

Traceable Measurement of the Spectral Irradiance of UV Water Disinfection Plants

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In cooperation with



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acknowledgement to



aufgrund eines Beschlusses
des Deutschen Bundestages

- **Measurement of effective microbicidal irradiance**
- **Transportable PTB Spectroradiometer systems**
- **Measurements in St. Augustin**
- **Discussion of results**

Measurement of microbicidal irradiance

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

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

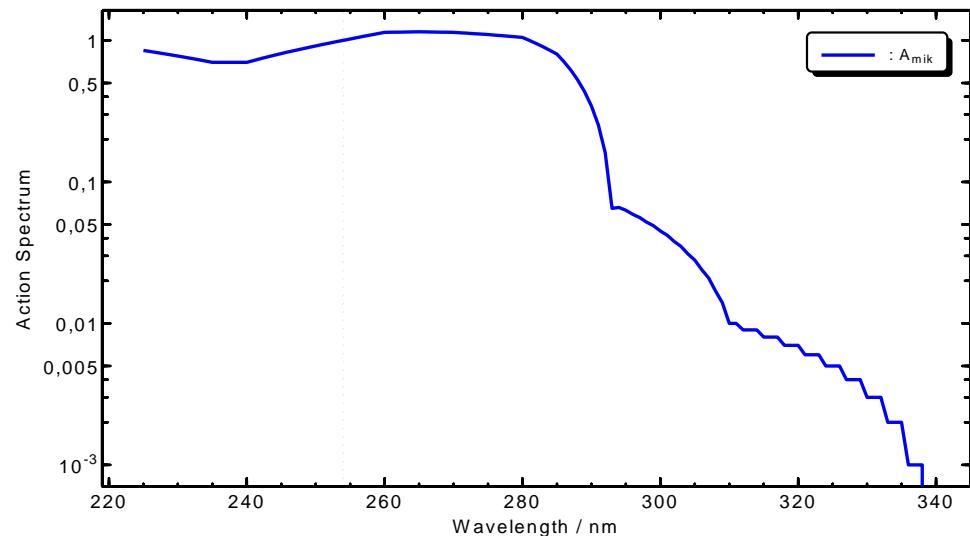
$A_{mik}(\lambda)$ action spectrum for *B. subtilis* spore inactivation

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

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

c_{mik} correction factor for UV radiometer

Y_S UV radiometer reading



Requirements for spectroradiometers

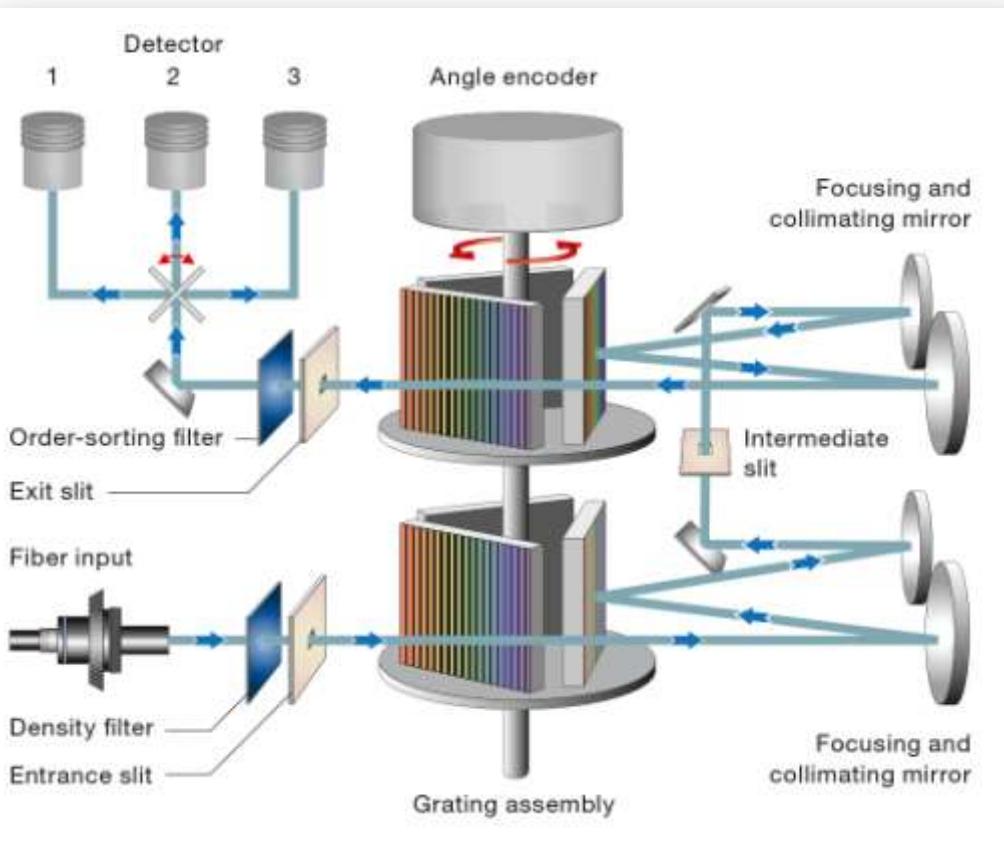
- High dynamics and linearity (4 orders of magnitude)
- Sufficient stray light reduction
- Defined geometry for reference plane for spectral irradiance
- Satisfactory repeatability and reproducibility
- Insensitive to high UV irradiances
- Resilient to environment conditions (temperature, humidity)

