Opsytec Dr. Gröbel

Safety and risk assessment for UV curing systems

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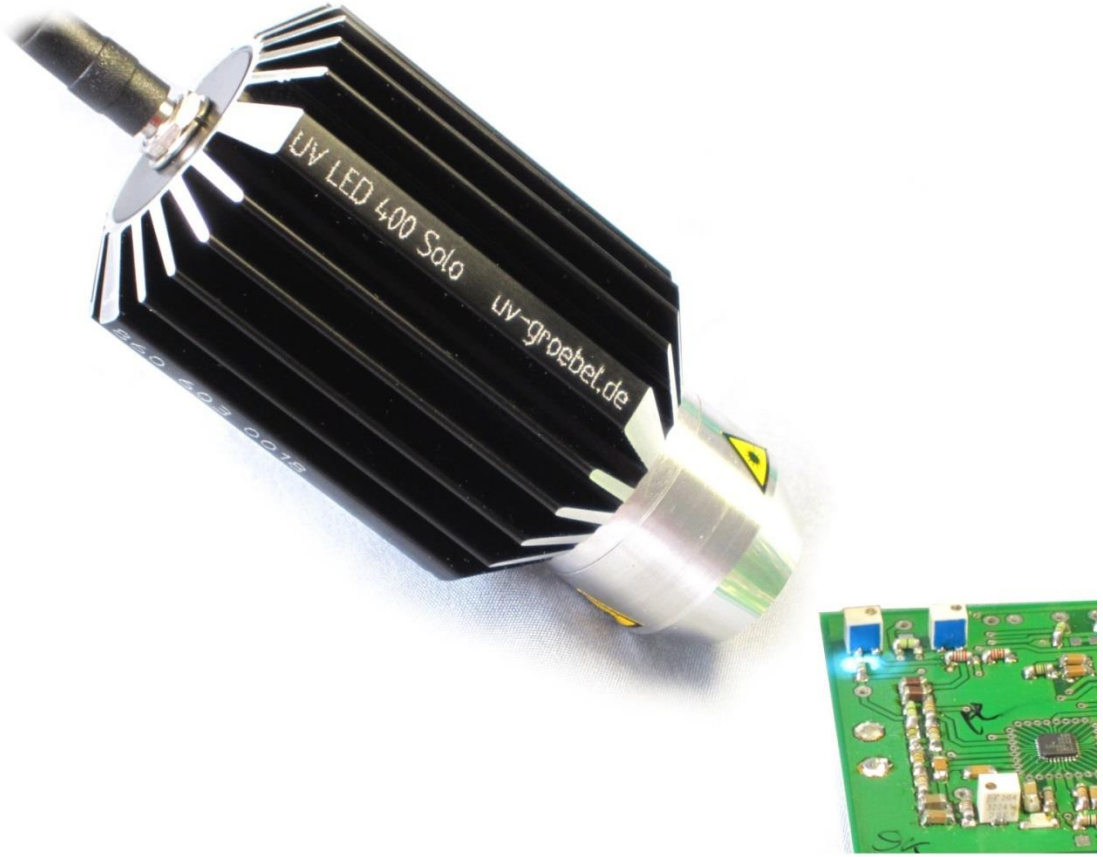
we apply photonics.

- **Opsytec Dr. Gröbel:**
  - Manufacturer of high quality UV equipment since 32 years
  - CAD and optical design
  - In-house mechanical workshop
  - Optical laboratory
  - Calibration



Is it dangerous?
Is it operated according actual law?

Personal and machinery safety

- European Directive 2006/25/EC

  Exposure limits for artificial optical Radiation (for workplace)

- DIN EN 14255-1:2005

  Measurement and assessment of personal exposures to incoherent optical radiation (for workplace)

