Combined Out-Of-Range and In-Band Stray Light Correction for Array Spectroradiometers

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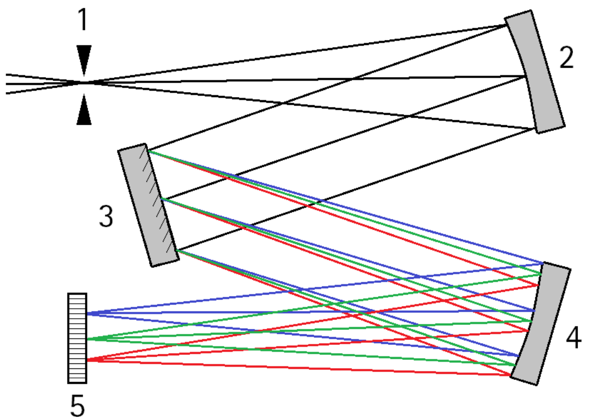
Presented by J. Leland *at* CORM-CIE 2019, Ottowa, ON

Introduction

- Array-spectroradiometers are extensively used for the measurement of light (VIS and NIR)



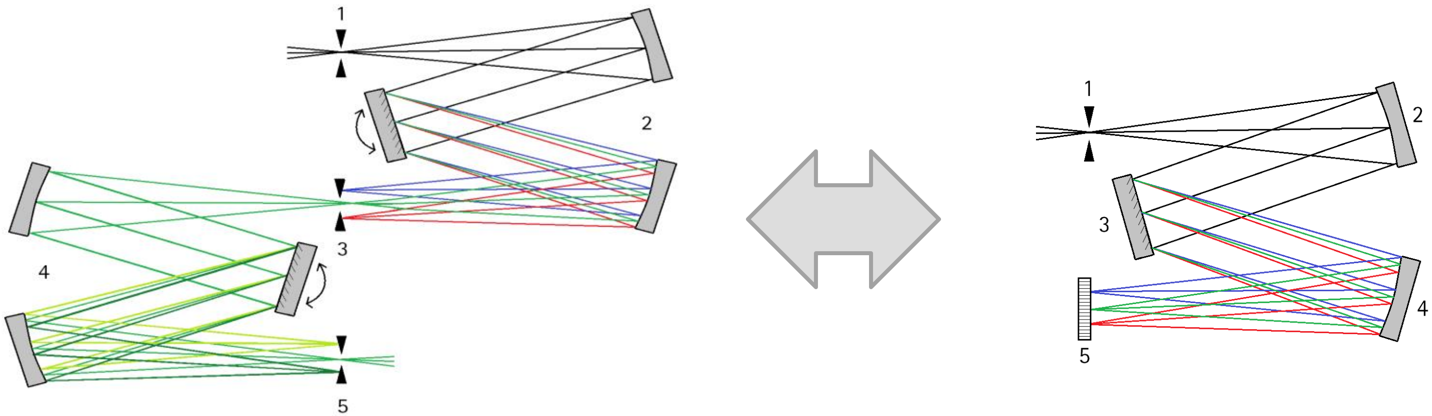
✓ fast measurement

✓ flexible, robust

✓ cost efficient

Introduction

- Double monochromator are the common used devices for precise measurements in the UV spectral region

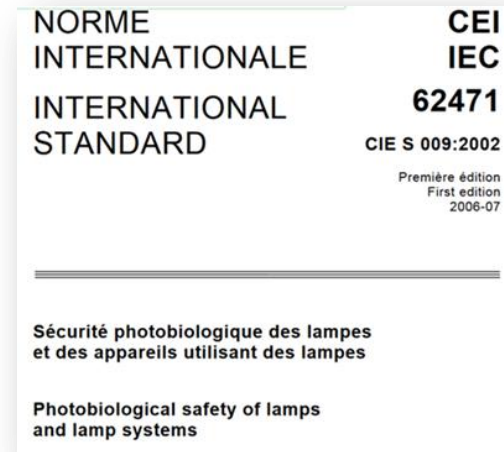


- for **e.g. photobiological safety measurements** (IEC/DIN EN 62471:2006, CIE S 009)

Introduction

B.1.1 Double monochromator: Recommended instrument

- The measurement of a source for the purpose of hazard classification requires accuracy during calibration and testing. The detector's broad spectral response and high spectral resolution required to provide accurate weighting leads to stringent requirements for out-of-band stray light rejection. .....
- The ratio of out-of-band energy to pass-band energy at 270 nm for tungsten or tungsten-halogen calibration lamps should be smaller than 10E-4**.** The double monochromator is the only instrument that provides the needed selectivity, and it is recommended for hazard measurements involving UV and visible radiation. It is recognized that monochromator systems introduce limitations in convenience and speed. Use of a single monochromator in the UV or visible spectrum should be used only if comparable results to that from a double monochromator can be obtained.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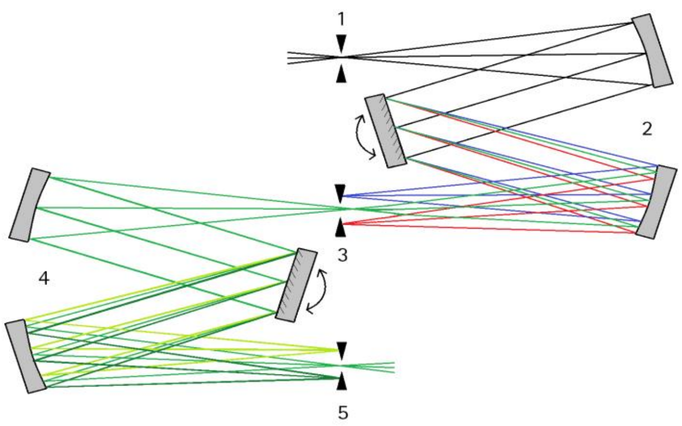
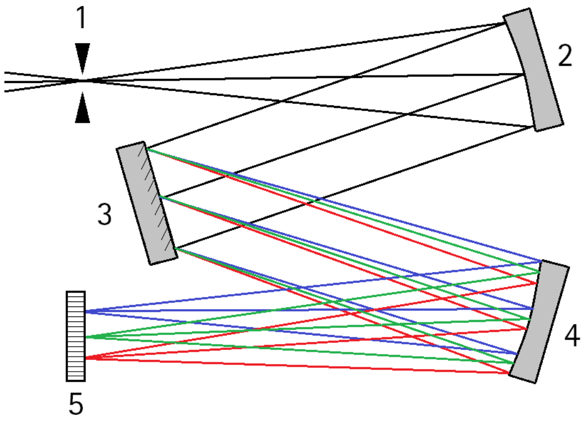
62471
CIE S 009:2002
Première édition
First edition
2006-07
Sécurité photobiologique des lampes et des appareils utilisant des lampes
Photobiological safety of lamps and lamp systems

IEC 62471:2006
CIE S 009:2002

- **Double Monochromator** <-> Array-Spectrometer





- slow scanning, bulky devices, higher cost

Goal:

"Use the advantages of array spectroradiometers also in the UV range!"

