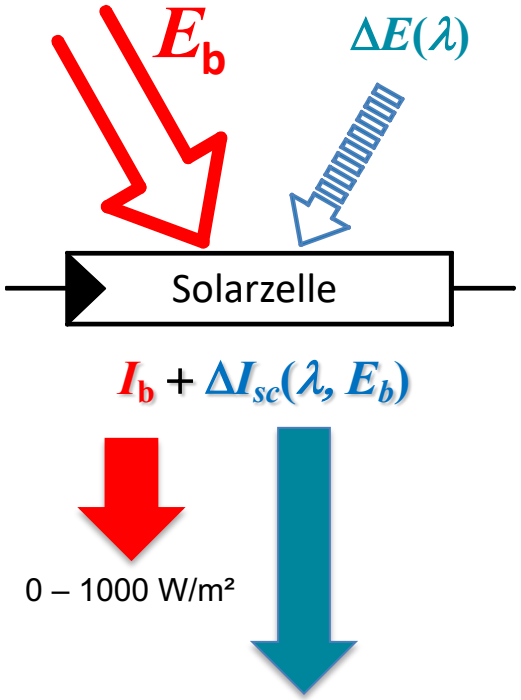


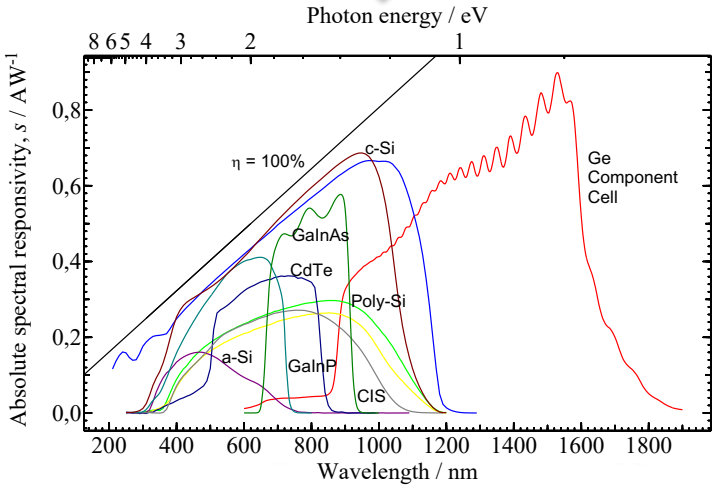






DSR-method of PTB

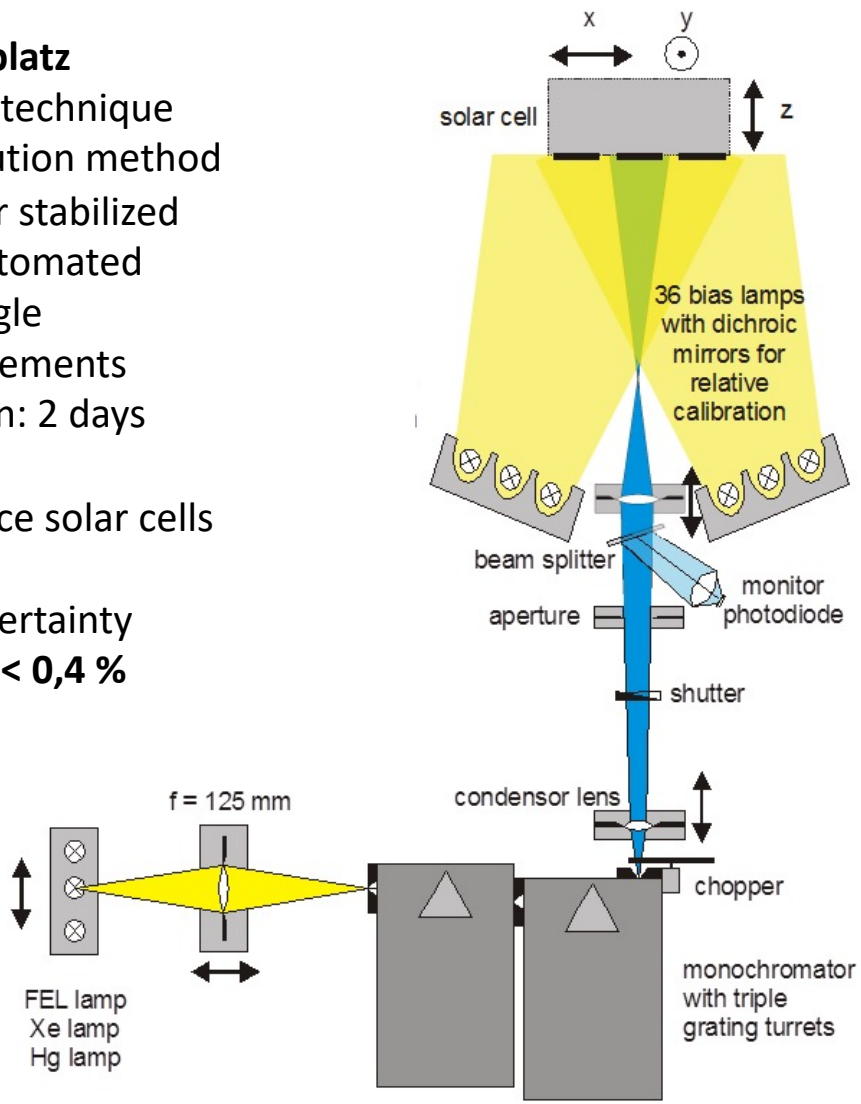




DSR-Messplatz

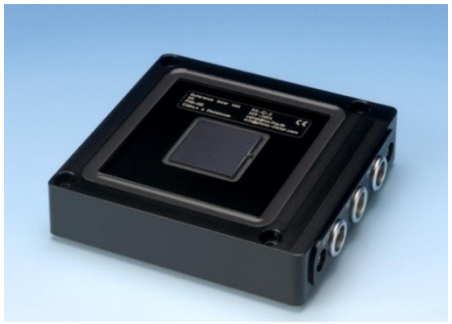
- Lock-In technique
- substitution method
- monitor stabilized
- fully automated
- 160 single measurements
- duration: 2 days