- DIN EN 62471:2009

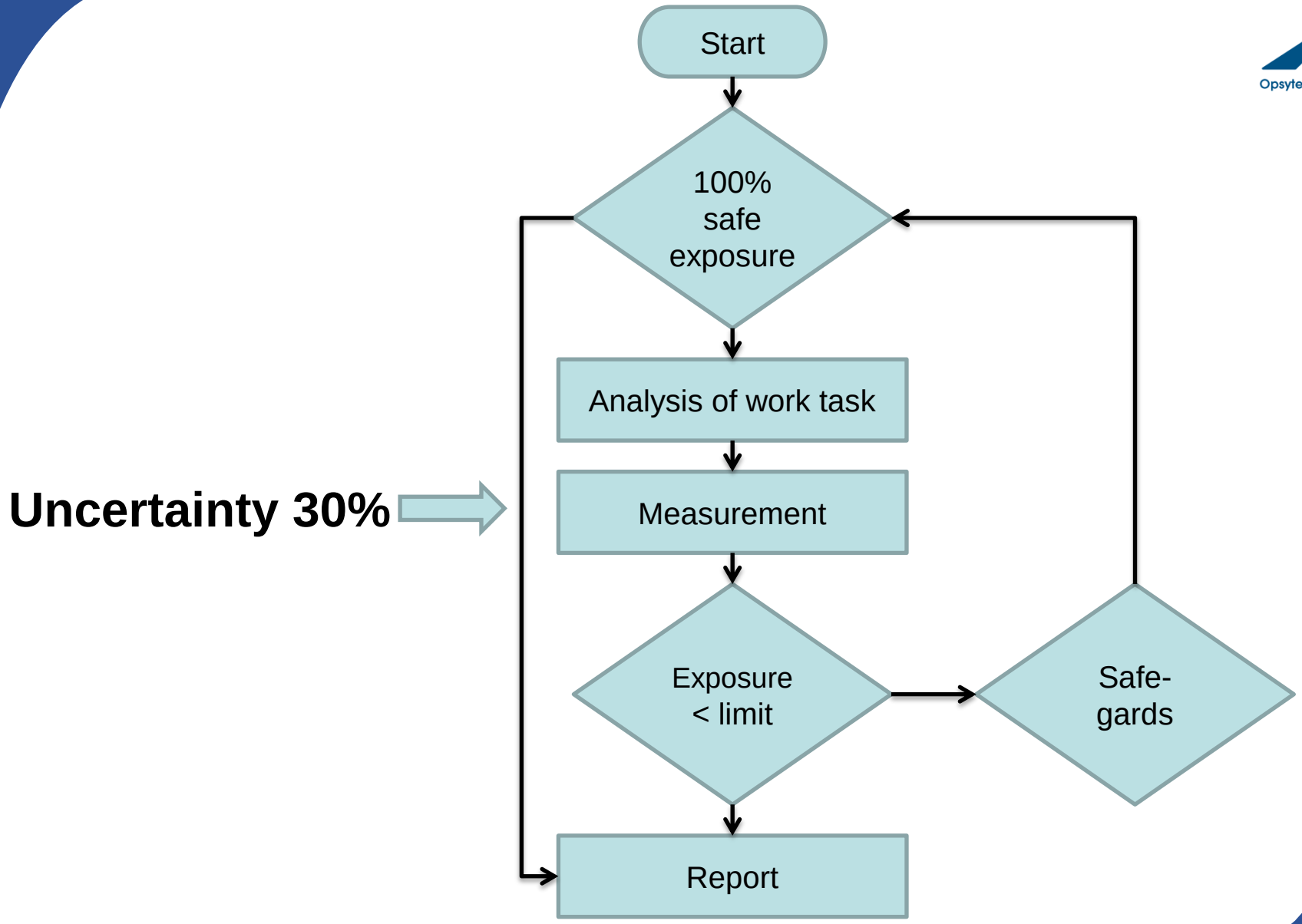
  Photobiological safety of lamps and lamp system (in 20 cm or at 500 lx), Classification category 0 to 3 (risk group)

- DIN EN 12198-1-3:2008

  Safety of machinery - Assessment and reduction of risks arising from radiation emitted by machinery (in 10 cm or closer)

  Classification category 0 to 2 (safeguards)

Simplified excerpt from DIN 14255

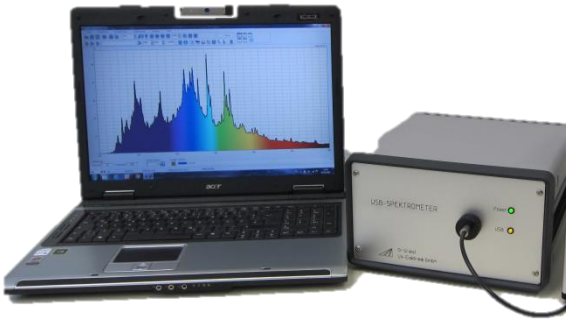


How to do good measurements

- **Measurement device must be:**
  - sensitive enough
    - 0.03 W/m² at 365 nm and
    - 0.001 W/m² at 270 nm
  - wide spectral range from 200 nm (up to 3000 nm)
  - calibrated
  - Uncertainty must be below 30 %
  - low noise & low stray light

  - **Expensive ?**

Measurement device overview



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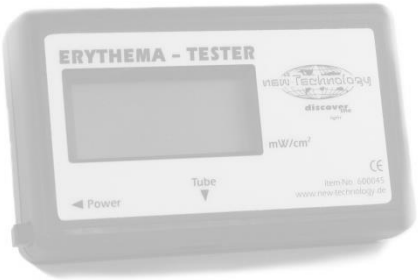
RL 2006/25/EC lists 8 exposure limits