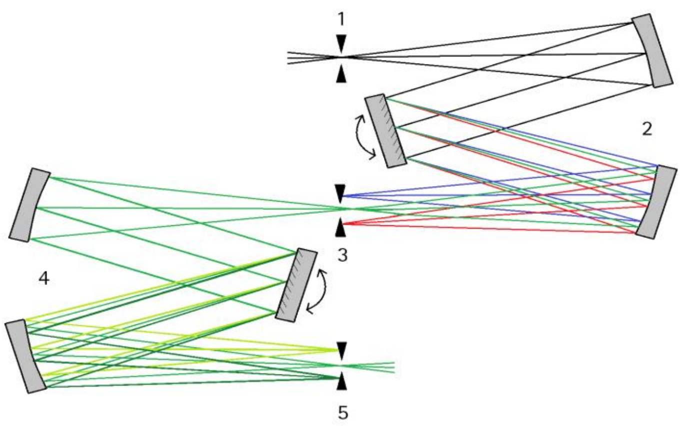
Question:

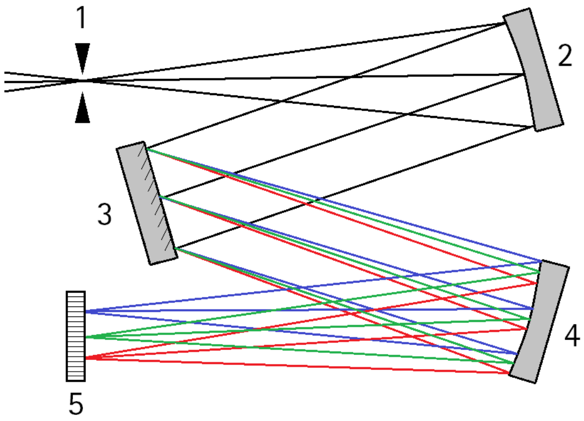
"What is limiting the application of array-spectroradiometers in the UV?"

Answer:

“Internal stray light“

Double Monochromator <-> Array-Spectrometer

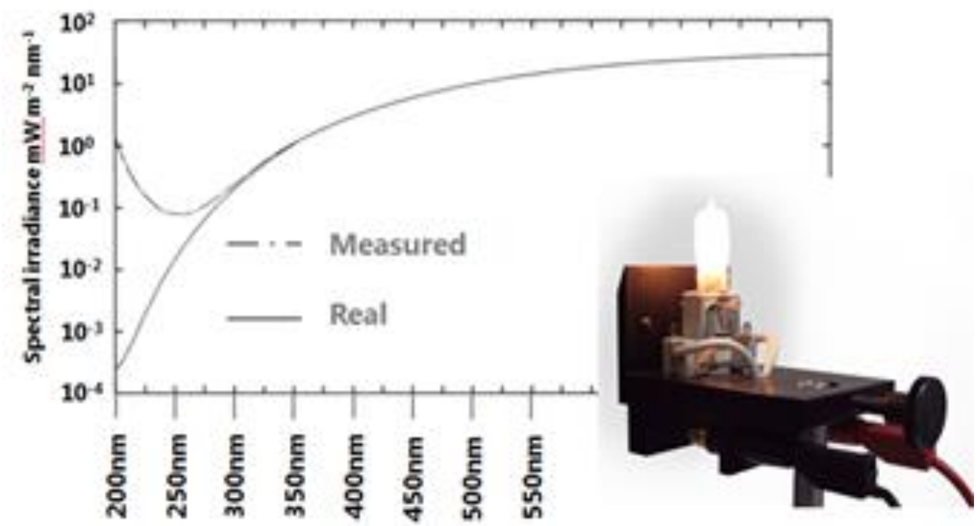




- slow scanning, bulky devices, higher cost
+ stray light performance

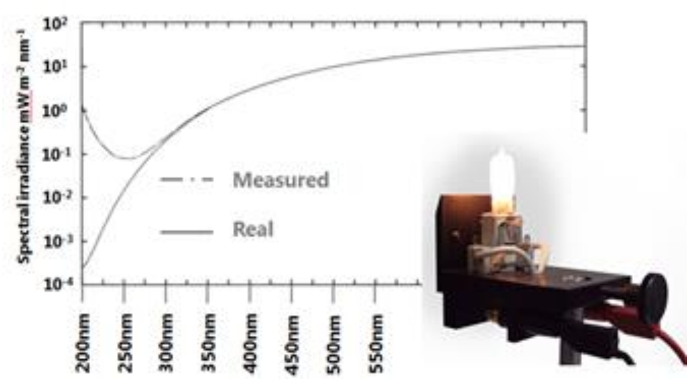
Introduction

- The **internal stray light** is the limiting factor for array-spectroradiometer measurements in the UV spectral range
  - Increases the measurement uncertainty significantly
  - Stray light can be larger than the signal to be measured