Transportable spectroradiometers used



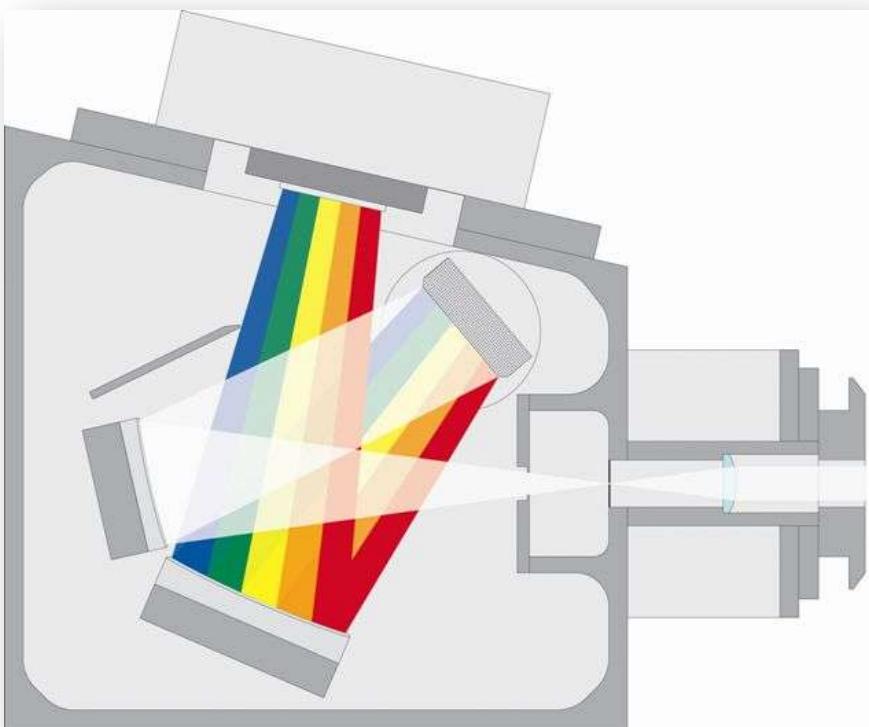
- Fast-scanning double monochromator system (Spectro320D)
- Compact array spectroradiometer (CAS140CT)

