Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

Development and setting up a calibration facility for UV sensors at high irradiance rates

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In cooperation with

sglux
The UV Experts

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- Metrology and Radiometrie at the PTB
- The importance of traceability
- Requirements for Transfer Standard Sources
- The transfer standard for high UV irradiances

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PTR / PTB – a brief description

History:

- Physikalisch-Technische Reichsanstalt founded in 1887
- Joint initiative of Werner von Siemens and Hermann von Helmholtz to improve metrology for industrial products

Physikalisch-Technische Bundesanstalt:

- National Metrology Institute (NMI) of Germany
- Federal Ministry of Economics and Technology (BMWi)
- 1800 staff members, 140 million € annual budget
- 10 scientific & technical divisions, more than 100 sections and projects
- Sites in Braunschweig & Berlin

Metrology:

- Science of correct measurement
- Determination of results with verification of uncertainty
- **Traceability of measurement results to national standards**

Advantages of traceability

- Consistent evaluation of measurement results (**common system of units**)
- Comparatibility of different measurement methods and procedures
- Long-term maintenance and repeatibility of measurement results
- International equivalence and recognition of measurement results and uncertainties
- High standard levels in quality management
- Key content of ISO/IEC 17025

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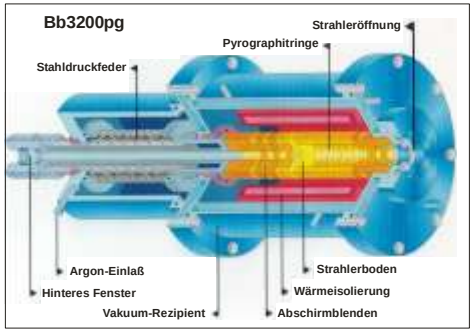
Radiometry at the PTB

- 15 working groups in 2 Divisions
- Realization, maintenance and dissemination of radiometric and photometric units
- R&D in the field of advanced measurement technologies and calibration standards
- Cooperation with external partners in scientific research & industry



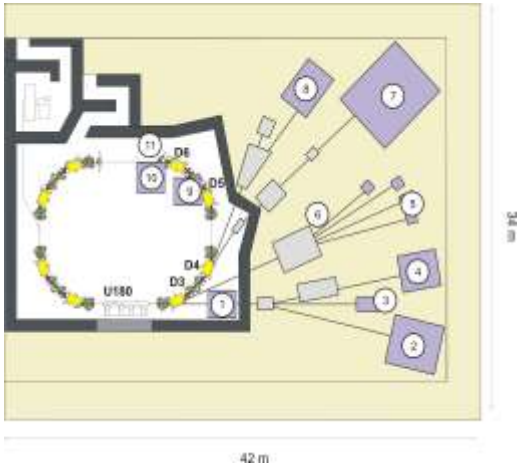
National primary Standards to realize SI-based radiometric units:

- Cryogenic radiometer (electrical substitution)

  Absolute radiometer for detector-based calibrations
- Blackbody (temperature radiation)

  Calculable radiation following Planck‘s radiation law
- Electron storage ring (synchrotron radiation)

  Calculable radiation following the Schwinger equation



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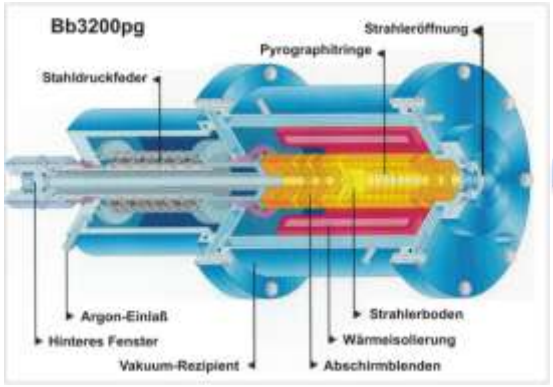
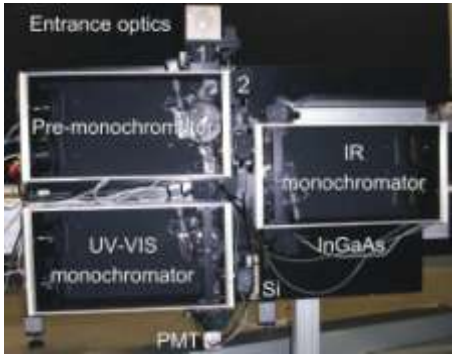
Source-based Spectroradiometry