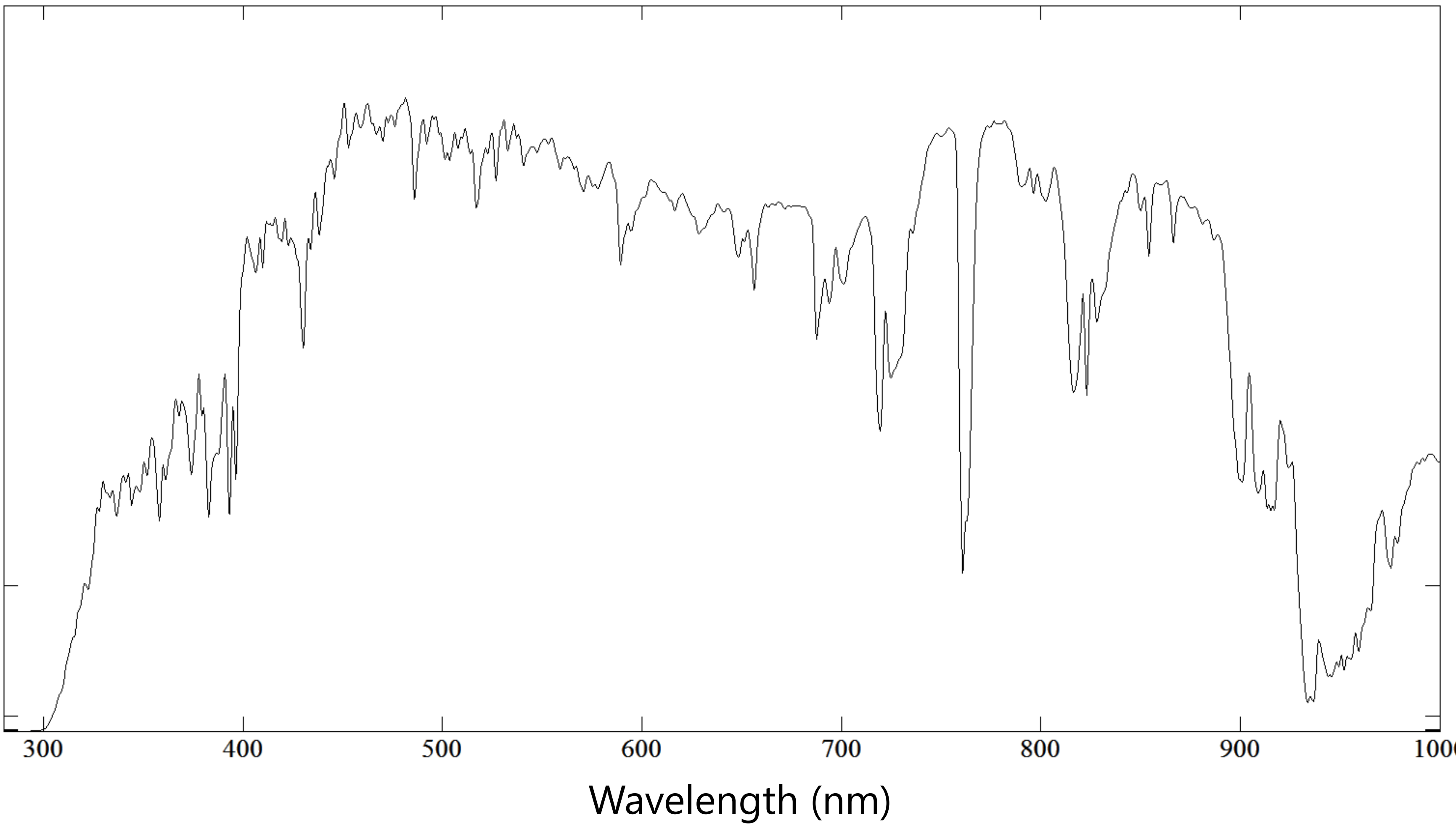


Introduction

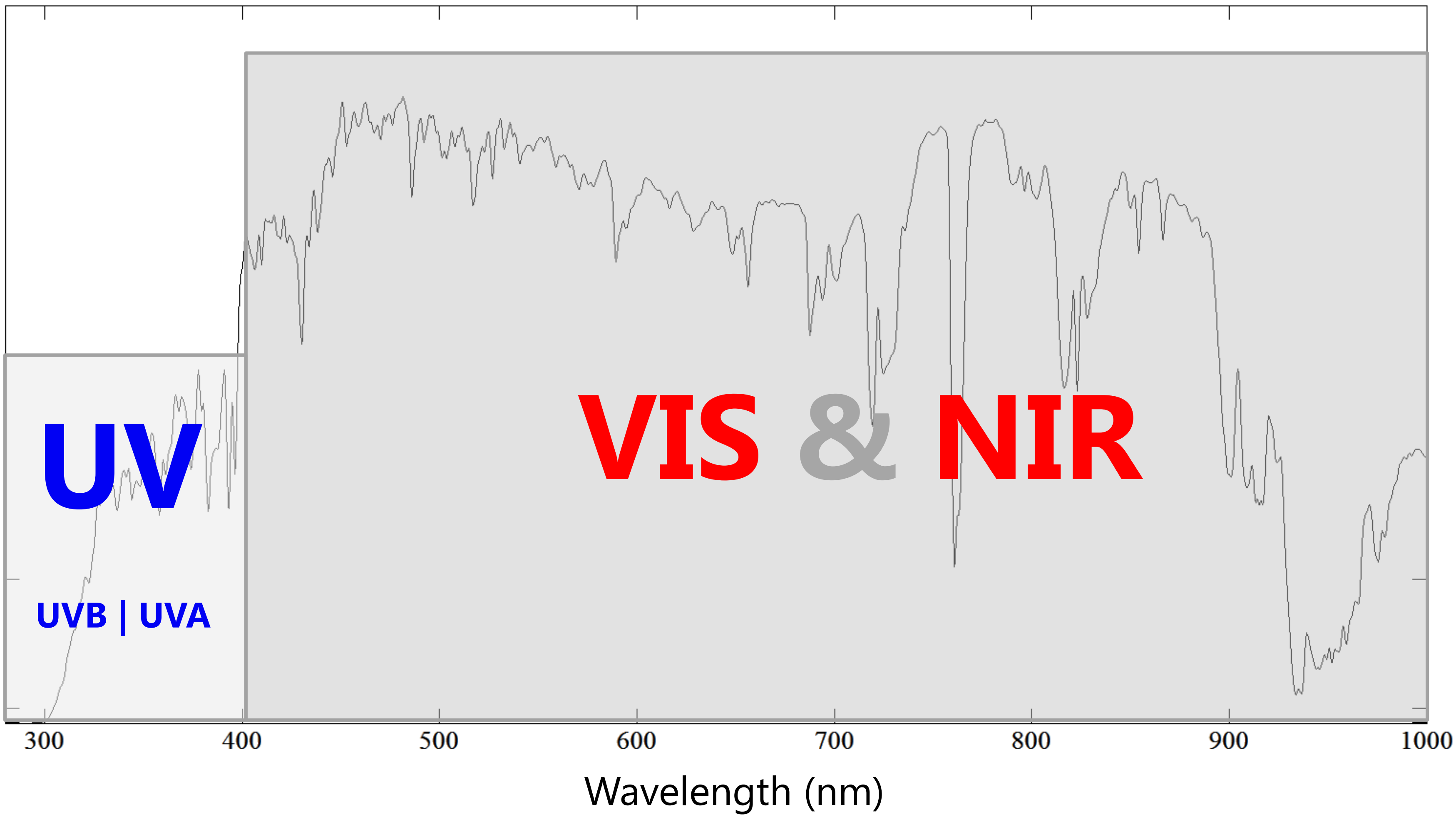
- The **internal stray light** is the limiting factor for array-spectroradiometer measurements in the UV spectral range
  - Increases the measurement uncertainty significantly
  - Stray light can be larger than the signal to be measured
- → Possibility of incorrect classification
  - higher risk group (IEC/DIN EN 62471:2006)
  - product rejection (sun beds)