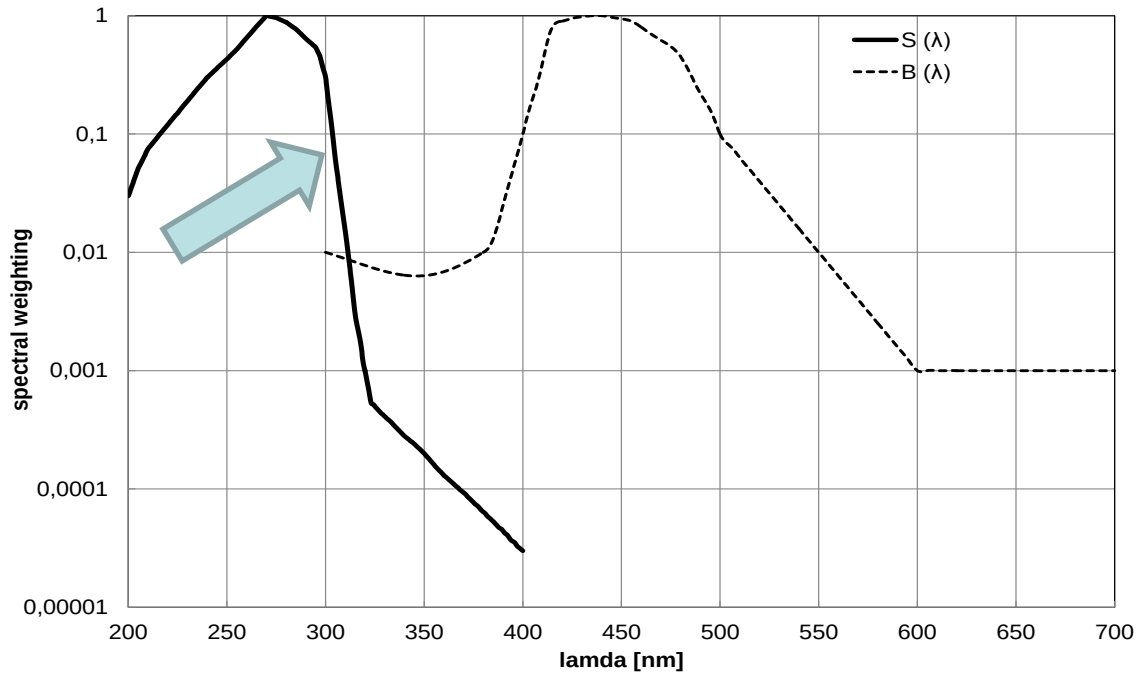


H_{eff} < 30 J/m²
H_{UVA} < 10^4 J/m²
E_B
L_B

DIN 5031-10 lists 28 sensitivity functions

- Note, sensors are often badly adapted and multiple sensors must be used

- UV action spectra S(λ) and B(λ)



$$E_{eff} = \int_{180}^{400} E_\lambda \, S_\lambda \, d\lambda$$

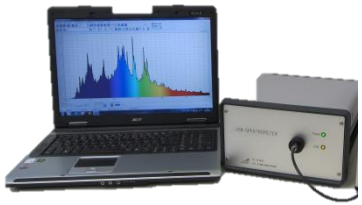
$$E_B = \int_{300}^{700} E_\lambda \, B_\lambda \, d\lambda$$

$$E_{UVA} = \int_{315}^{400} E_\lambda \, d\lambda$$

- S(λ) changes over 4 orders of magnitude within 20 nm
- B(λ) is wide range specification

Equipment comparison

- **Double monochromator**
  - f = 2 x 320 mm



- **Laboratory spectrometer**
  - f = 140 mm

- **Mobile spectrometer**
  - f = 75 mm

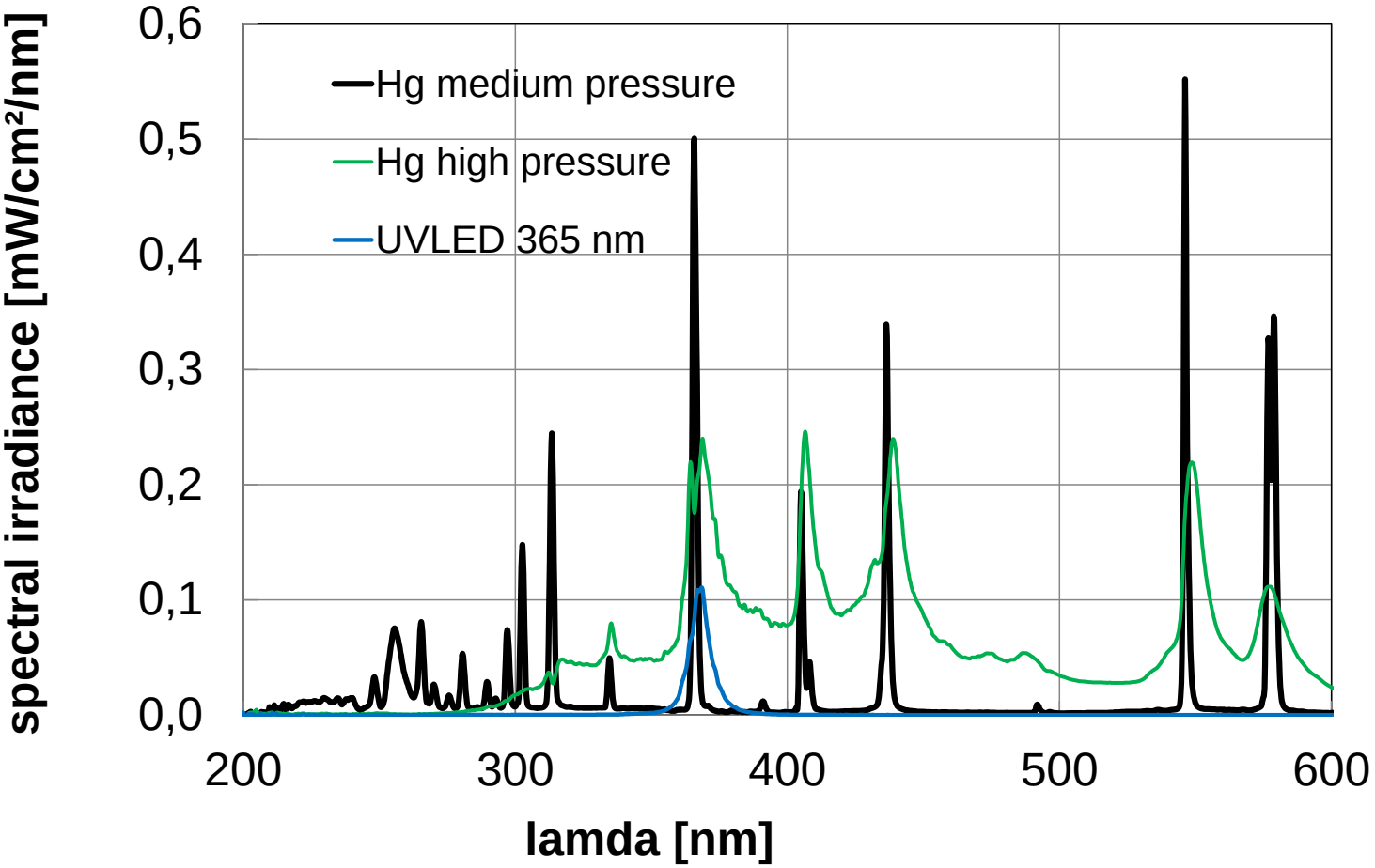
- **UV Sensors**
  - UVA, UVB, UVC, blue light