- reference solar cells 2x2cm²
- rel. uncertainty $U(I_{STC}) < 0{,}4\ \%$



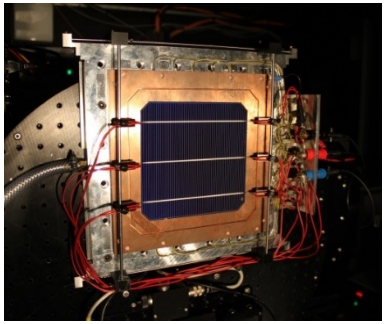
Calibration Objects

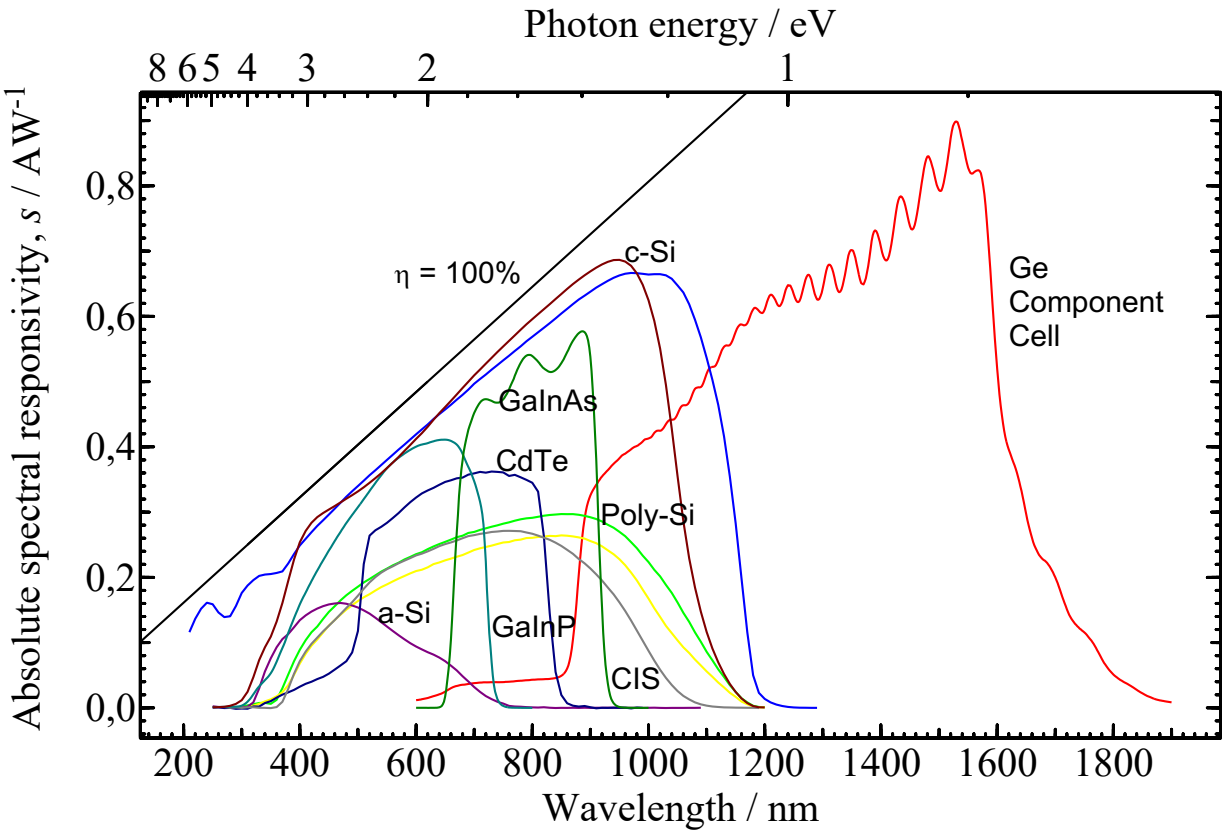
Reference solar cells



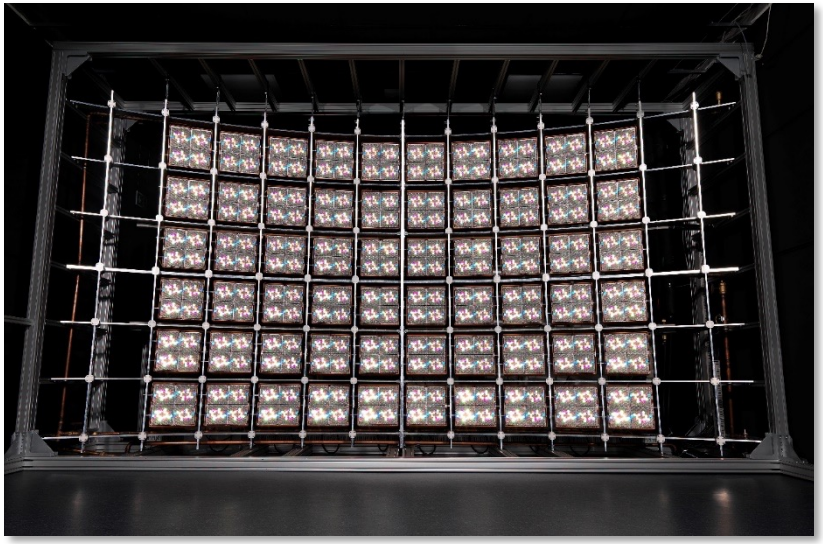
Component solar cells

Industry solar cells





Competence Centre for PV Metrology



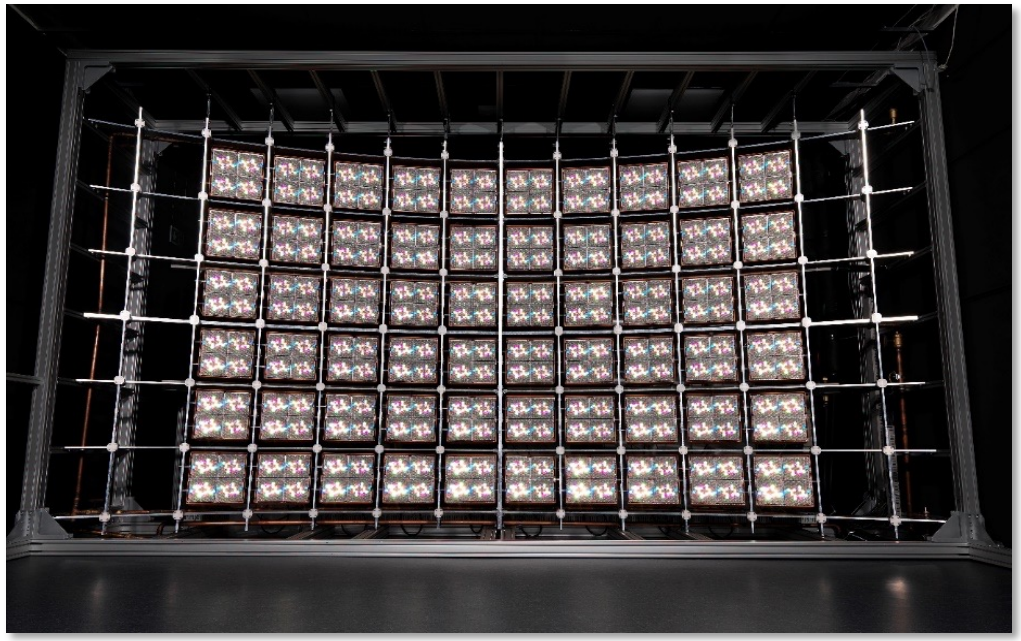
LED-based module sun simulator with over 16,000 high-power LEDs for energy rating

Measurement facility under construction for the world's most accurate module calibration (power and angle dependence)