Origin of stray light

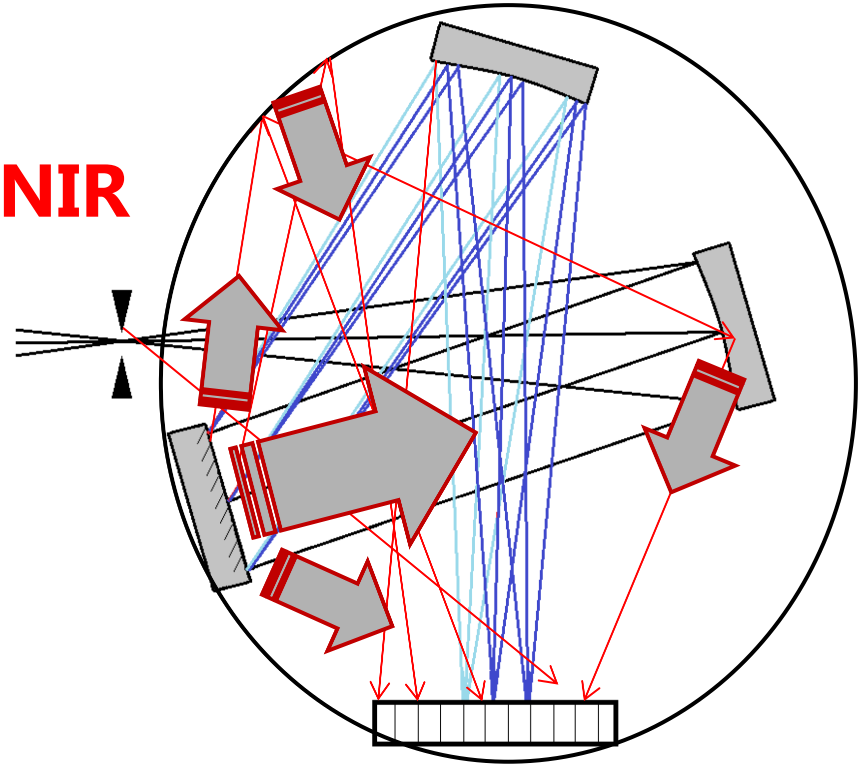


Origin of stray light



Origin of stray light

UV & VIS & NIR



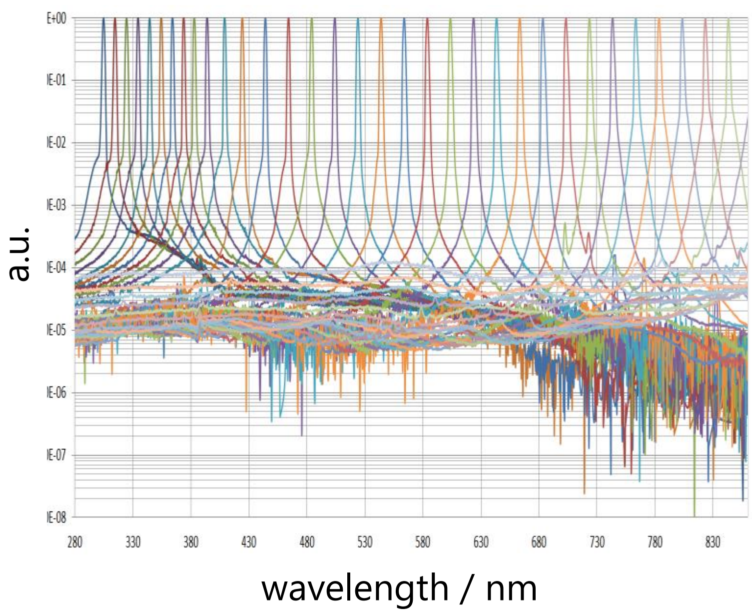
UV

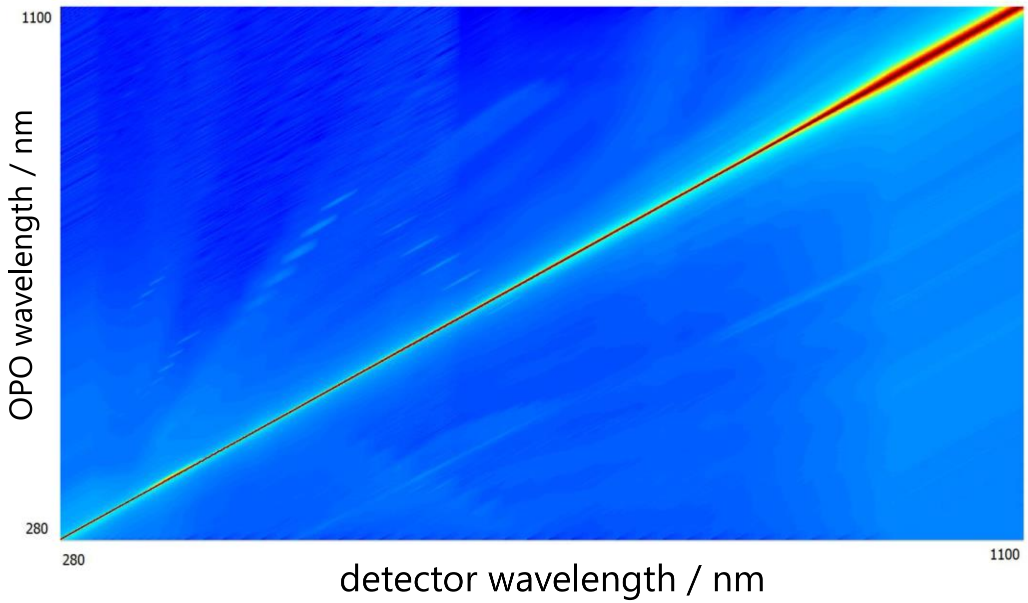
Correction of stray light

Mathematical stray light correction

- Characterization of the device with LSF (Line Spread Functions) over the full spectral range
- Determination and application of correction matrix

(Zong *et al.* 2006, Nevas *et al.* 2014)