The fast-scanning spectroradiometer



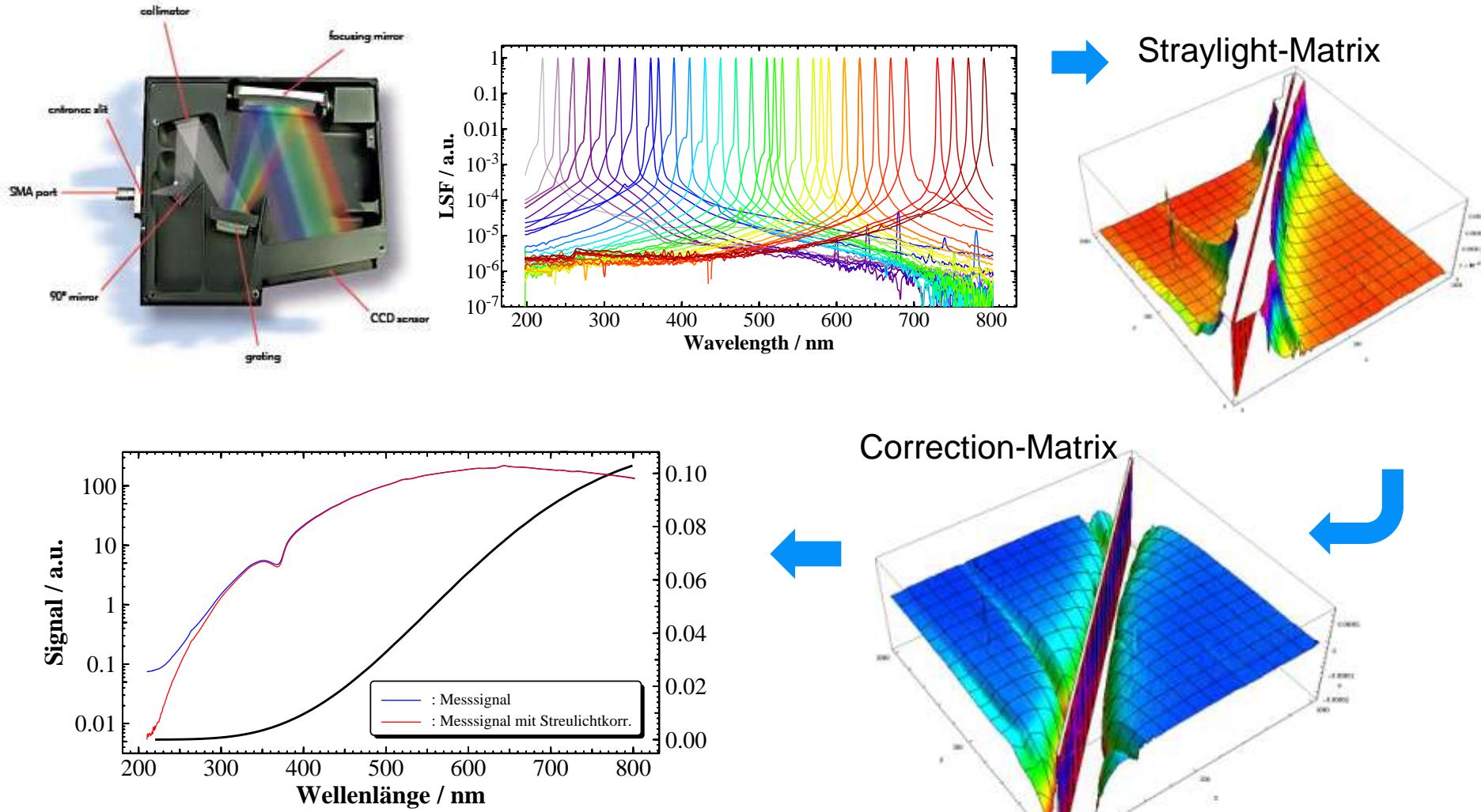
- Double monochromator system
- Synchronous scanning
- 200 nm – 1650 nm
- Variable bandpass
- 3 density filters
- Fiber coupled entrance optics