Experimental Setup

- **Measurement of three sources:**
  - mercury medium pressure lamp (6 kW)
  - mercury high pressure lamp (120 W)
  - UV-Led 365 nm (1,5 W)

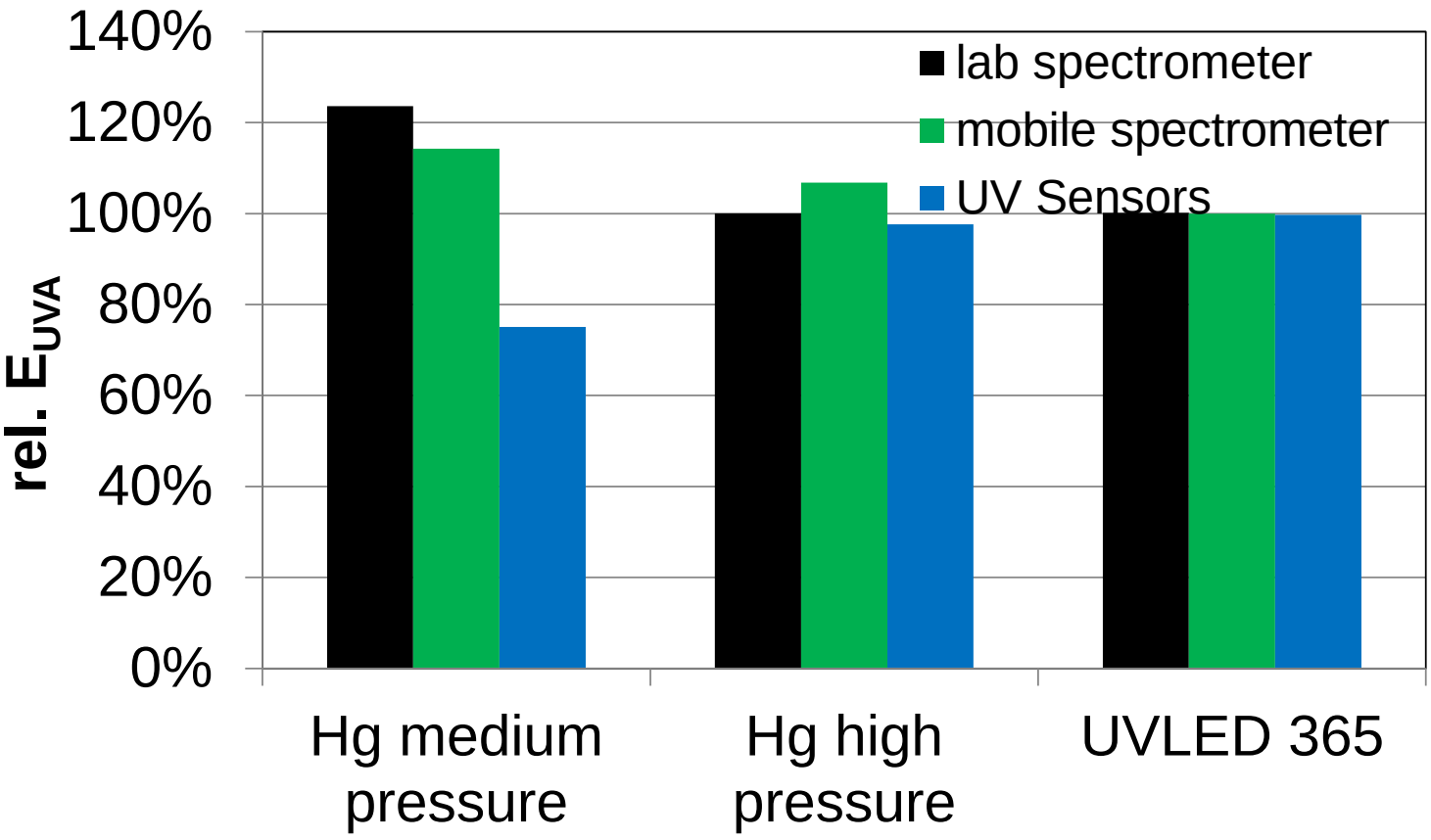
- **Measurement parameters:**
  - measurement of stray light in handling or sounding area
  - low irradiance of 1 to 8 mW/cm²
  - daily exposure limits 0,4 to 143 s, meaning still dangerous sources