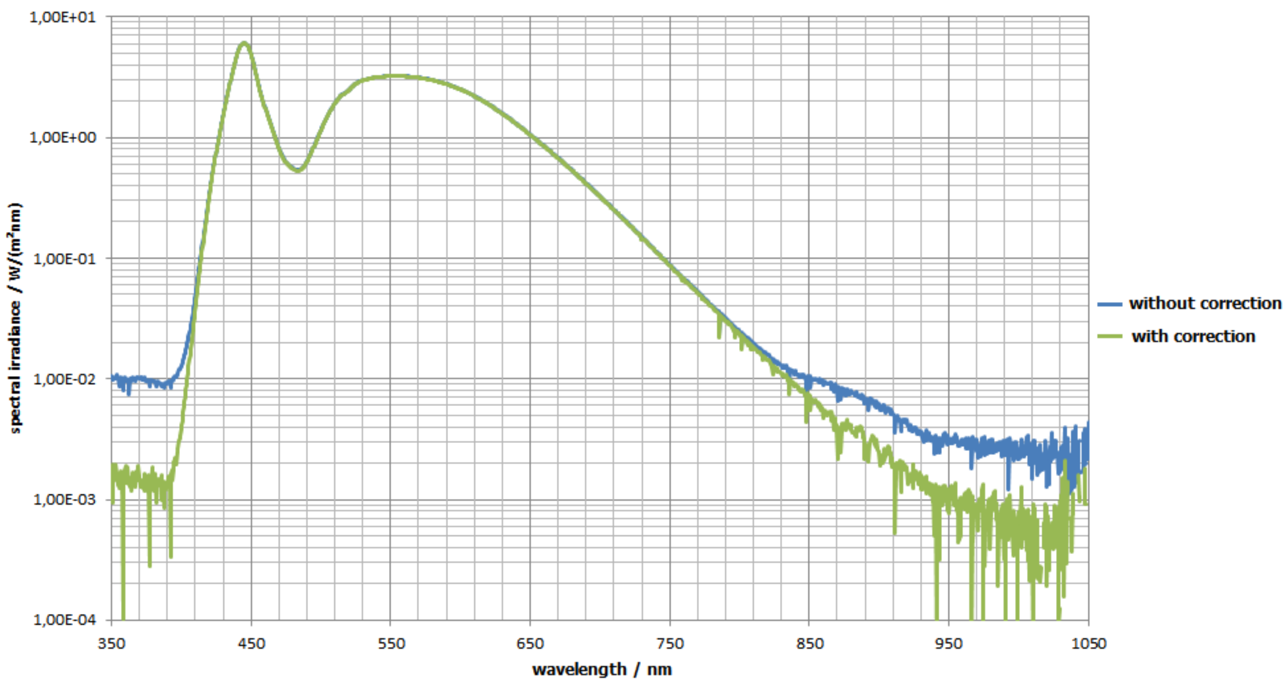




Correction of stray light

Mathematical stray light correction

- Correction of 1 to 2 order of magnitude of In-Range stray light

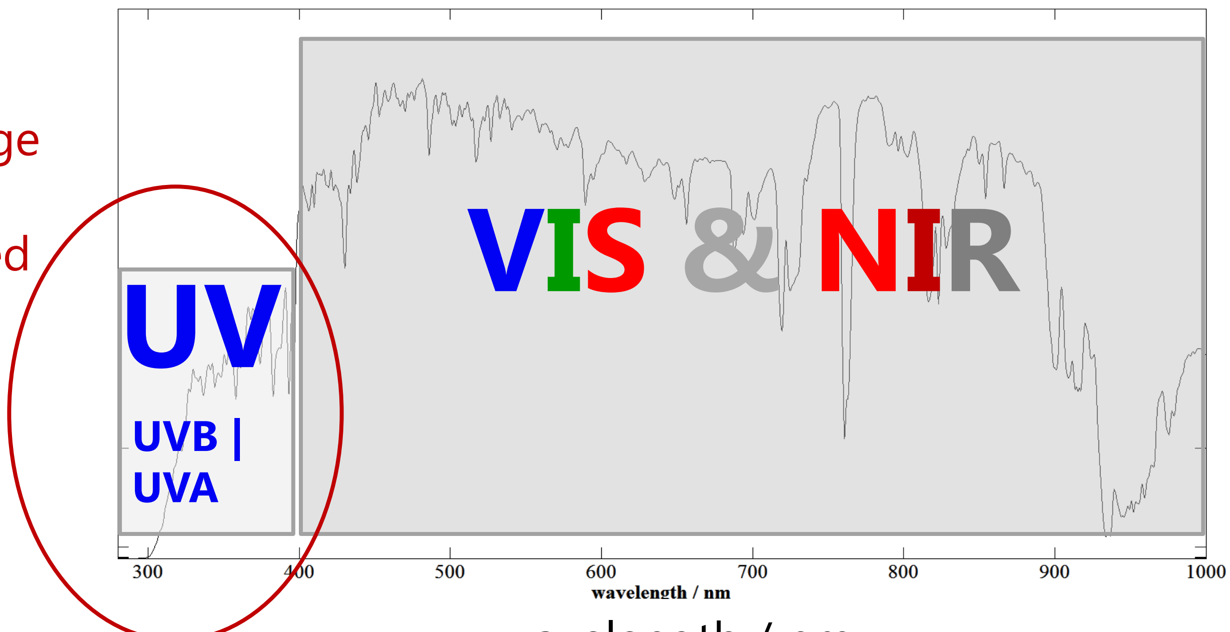


Correction of stray light

Mathematical stray light correction

- Correction of 1 to 2 order of magnitude of In-Range stray light
- For pure UV spectroradiometers not effective. VIS and NIR spectral range can not be characterized and corrected with a single device

Just this spectral range can be characterized



wavelength / nm

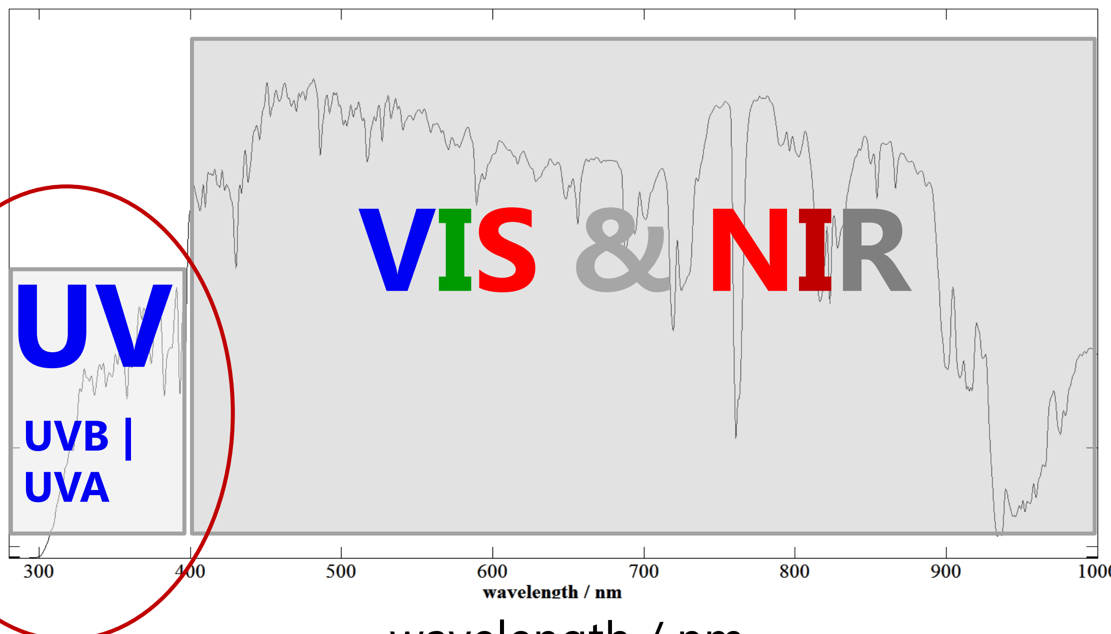
Correction of stray light

Mathematical stray light correction

- Correction of 1 to 2 order of magnitude of In-Range stray light
- For pure UV spectroradiometers not effective. VIS and NIR spectral range can not be characterized and corrected with a single device

Just this spectral range can be characterized

No bandpass filter from 200 nm to e.g. 400 nm available



wavelength / nm

Question:

“How to overcome this limitation?”