The array spectroradiometer

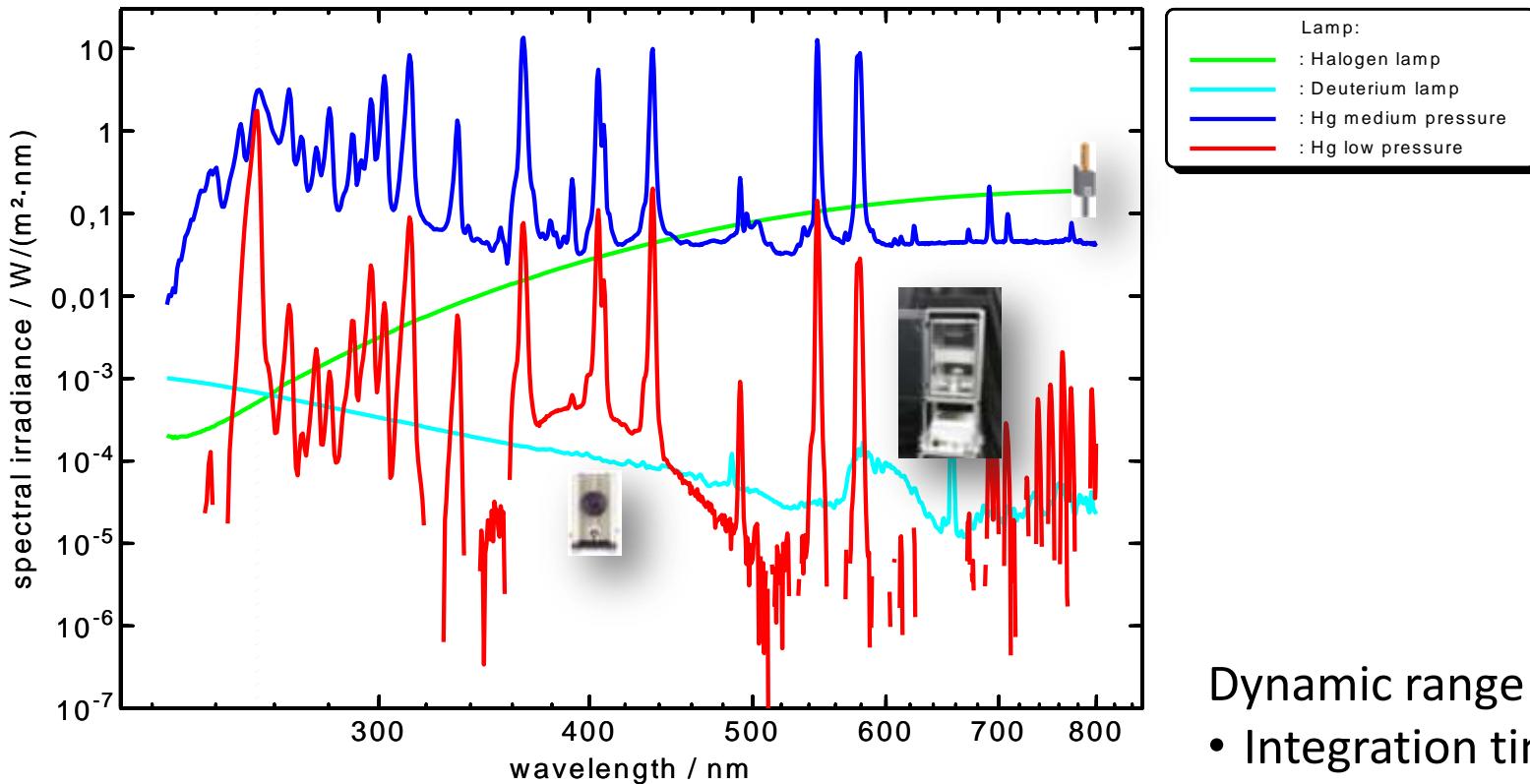


- crossed czerny turner optical bench
- Back-thinned CCD 1024x128
- 200 nm – 800 nm
- FWHM 2.5 nm
- 3 density filters
- Fiber coupled entrance optics