Measurement results



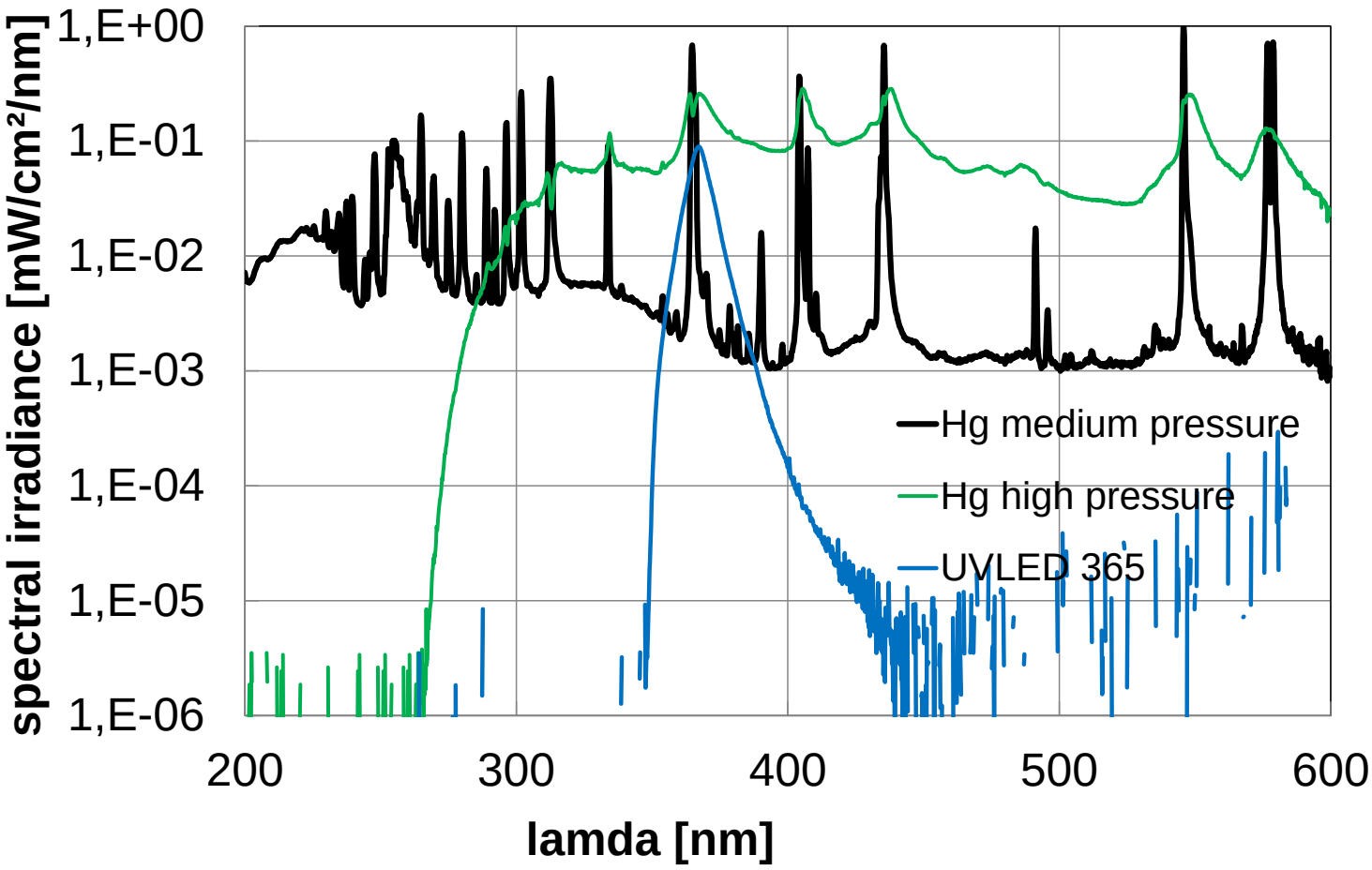
- measured with laboratory spectrometer

Measurement results E_{UVA}