Further advanced approaches

- Use of two specroradiometers with different spectral range (one full range of Si, one pure UV)
  - Nevas *et al*. 2014 from PTB

- Use multiple bandpass filters
  - Shaw *et al. 2008* from NPL

- A lot of information is given in the now published document CIE 233

Question:

“Is there another possible approach for the UV range?“

Our approach

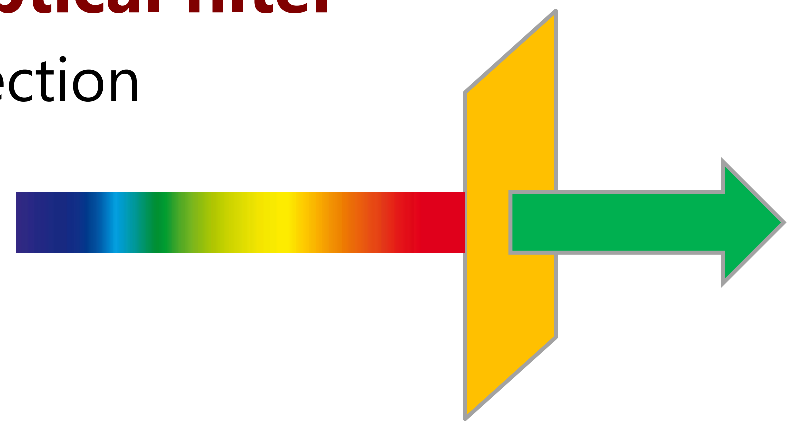
reduce stray light **physically**

and

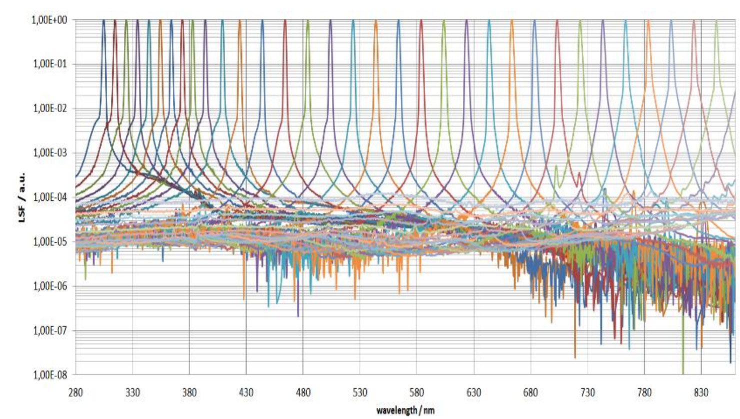
correct remaining stray light **mathematically**

Our approach

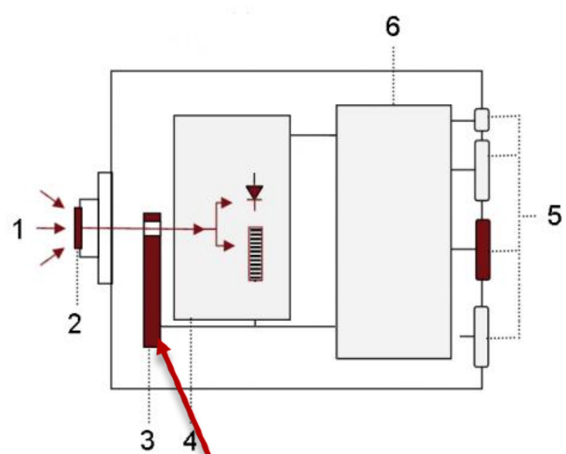
- **Stray light correction by optical filter**
  - Out-of-Range stray light correction (highpass edgefilter)

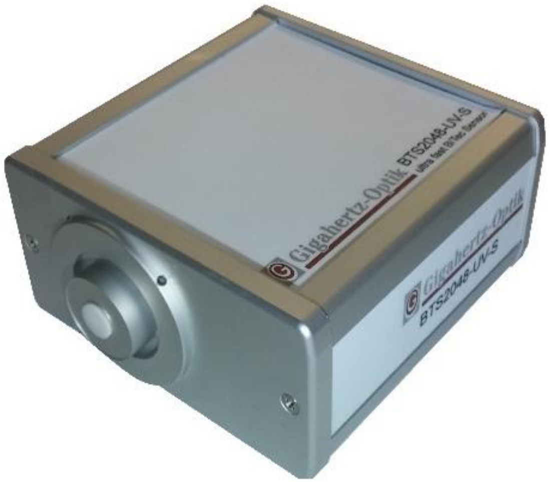


- **Mathematical stray light correction**
  - In-Range stray light correction



Schematical Overview



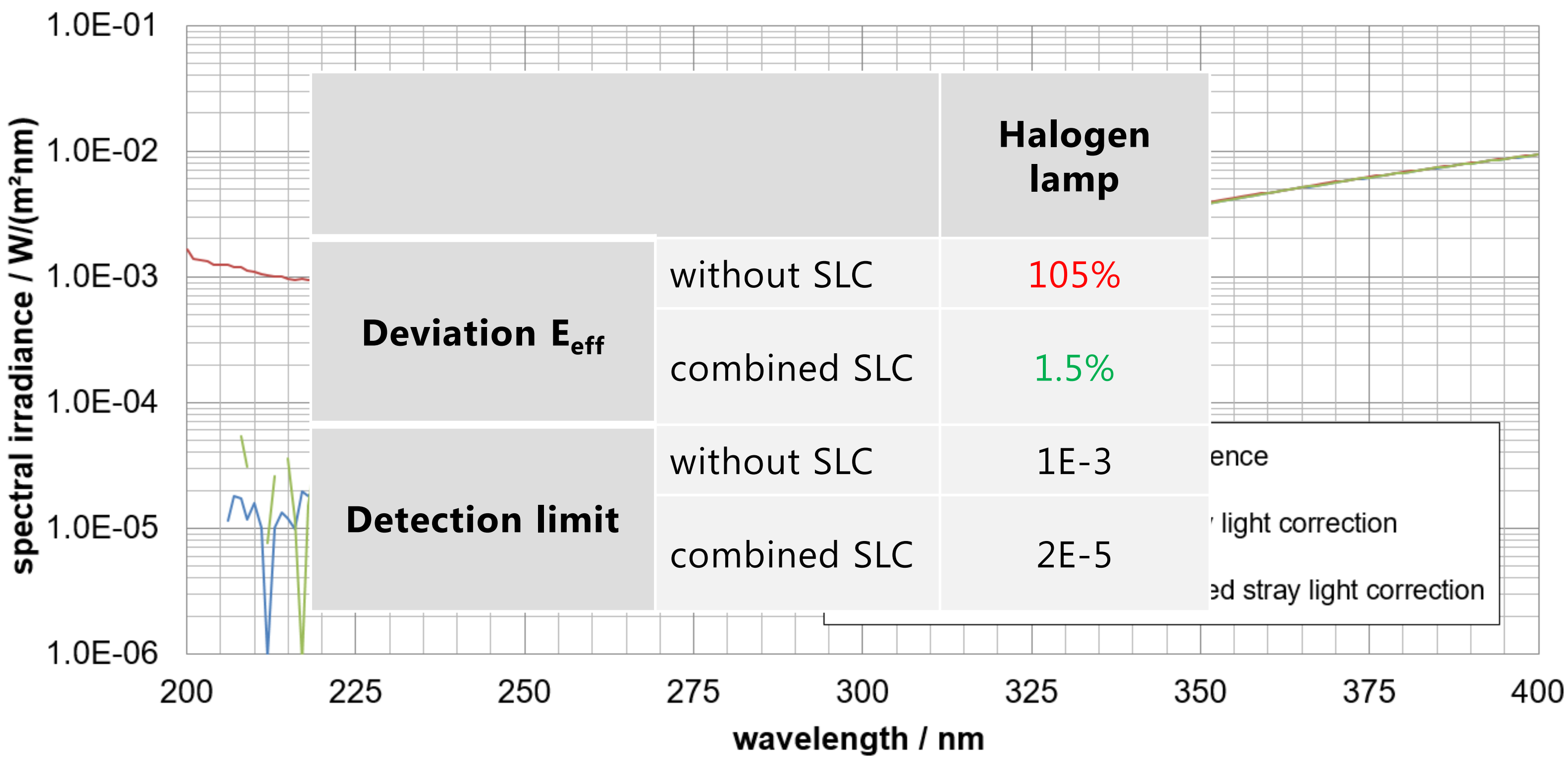


Schematical setup of the BTS2048-UV-S

1) Incoming optical radiation
2) Cosine diffuser
3) **Filter wheel with optical filter**
4) BiTec spectral sensor
5) Electrical connectors
6) Microprocessor for data processing and communication.