LED-based solar simulator

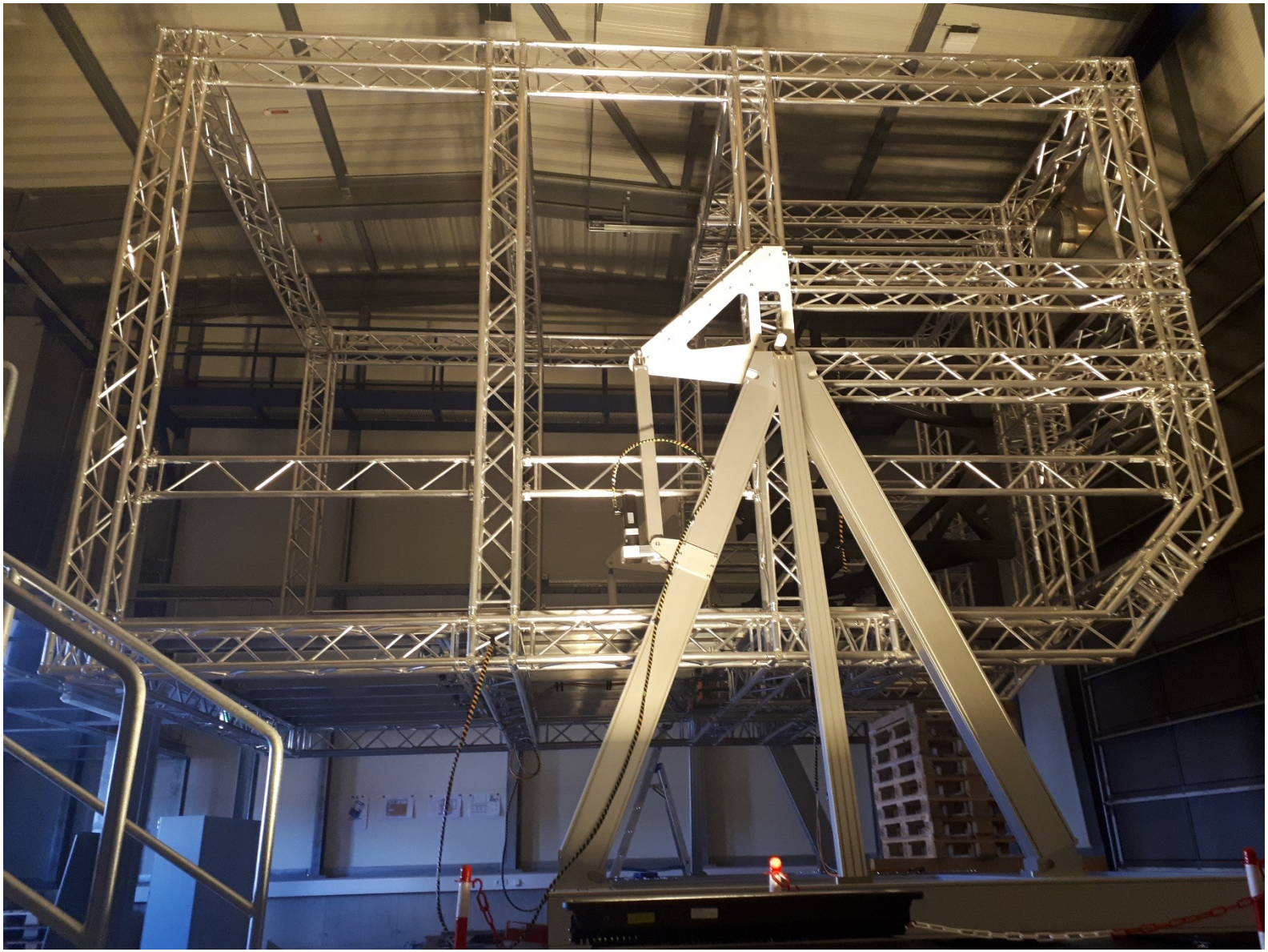
LED-based solar simulator for solar module calibration

- 16.320 LEDs
- 18 different colors
- Area of LEDs: 2.4x4.7 m²
- Measurement area: 2x1 m²
- Module can be rotated computer controlled for bifacial modules
- Will be combined with a climate chamber with front and backside shutter for bifacial modules



=> Not only standard test conditions can be realized, but any spectrum (daily course, cloudy weather) for energy rating

Solar mobule tube



Solar mobule tube

Solar module tube

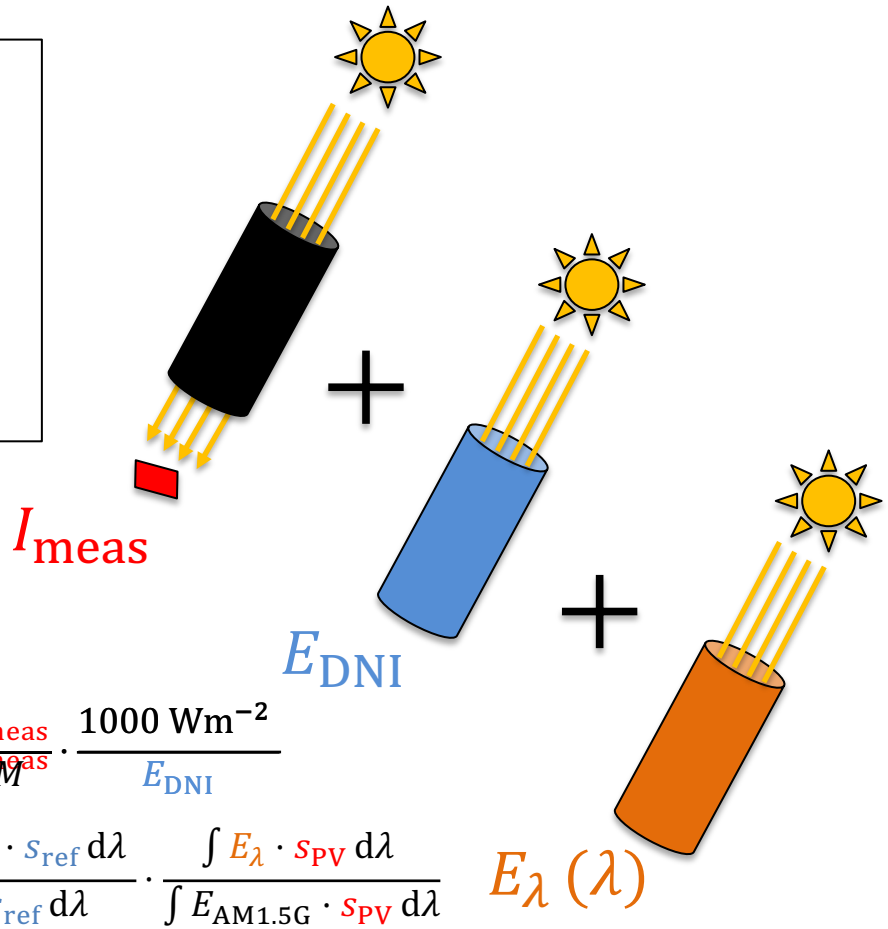
- Measurement area: 2.4 x2.4 m^2
- Module can be rotated computer controlled
- Climatization will be included
- Monitoring of solar irradiance and the solar spectra is needed

Advanced direct sunlight method

Outdoor calibration why?

IEC 60904-4:
Independent primary calibration of reference solar cells with sunlight

- Internal comparision with the indoor methods
- Lowering the uncertainty through combination of two methods
- Upscaling for solar modules possible



Reduction of short circuit current to standard test conditions:

- Irradiance to 1000 $\mathrm{Wm^{-2}}$
- Spectral irradiance to AM1.5G-spectrum

$$I_{STC} = \frac{I_{meas}}{M} \cdot \frac{1000\ \mathrm{Wm^{-2}}}{E_{DNI}}$$

$$M = \frac{\int E_{AM1.5G} \cdot s_{ref}\,d\lambda}{\int E_\lambda \cdot s_{ref}\,d\lambda} \cdot \frac{\int E_\lambda \cdot s_{PV}\,d\lambda}{\int E_{AM1.5G} \cdot s_{PV}\,d\lambda}$$

Quelle: IEC 60904-4:2009: Reference solar devices – Procedures for establishing calibration traceability