straylight correction matrix



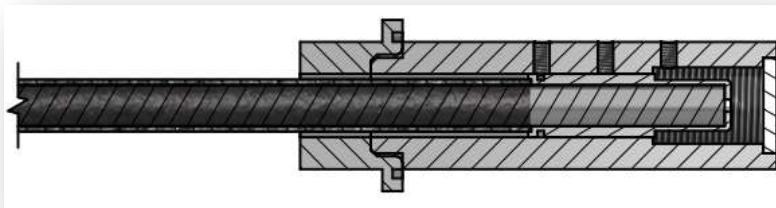
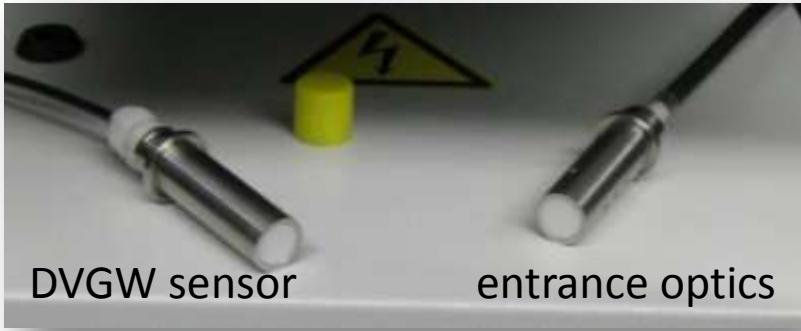
Transfer standard sources



Dynamic range coverage:

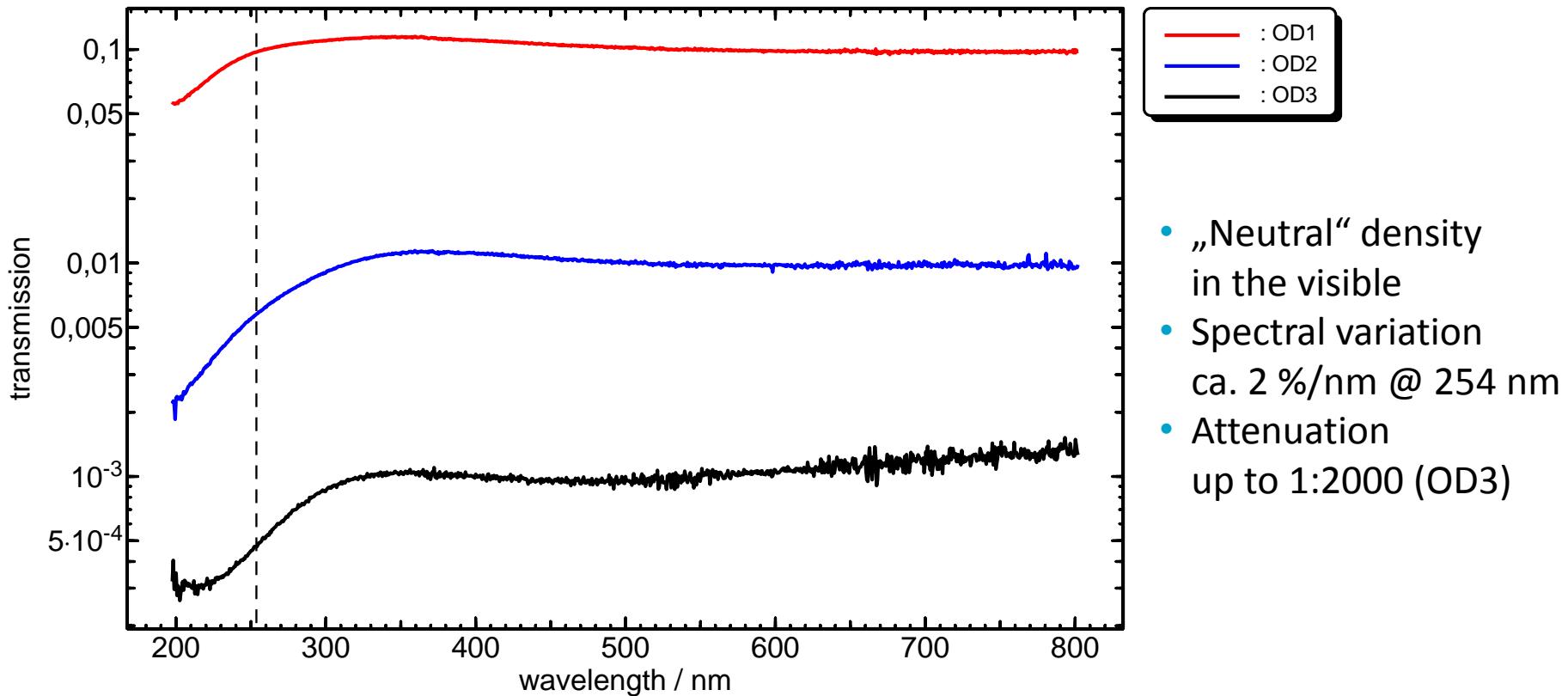
- Integration time
- Density filters
- Entrance optics