- Realization, maintenance and dissemination of spectral irradiance $E_\lambda(\lambda)$ [W/(m²·nm)]
- Spectral range 200 nm - 2500 nm
- Traceable to a high-temperature cavity radiator (blackbody) as national primary standard
- 1000 W quarz-halogen-lamps and 30 W Deuterium lamps as transfer-standard
- Direct substitution method using double-monochromator-based spectroradiometers to compare primary standard and transfer standards





Motivation for UV transfer standards

- Comparisons of UV measuring instruments from different manufacturers are often unsatisfying.
- Direct calibration of broadband UV radiometers with low uncertainties is recommended.
- Strong request for traceable calibrations at high UV irradiance levels .
- The demands of DVGW and ÖNORM have to be fulfilled.
- The effort and costs for such calibrations should be affordable

Source-based calibrations against transfer standard sources

Radiometry for high UV irradiances

Transfer standard lamp

- Quartz tungsten halogen lamp
- max. 0.5 mW m^{-2} nm^{-1} @ 254 nm
- high fraction of IR spectrum
- continuous spectral distribtion
- point source

UV source for water treatment

- Low pressure or medium pressure Hg lamp
- > 1 W m^{-2} nm^{-1} @ 254 nm
- primarily UV radiatior
- line source
- extended source

„Classical“ transfer standards are nor suitable for high UV apllications

Traceability with radiant sources

Requirements for transfer standards to disseminate spectral irradiance

- The radiometric source system for calibration should meet the customer‘s application (radiant power, spectral distribution etc.)
- Long-term stability and reproducibility of all radiant sources and components.
- Completely defined and exactly reproducible geometric parameters (reference plane, distance, optical axis alignment, angular dependence)
- Uniform irradiance distribution at reference distance
- Insensitivity in terms of transport and environment conditions

Preliminary studies and objectives

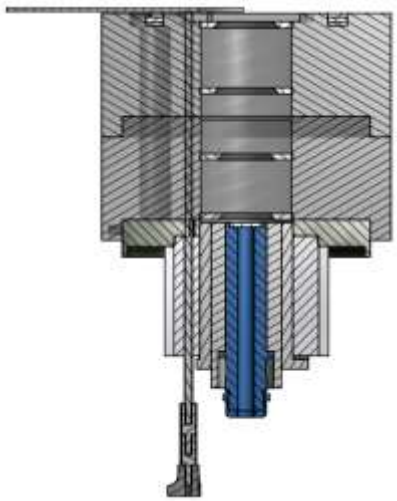
- Several commercially available UV radiators designed specially for UV disinfection have been characterized, and their suitability for use as a calibration standard has been investigated.
- To be able to calibrate sensors for UV water disinfection based on Hg medium-pressure radiators and on Hg low-pressure radiators, both types of lamps have been investigated.
- The stability, reproducibility and spectral irradiance of several lamp types have been tested.
- Two radiators have been selected and the demands for a calibration facility have been formulated