instrumentation

1) Solar cell – I_{meas}

2) Camera

3) Absolute Cavity Radiometer (PMO 6) – E_{DNI}

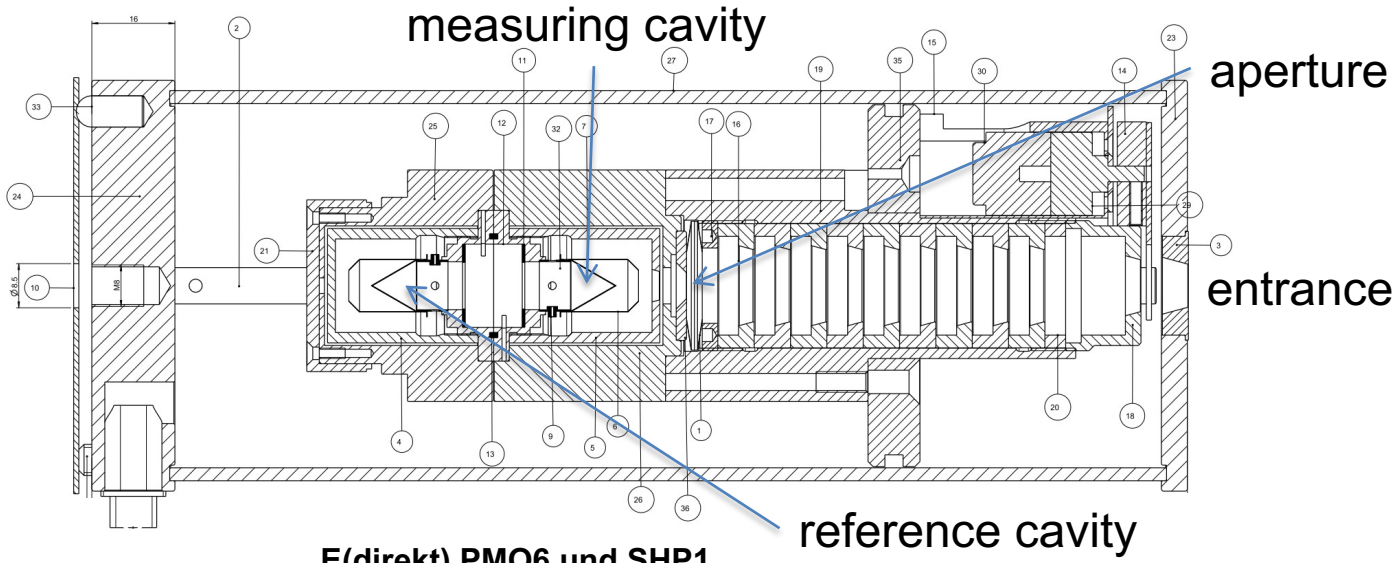
4) Pyrheliometer (SHP 1) – E_{DNI}

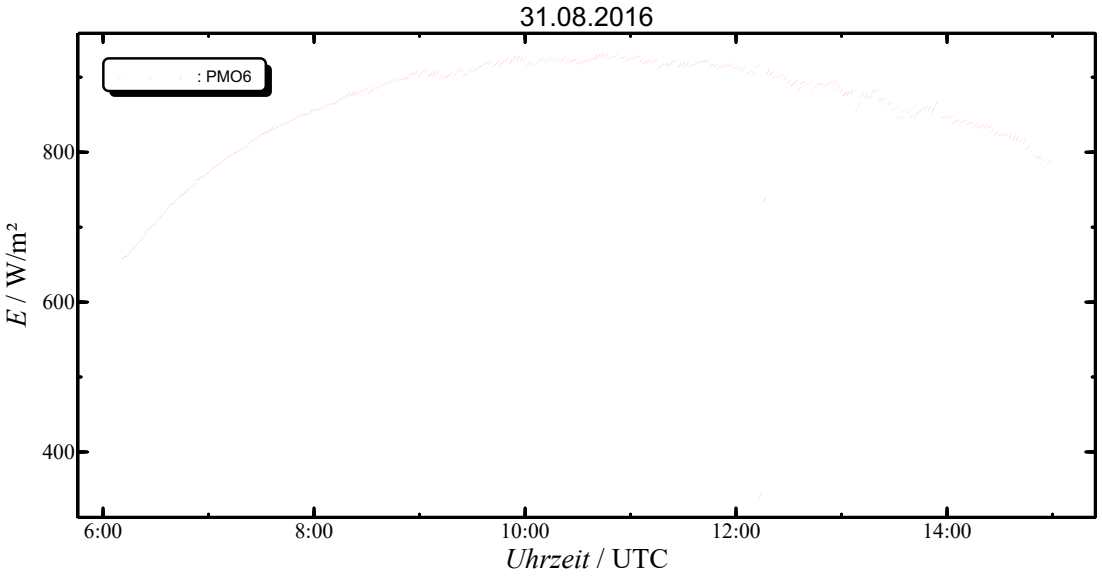
5) CCD-Spektrometer (CAS 140 CT) – E_{λ}
280 - 1650 nm

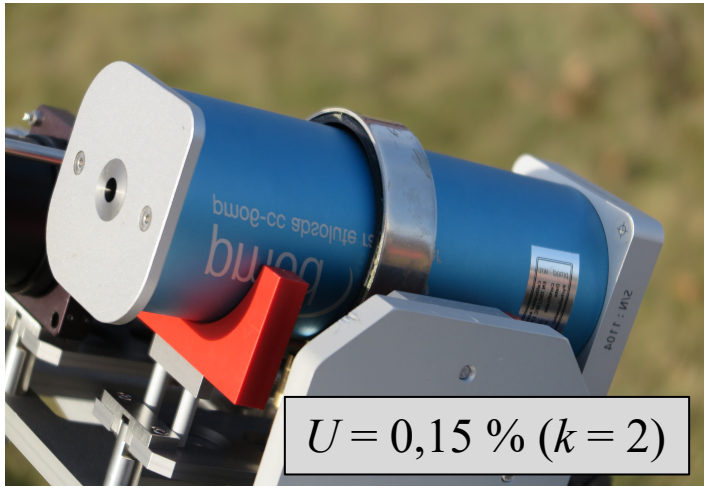
6) FT-Spektrometer (Bruker Vertex 80) – E_{λ}
750 - 2500 (4000) nm