Entrance optics of the spectroradiometers



- Fiber coupled
- Design similar to 160° DVGW sensor
- UV resistant
- Cosine response
- Low transmittance

Attenuation with neutral density filters

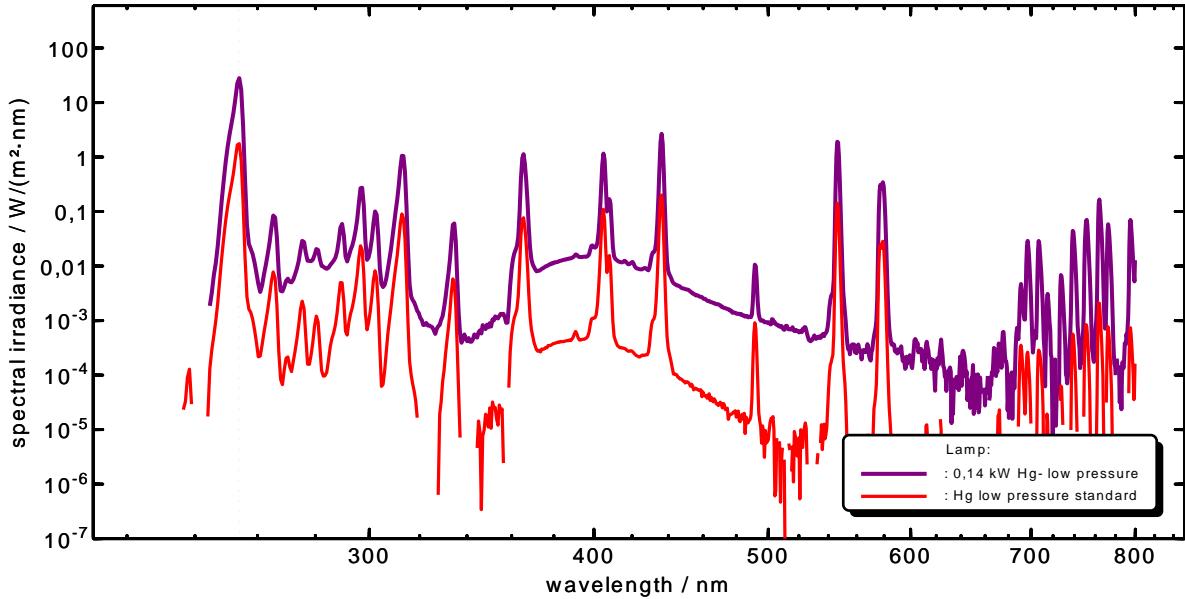


Measurements at water disinfection plant



- DVGW test laboratory for UV disinfection plants in St. Augustin-Meindorf / Germany
- Measurements in January 2013 at 3 systems
 - 0,14 kW Hg low pressure facility (5.2 m³/h)
 - 48 kW (6 x 8 kW) Hg medium pressure (2900 m³/h)
 - 18 kW (6 x 3 kW) Hg medium pressure (780 m³/h)
- Ambient air temperature 12°C
- 160° sensors and adapted entrance optics used
- Comparison with 160° TZW sensor