The transfer standard for high UV irradiance

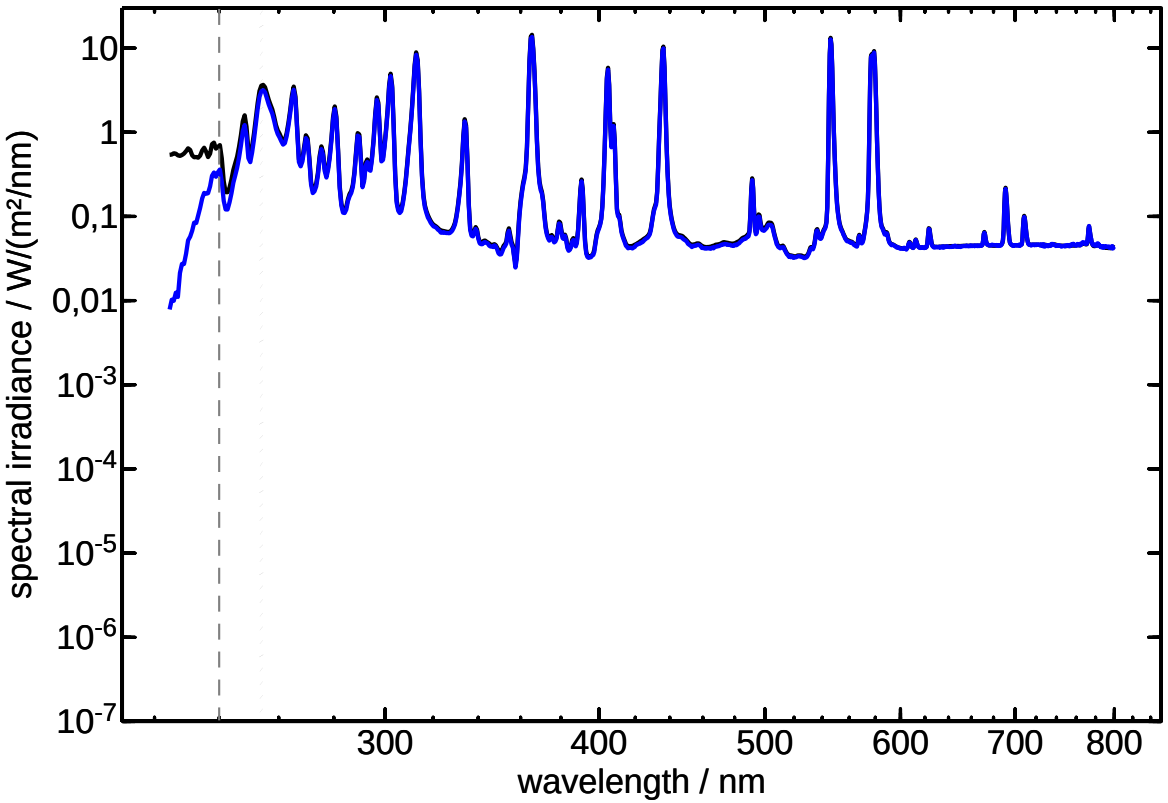
- ventilated cabinet
  produced by uv-technik meyer GmbH,
  modified by PTB
- highly reflective walls
- 1000 W medium pressure Hg lamp
  at the top
- remountable 40 W low pressure Hg lamp
  in the middle
- build-in temperature sensors, UV monitor sensors
- external power supplies & measuremement electronics
- UV sensor mount at the bottom

UV sensor mount

- manual shutter
- UV monitor sensors
- temperature sensor
- baffle tunnel
- filter holder
- mount for DVGW & ÖNORM sensors