7) Angular sensor

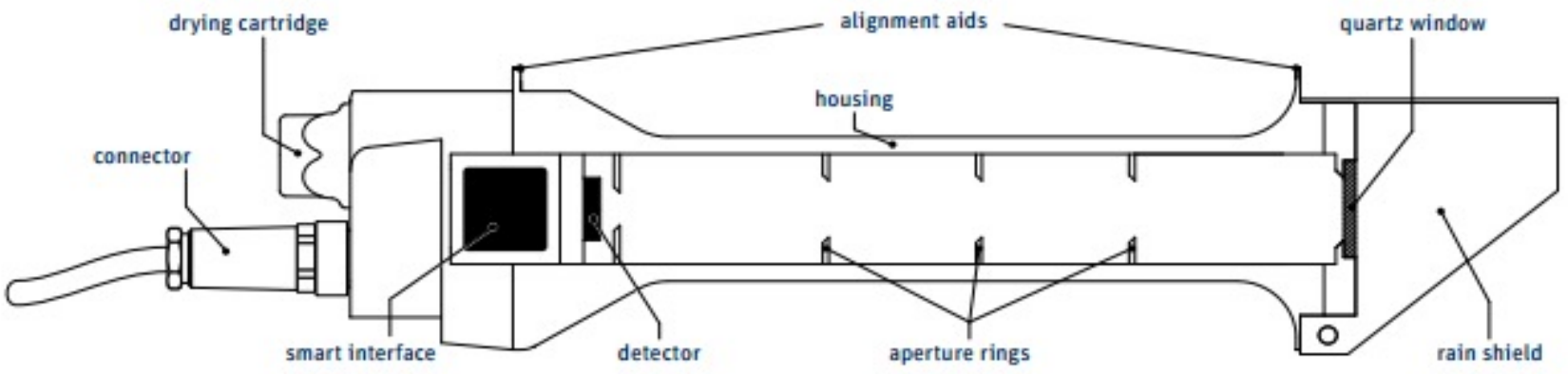
Absolut Cavity Radiometer





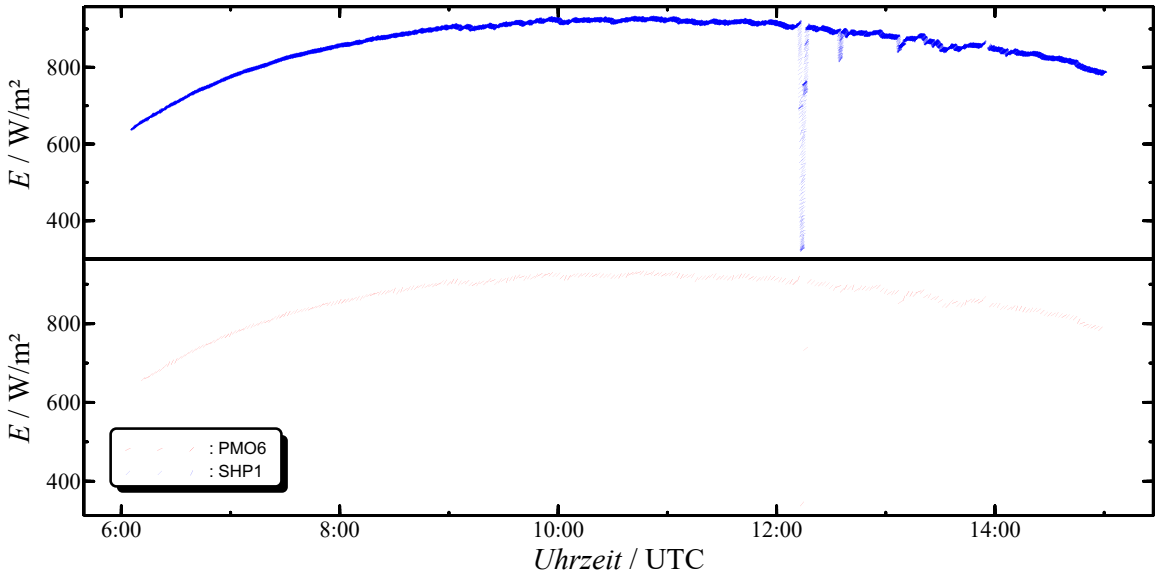


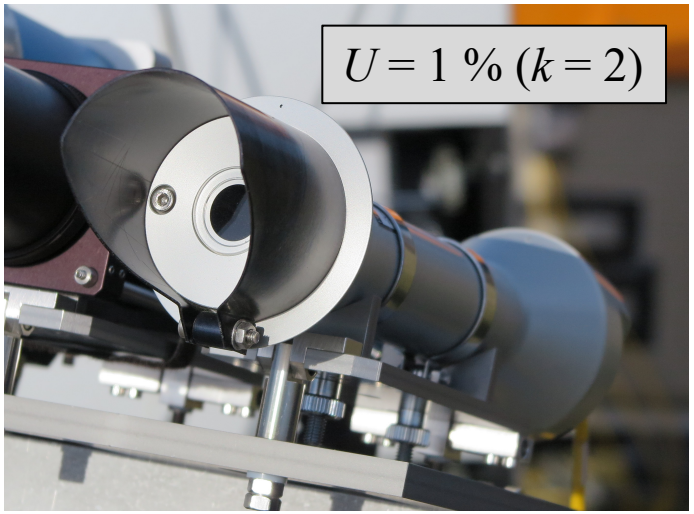
Pyrheliometer



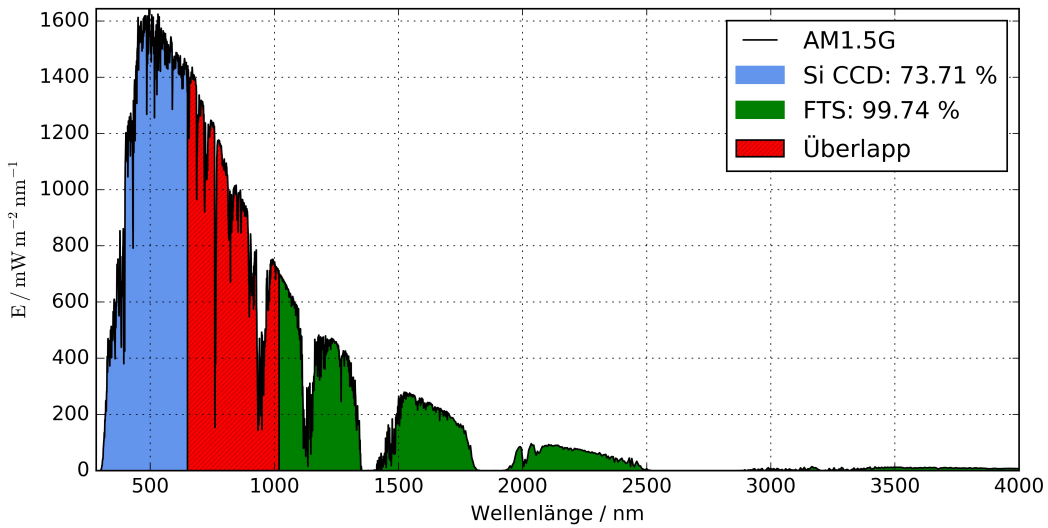