0,14 kW Hg low pressure system

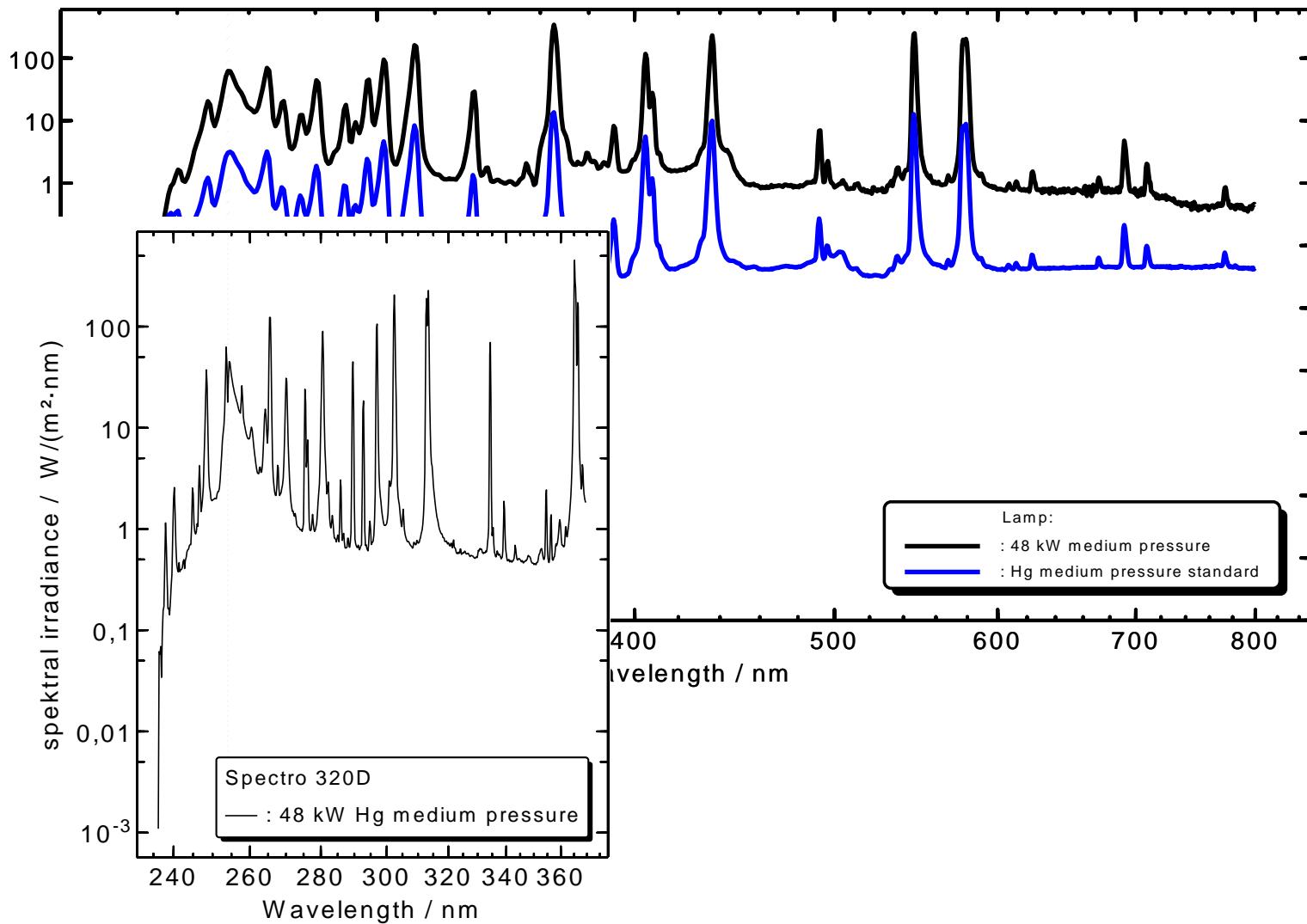


Measured microbicidal irradiance E_{mik} [W/m²]

rel. el. power	TZW 160°	Spectro 320D	CAS 140CT	PTB-1	PTB-2	PTB-3	PTB-4
100 % 6 m ³ /h	61	65	62	66	63	63	65
50 % 0,6 m ³ /h	29	31	29	31	30	30	31