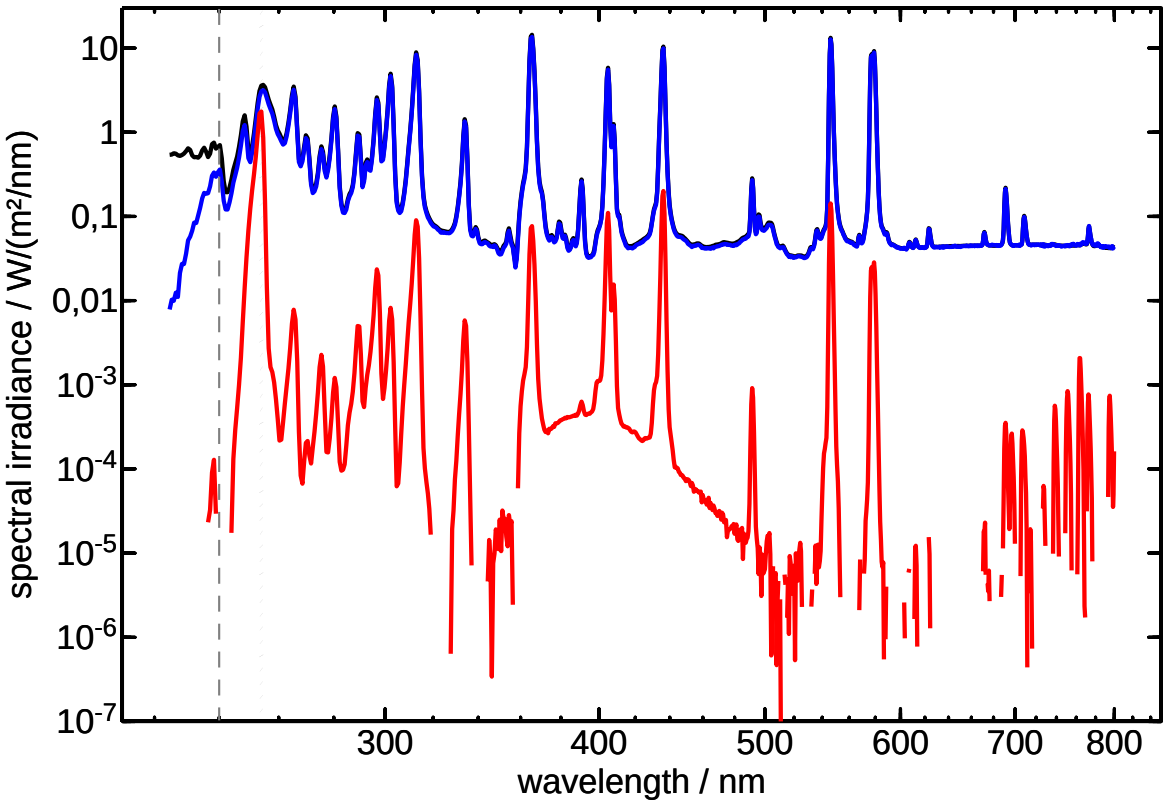


Medium pressure lamp



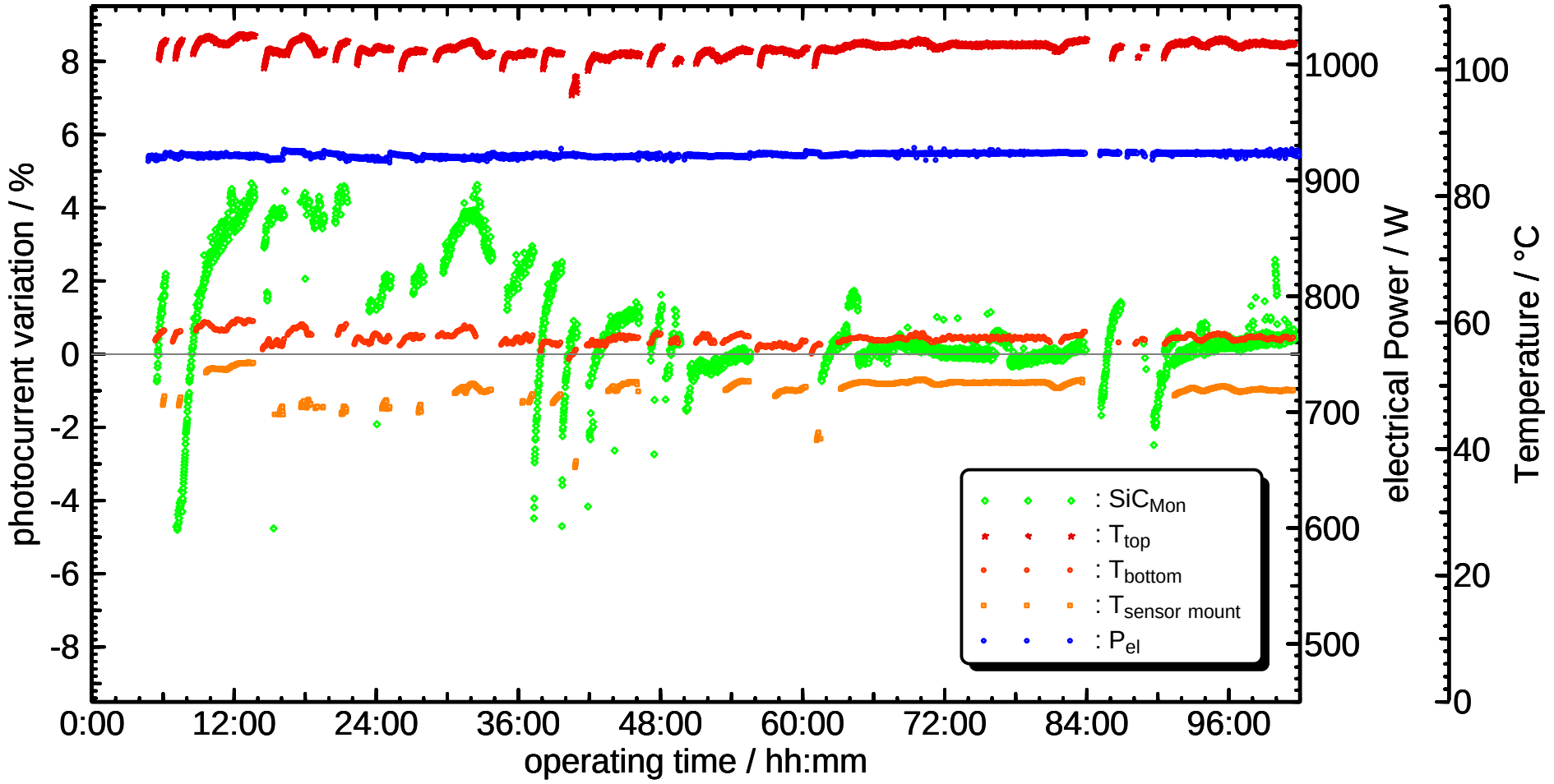
- 1000 W UVH 1022 operated @ 920 W
- distance ~ 500 mm
- additional 240 nm long-pass filter
- E_{mik} = 47 W/m²