E(direkt) PMO6 und SHP1

31.08.2016





Spectral irradiance measurement

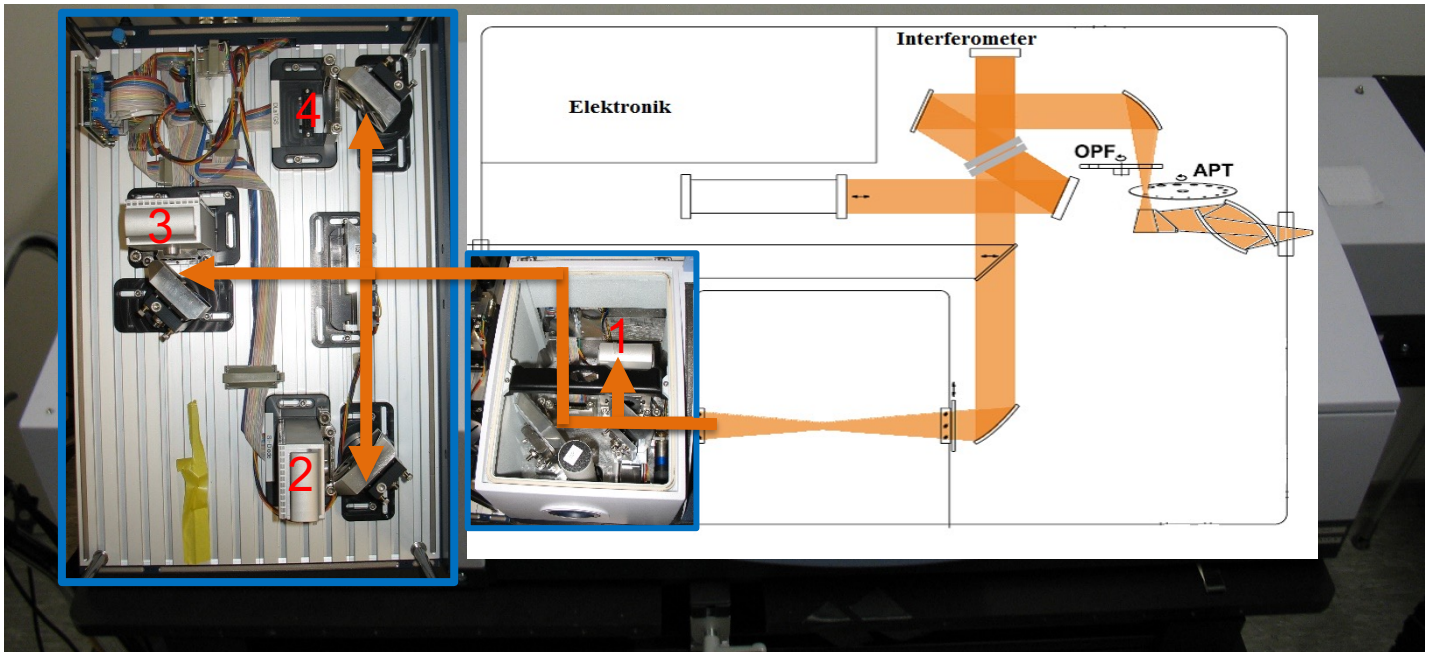


option 1:
Using three ccd-spectrometersmeters up to 2150 nm

option 2:
Using a FT-Spektrometer up to 2500 (4000) nm