48 kW Hg medium pressure system



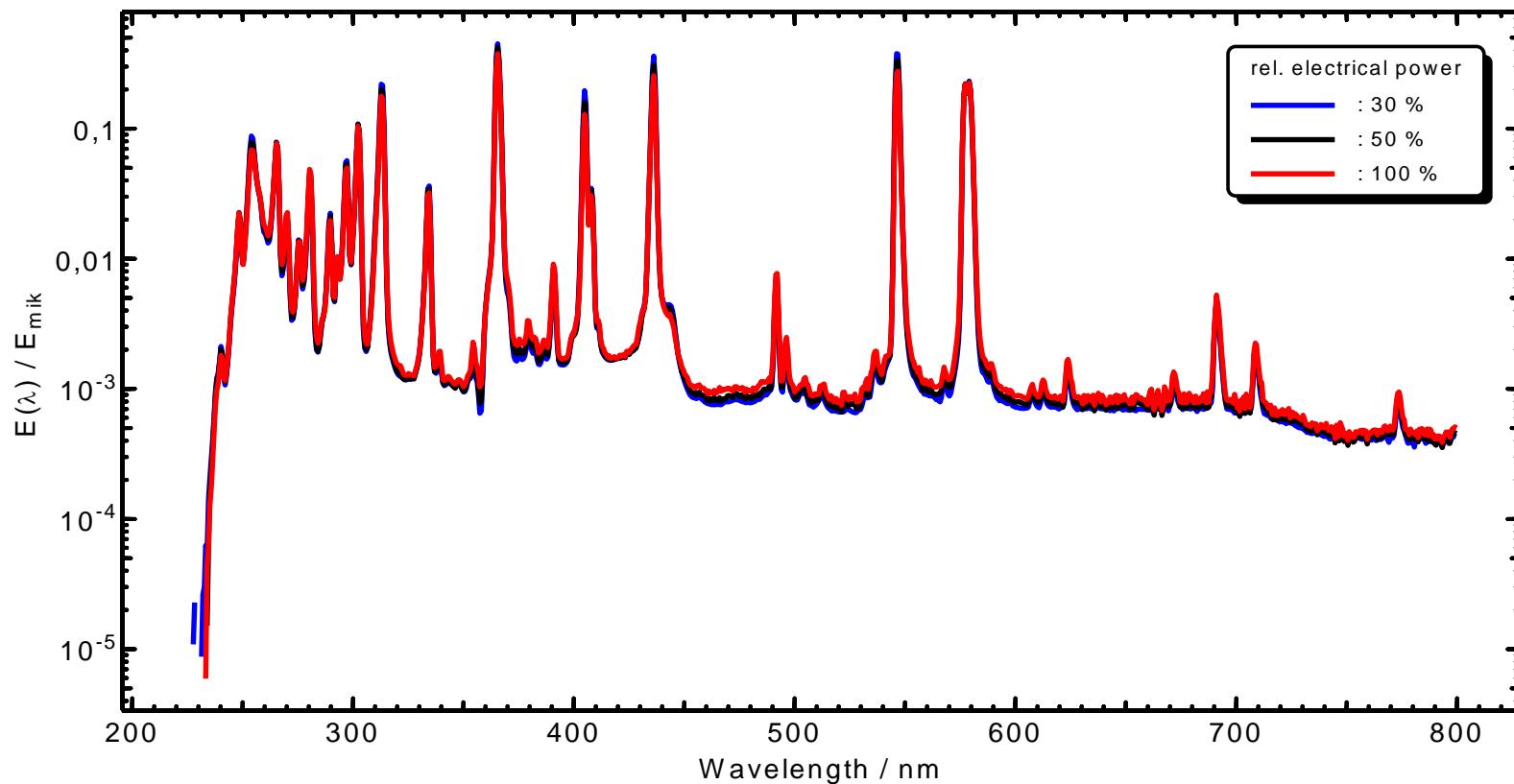
48 kW Hg medium pressure system

Measured microbicidal irradiance E_{mik} [W/m²]

rel. el. Power	TZW 160°	Spectro 320D	CAS 140CT	PTB -1	PTB -2	PTB -3	PTB -4
30 %	181	206	193	206	200	196	203
50 %	350	401	378	-	386	379	389
100 %	827	969	906	-	910	898	920

Normalized spectra

Spectra at different electrical power levels normalized with E_{mik}



Summary & Outlook

- PTB provides spectral irradiance calibrations traceable to national primary standards and the SI system.
- Transportable spectroradiometer systems have been adapted for high UV irradiance measurements.
- Successful measurements at medium pressure Hg and a low pressure Hg lamp facilities have been carried out.
- The effective microbicidal irradiances agree within < 15 %.

- 40° sensor geometry could be developed
- Discussion about calibration service / support



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Thank you for your attention!



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