Low pressure lamp



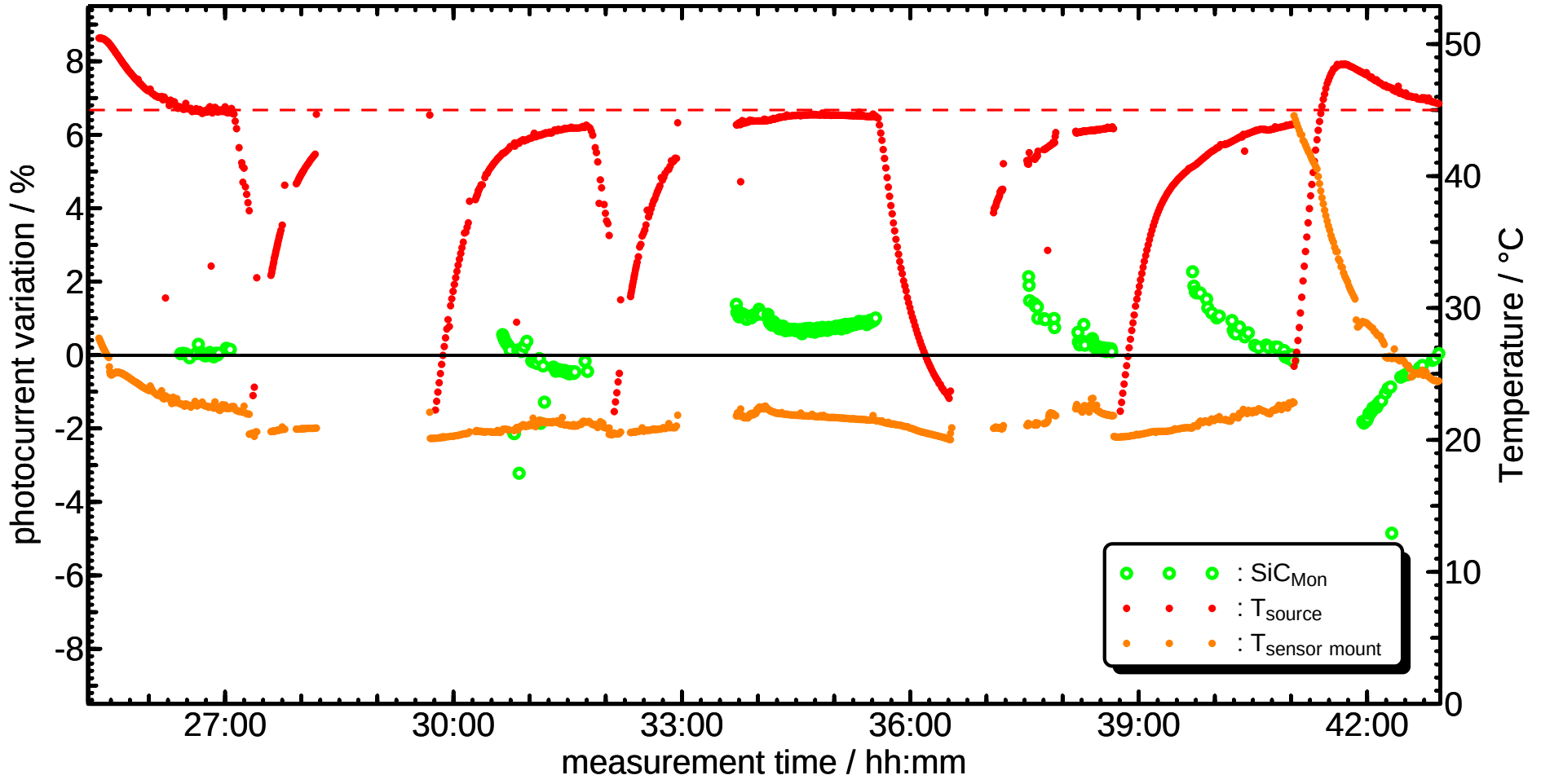
- 40 W UVI-40-4C-P
- separate housing
- distance ~ 300 mm
- E_{mik} = 4 W/m²