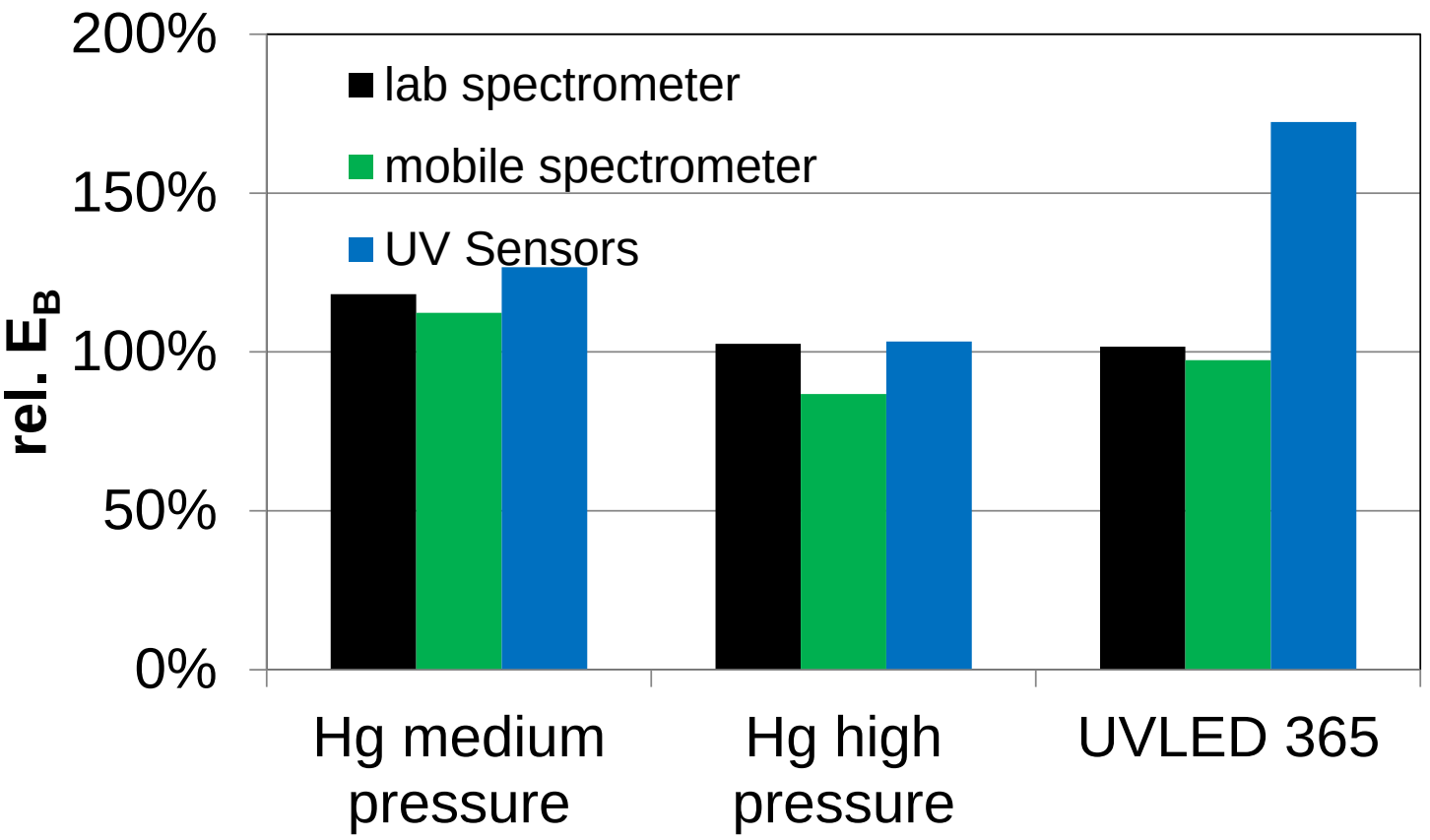
- Results are normalized to double monochromator
- Sensor values use averaged sensitivity value