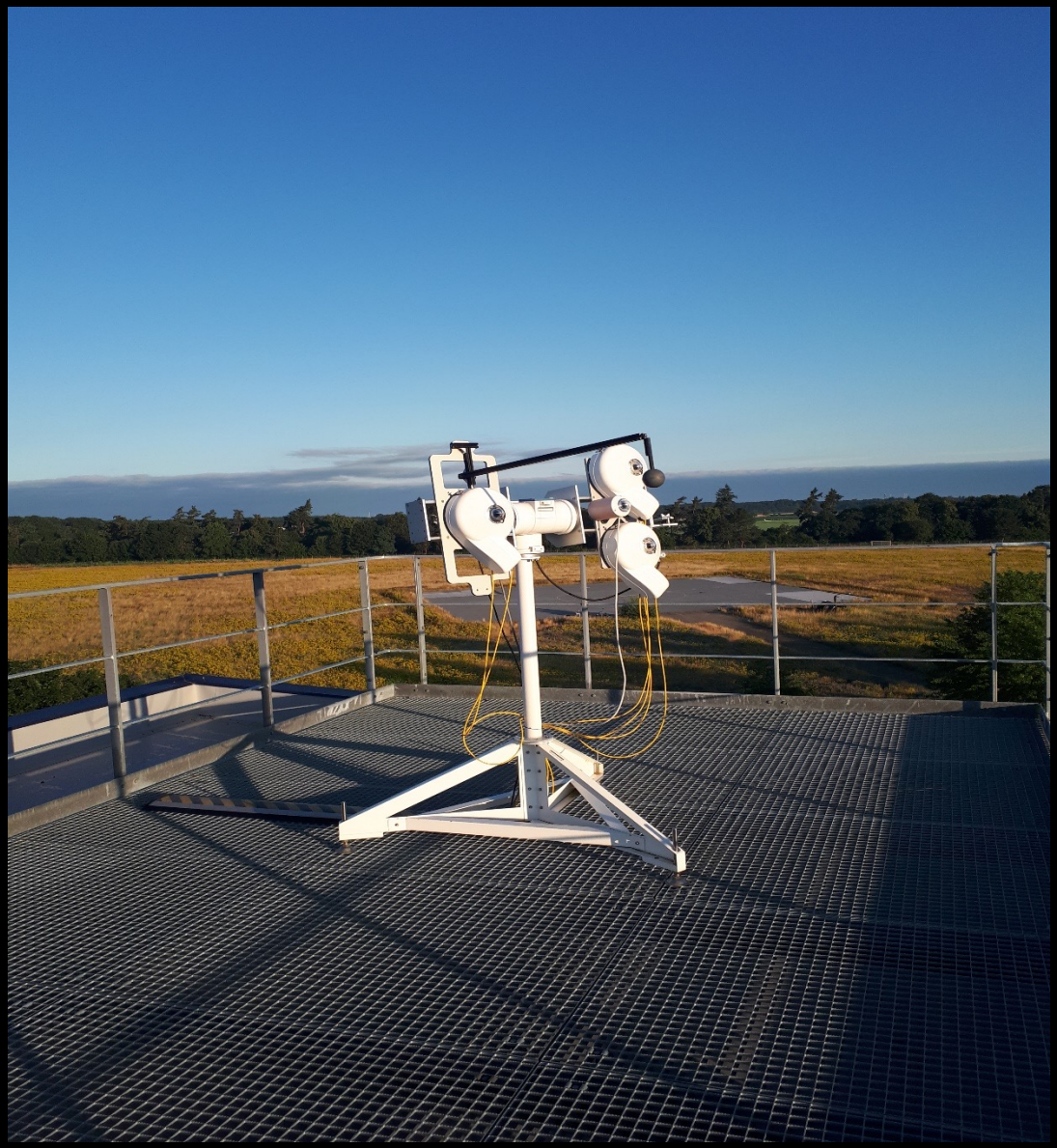
option 3:
Combination of both types

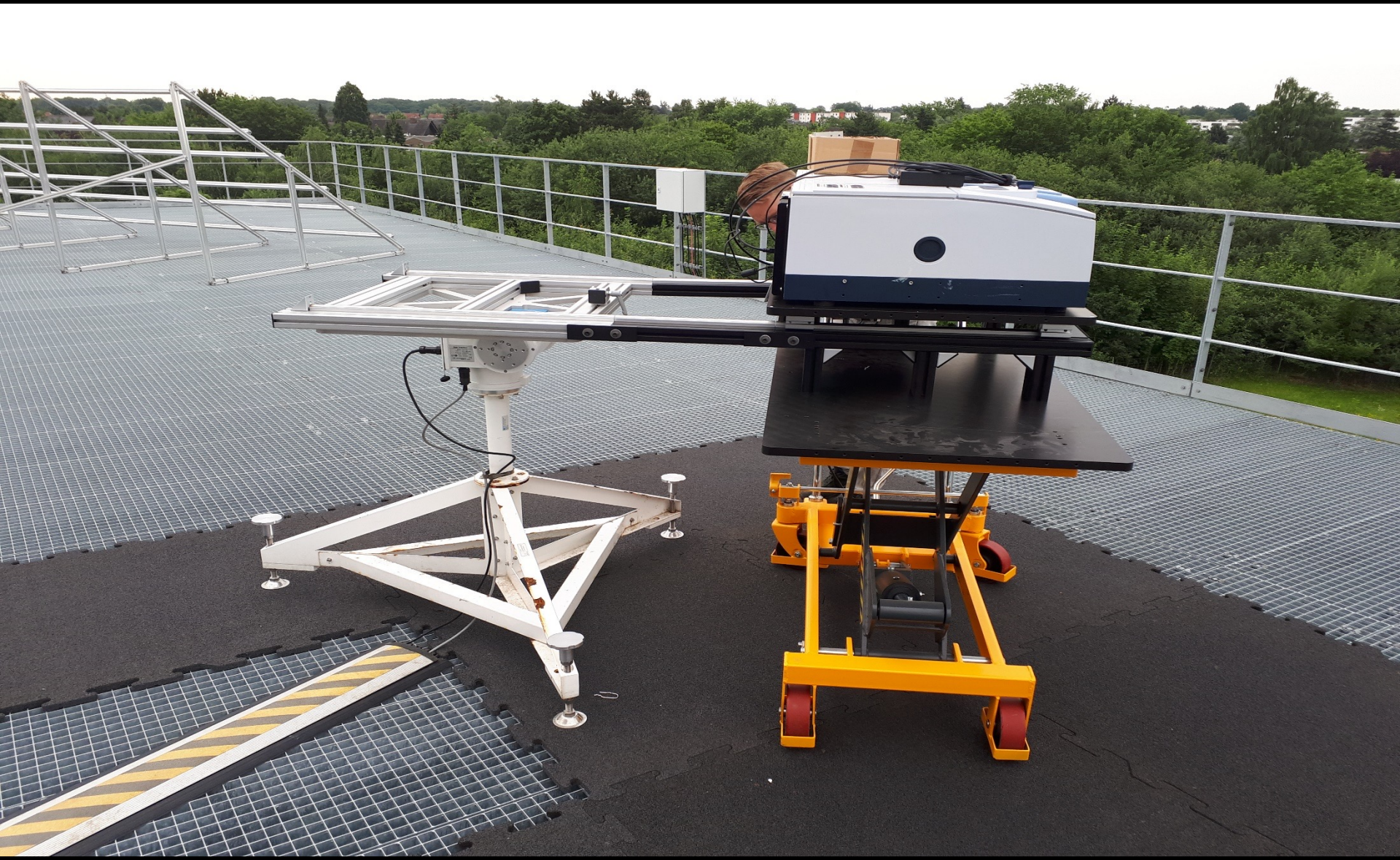
Configuration of the FT-Spektrometer

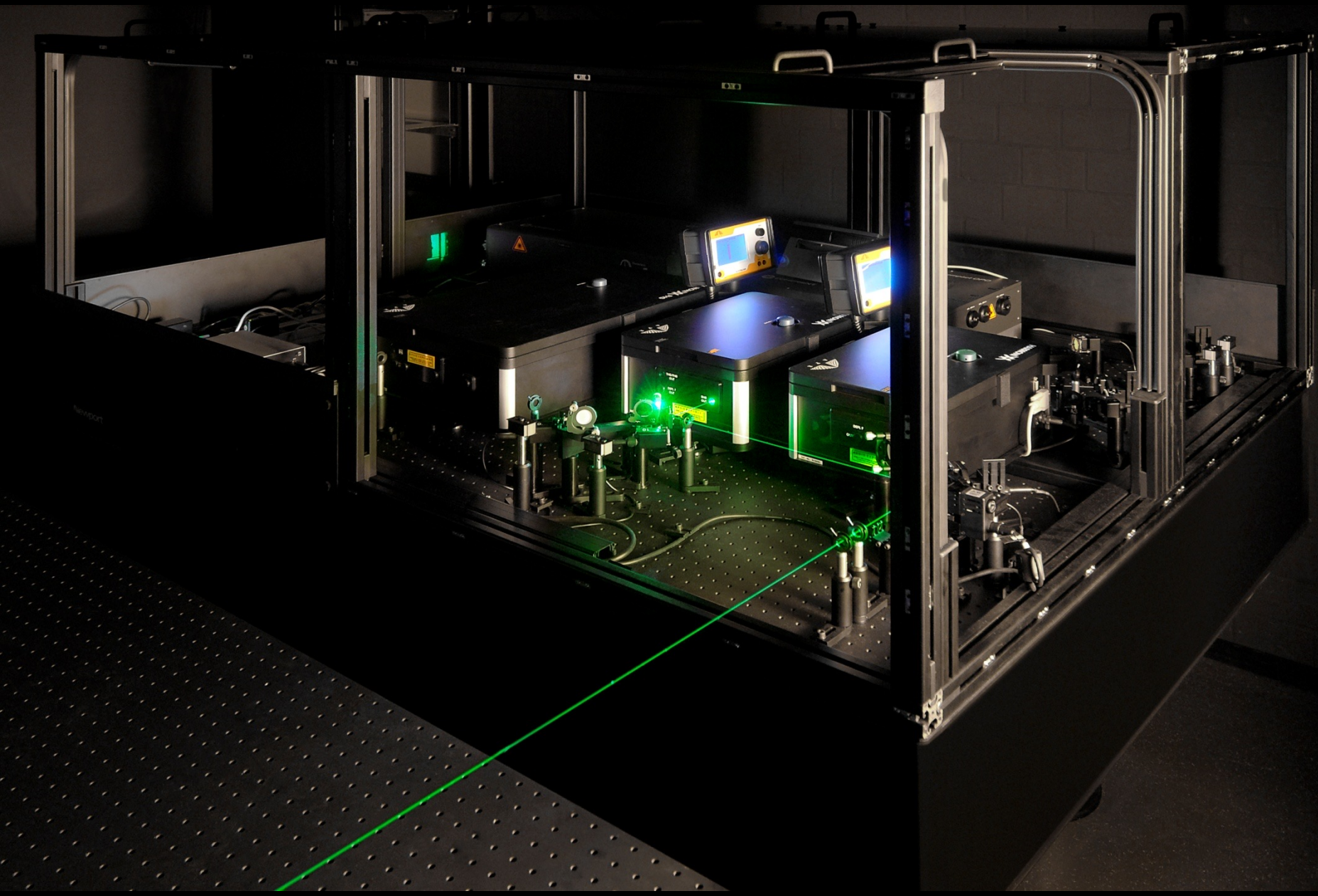


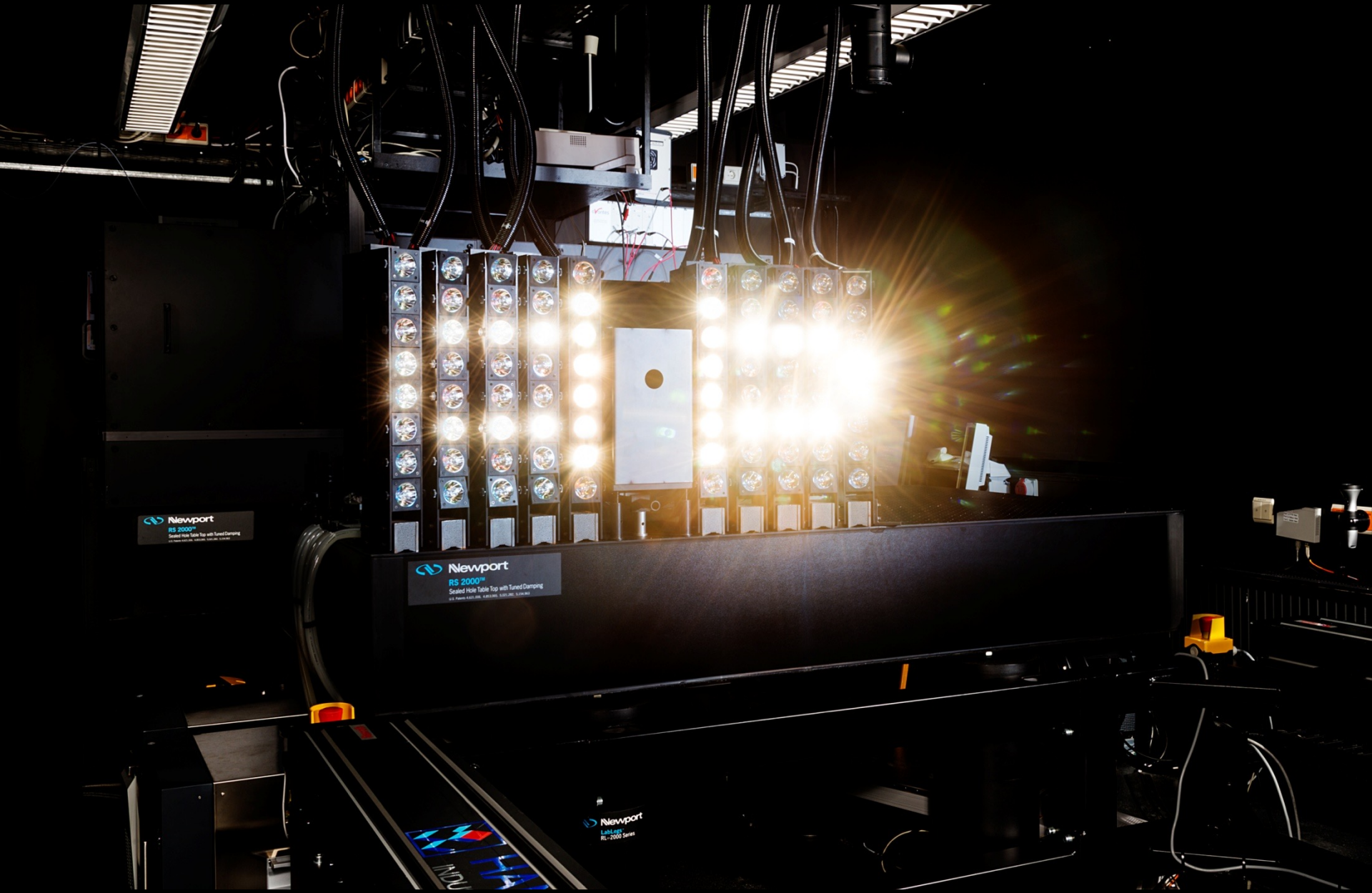
Detektoren:

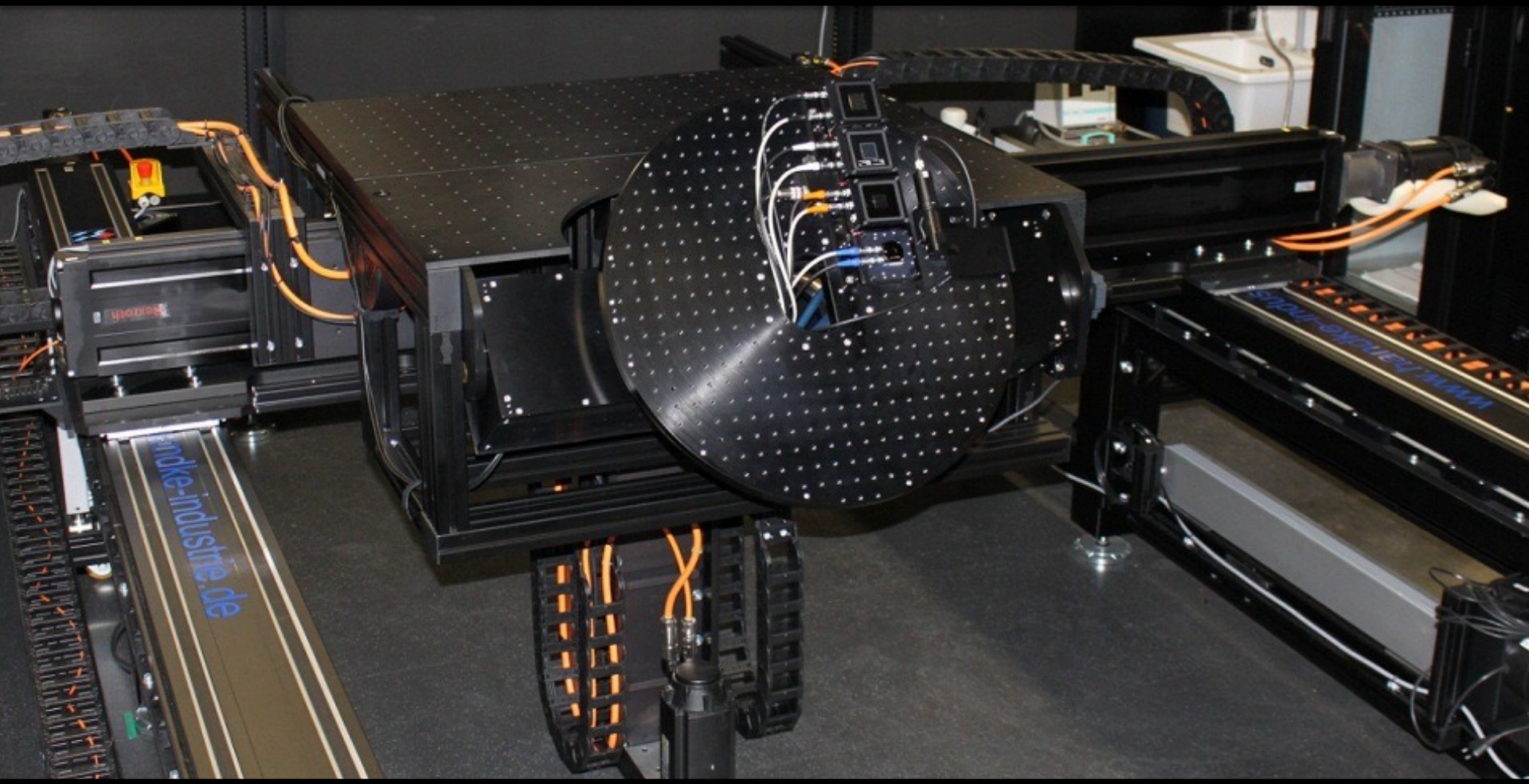
1 – GaP-Photodiode (300 – 400 nm)
2 – Si-Photodiode (400 – 1000 nm)
3 – InGaAs-Photodiode (650 – 2500 nm)
4 – DLaTGS-Sensor (1500 – 25000 nm)








Newport
RS 2000™
Sealed Hole Table Top with Tuned Damping
Newport
RS 2000™
Sealed Hole Table Top with Tuned Damping
Newport
LabLegs
RL-2000 Series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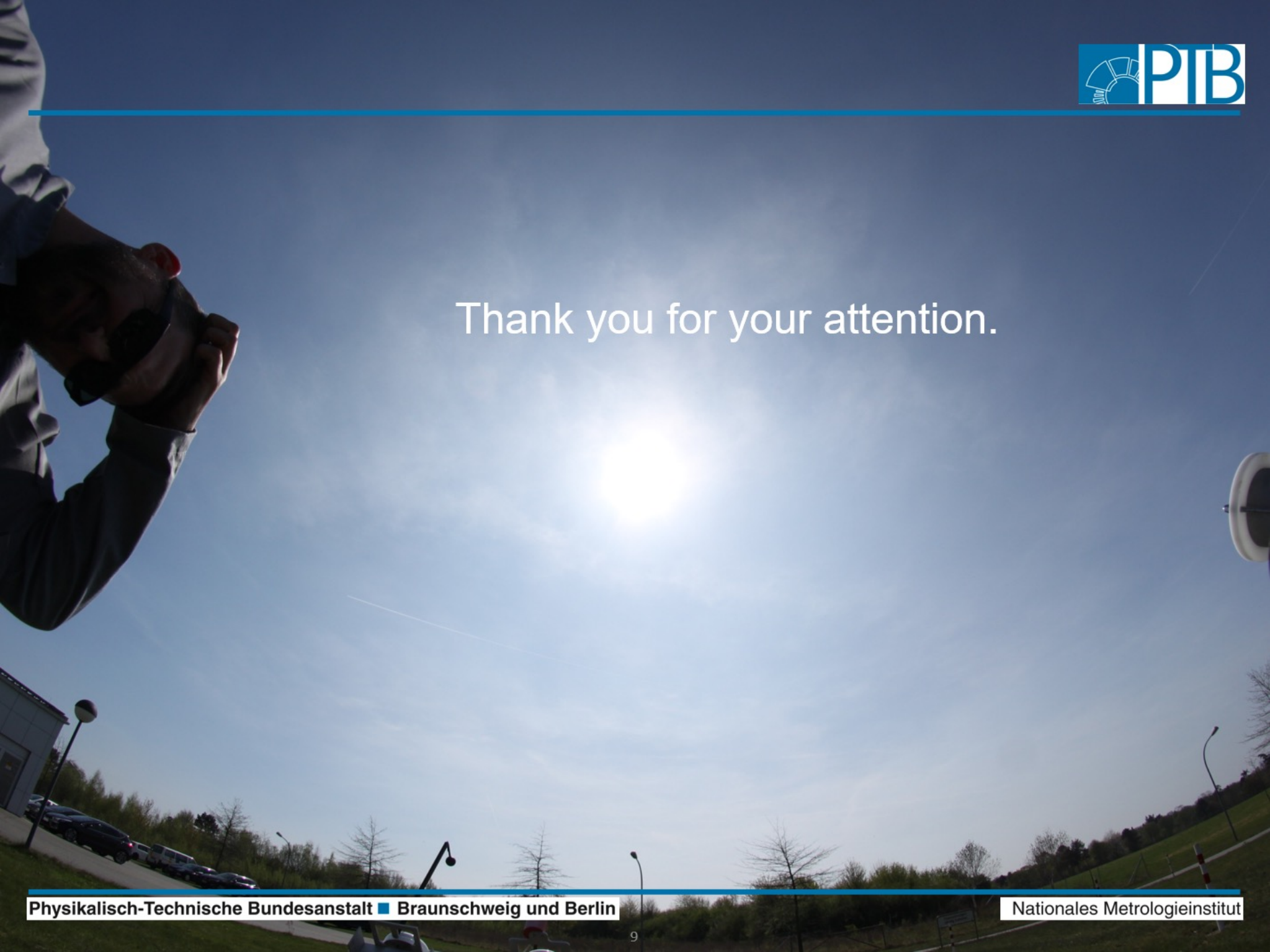
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