Facility in operation: medium pressure lamp



It works!

Facility in operation: low pressure lamp



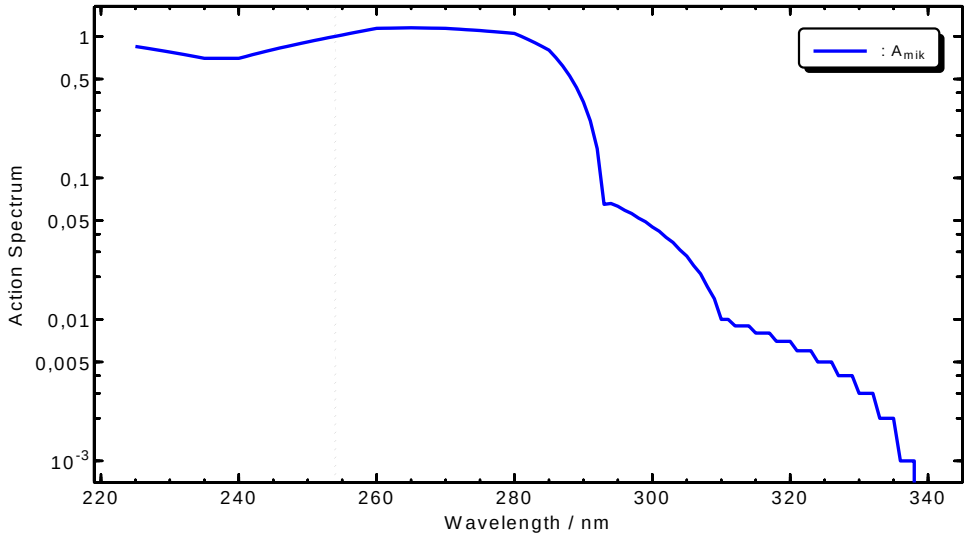
Calibration of microbizidal irradiance sensors

$$E_{mik,S} = \int_{200}^{340} A_{mik}(\lambda) * E_S(\lambda) d\lambda \qquad [W/m^2]$$

$E_s(\lambda)$ spectral irradiance of UV radiant source

$A_{mik}(\lambda)$ action spectrum for B. subtilis spore inactivation

$E_{mik,S}$ microbicidal Irradiance of source S



$$C_{mik,S} = \frac{E_{mik,S}}{Y_S}$$

$C_{mik,S}$ correction factor of UV radiometer

Y_S UV radiometer reading

More about it later

Summary & Outlook

- PTB provides spectral irradiance calibrations traceable to national primary standards and the SI system.
- A transfer standard source for high UV irradiances has been constructed and characterized.
- A medium pressure Hg lamp and a low pressure Hg lamp provide different spectra at different irradiance levels.
- The system might serve as a calibration facility for DVGW & ÖNORM conform UV sensors.
- Calibration by direct substitution to reference sensors can be carried out.

Thank you for your attention!

to be continued…

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