Measurement results



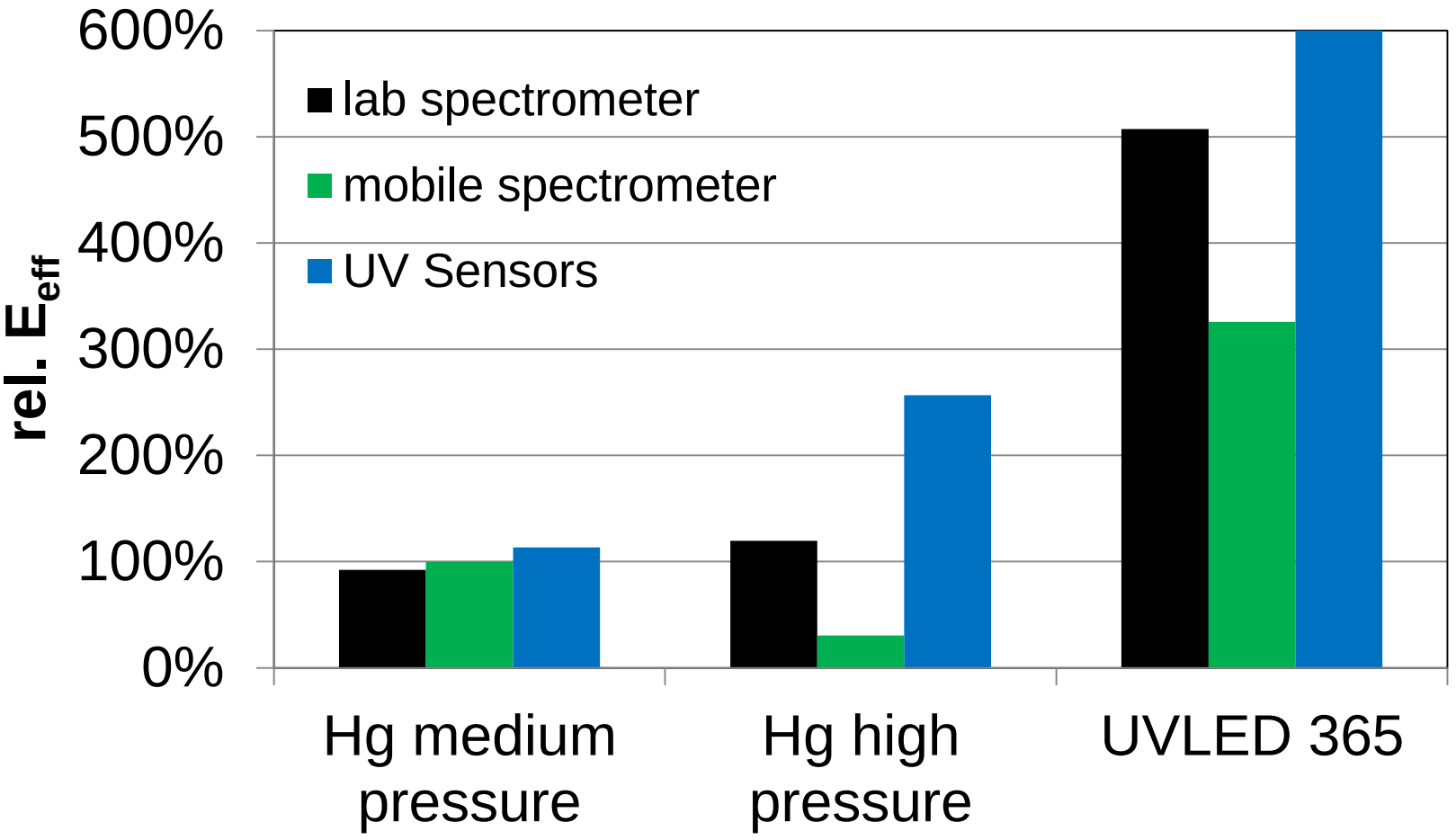
- High noise equivalent power in UVC + UVB spectral range for laboratory spectrometer

Measurement results E_B



- UV sensors are out of tolerance
- E_B seems to be ok for spectrometer, but ..