Measurement results – Halogen lamp

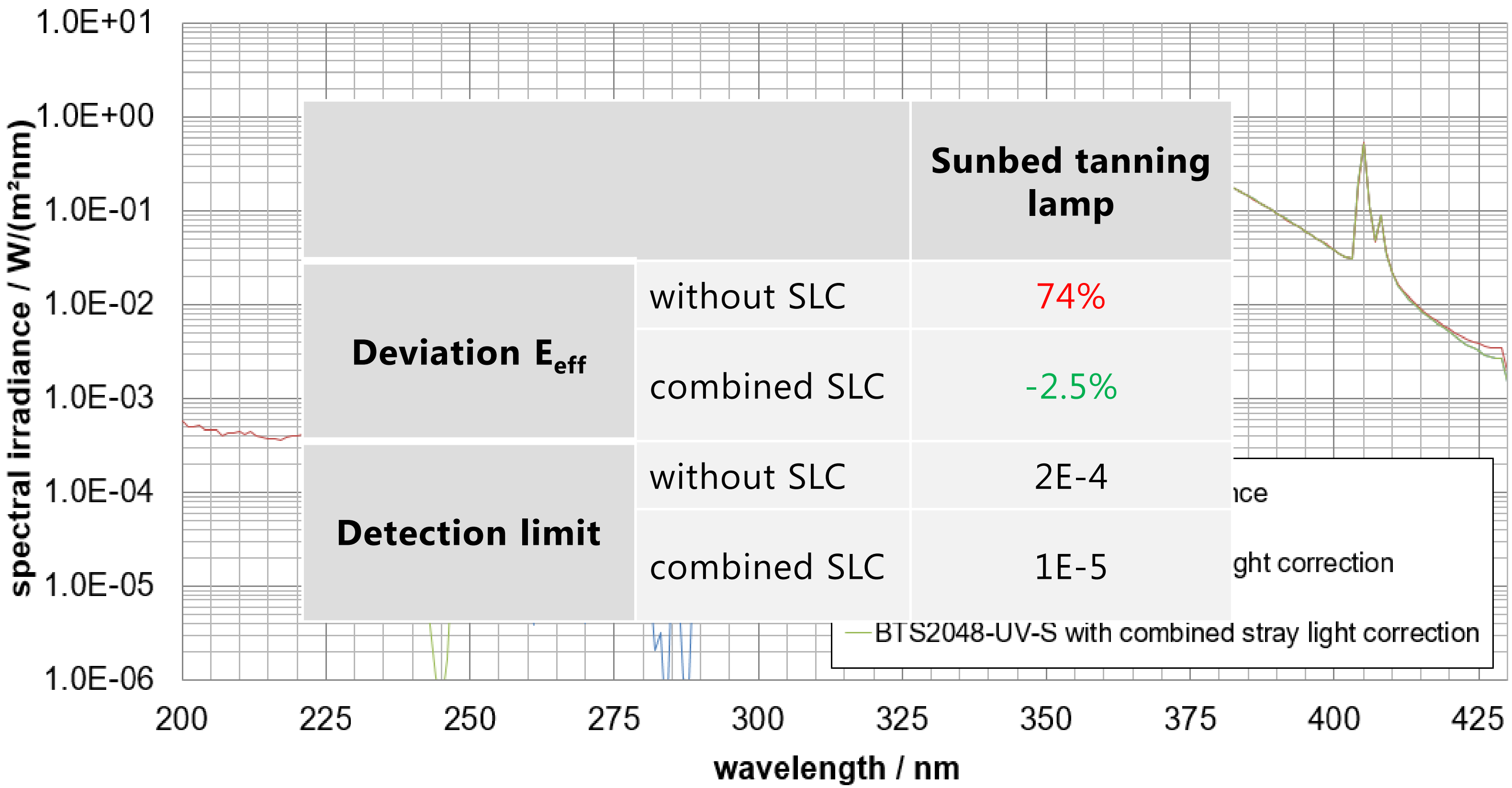
- 250 W halogen lamp measurement at 500 mm distance



		Halogen lamp
Deviation E_{eff}	without SLC	105%
	combined SLC	1.5%
Detection limit	without SLC	1E-3
	combined SLC	2E-5

Measurement results – Sunbed tanning lamp

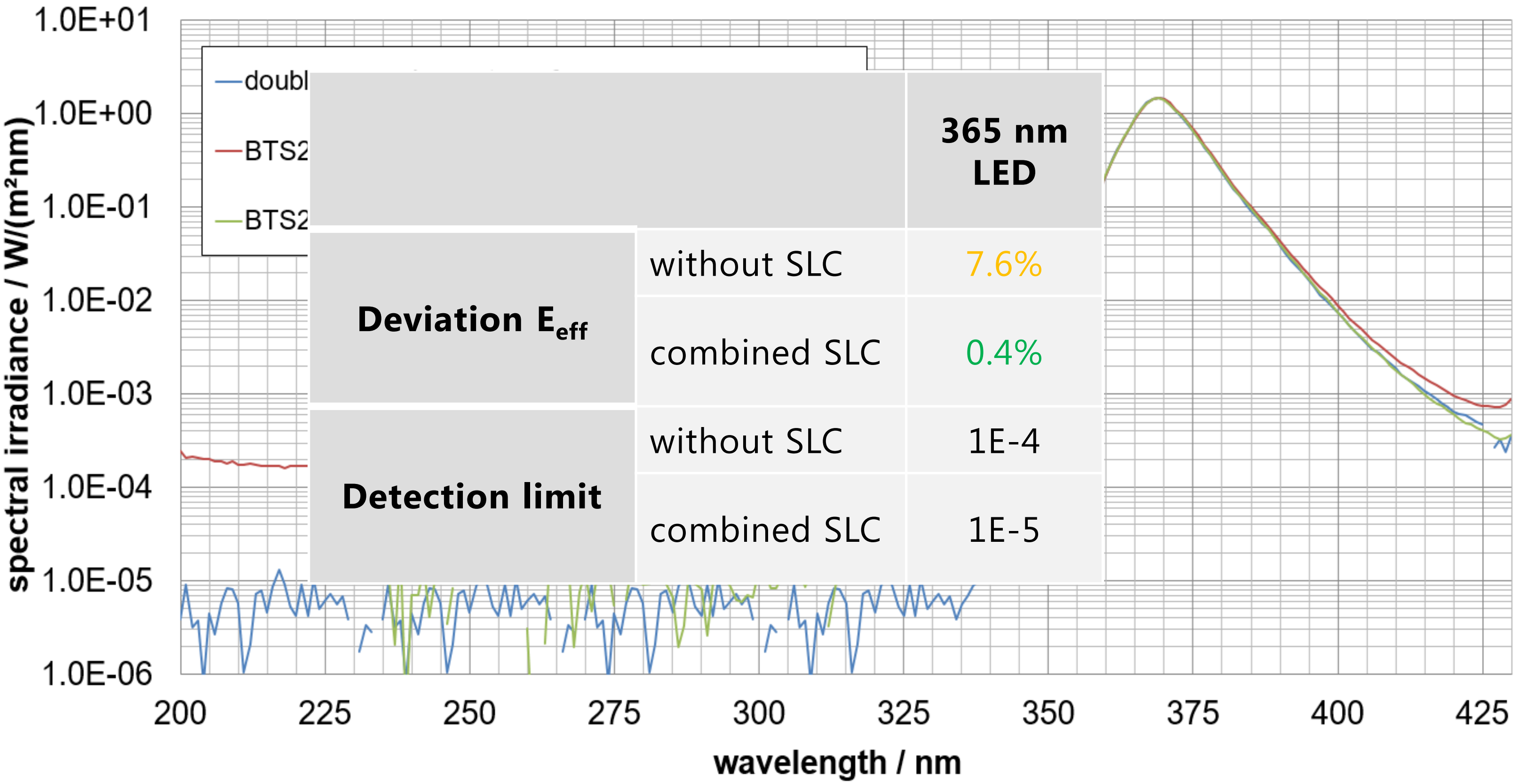
- 4x 15 W sunbed tanning lamp measurement at 150 mm distance