Measurement results E_{eff}

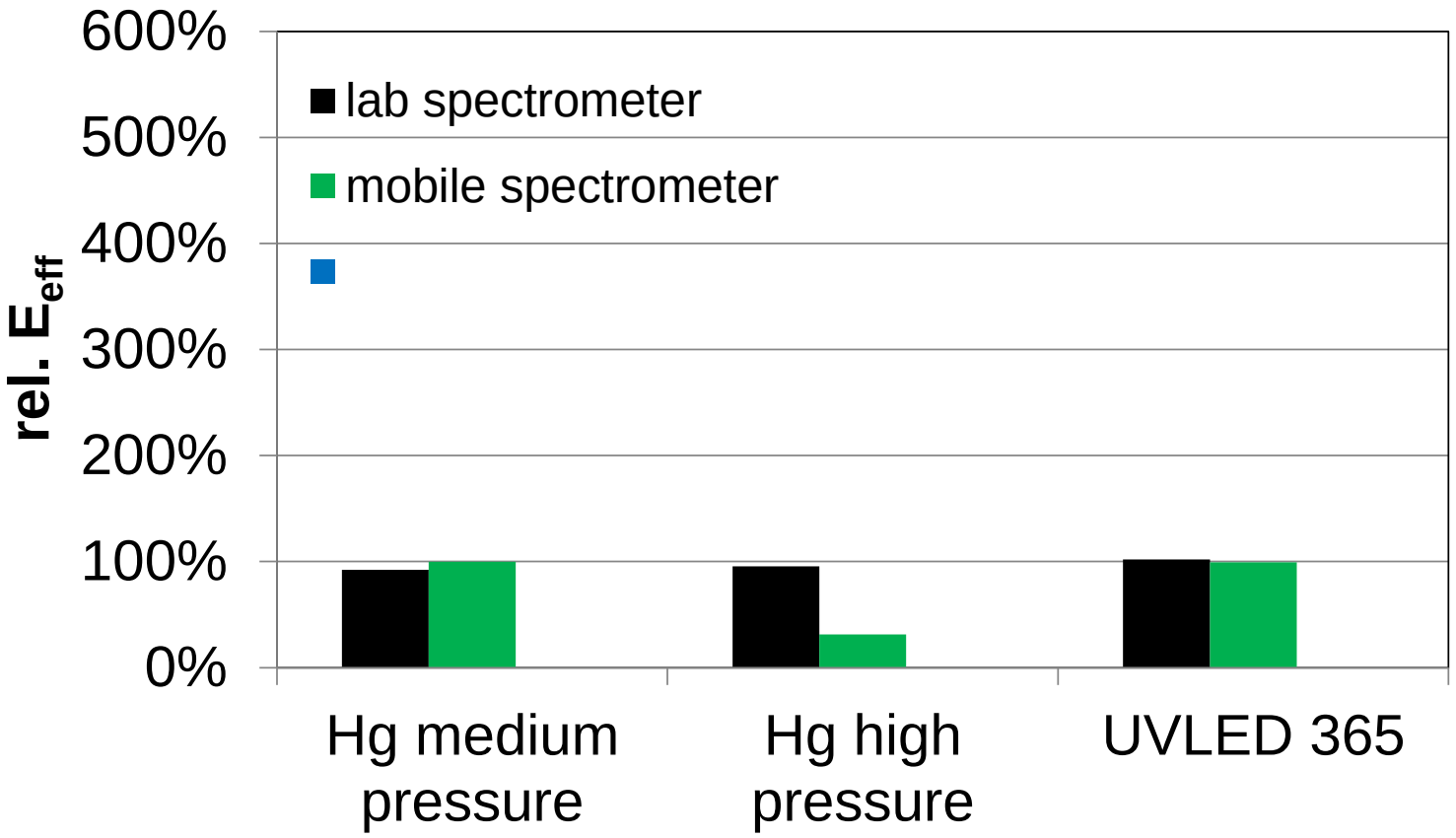


- E_{eff} is far away from real value
- Spectrometer measurements are not automatically ok

How to do good measurements

- **Additional correction for spectrometer :**
  - use standard sensors to estimate that there is no UVC or UVB
  - calculate effective exposure in “practical” spectral range
- **Don‘t use UV sensors without effective calibration**

Corrected measurement results E_{eff}



- When the spectrometer dynamic range is comparable to that of the action spectra, measurements are normally good

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- **How to do exact measurements at low irradiance:**

1. Measure the spectra with spectrometer
2. Check for stray light
3. Calculate effective irradiance
4. Calibrate UV Sensor
5. Measure at workplace (very low intensity)
6. Determine daily exposure

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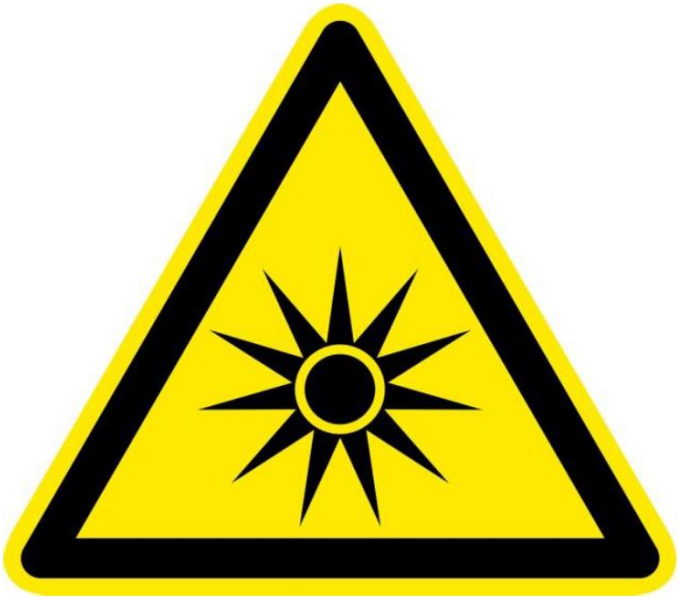
- **Uncertainty calculation:**
  - assuming independent errors
  - total uncertainty is 13 %
  - Uncertainty is good for DIN EN 14255-1

	uncertainty
Spectrometer calibration	7 %
Transfer uncertainty to obtain lamp spectra	4 %
Spectral sensitivity of reference detector	6 %
Transfer uncertainty for spectral UV sensor sensitivity	3 %
Absolute sensor calibration [mW => V]	7 %
Voltage calibration	2 %
total uncertainty	**12.8%**

Warning signs



Maximum daily duration of stay without skin and eye protection: 10 minutes

Summary

- For risk assessments, spectra, working position and duration must be considered
- Spectrometer can be used as universal tool
- Noise & stray light are problematic
- Sensitivity can be enhanced by combined sensor measurement
- Uncertainty of 13% is good enough for DIN EN 14255
- Machinery must be labeled
- Written report

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Thank you for your attention.

More information at booth 37