		Sunbed tanning lamp
Deviation E_{eff}	without SLC	74%
	combined SLC	-2.5%
Detection limit	without SLC	2E-4
	combined SLC	1E-5

Measurement results – LED

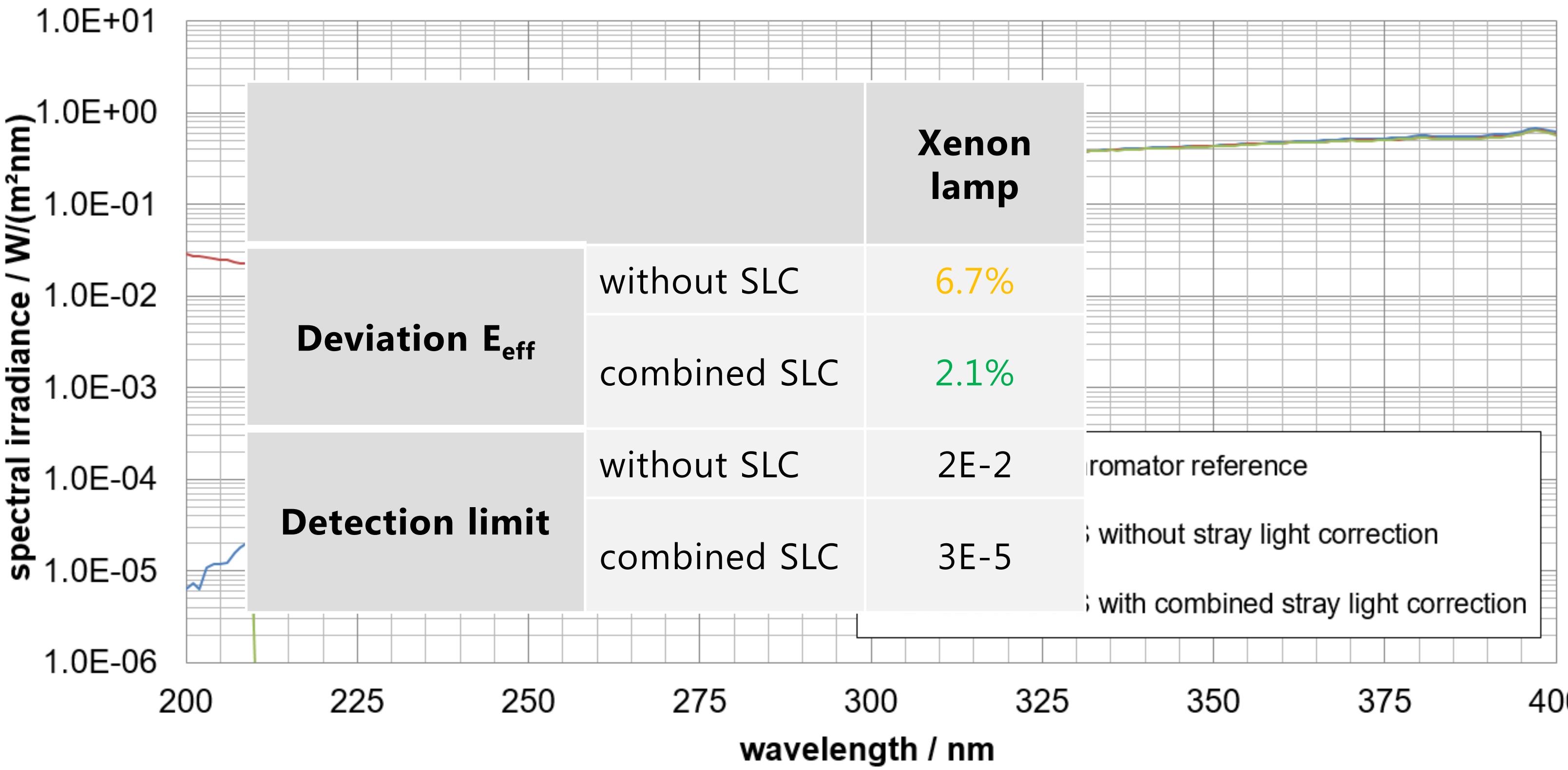
- 365nm LED measurement at 500 mm distance



		365 nm LED
Deviation E_{eff}	without SLC	7.6%
	combined SLC	0.4%
Detection limit	without SLC	1E-4
	combined SLC	1E-5

Measurement results – Xenon lamp

- 450 W Xenon lamp measurement at 180 mm distance



		Xenon lamp
Deviation E_{eff}	without SLC	6.7%
	combined SLC	2.1%
Detection limit	without SLC	2E-2
	combined SLC	3E-5

Summary

		Halogen lamp	Sunbed tanning lamp	Xenon lamp	365 nm LED
Deviation E_{eff}	without SLC	105%	74%	6.7%	7.6%
	combined SLC	1.5%	-2.5%	2.1%	0.4%
Detection limit	without SLC	1E-3	2E-4	2E-2	1E-4
	combined SLC	2E-5	1E-5	3E-5	1E-5

→ E_{eff} of all tested lamps was measured with a deviation lower than 3% to a double monochromator reference

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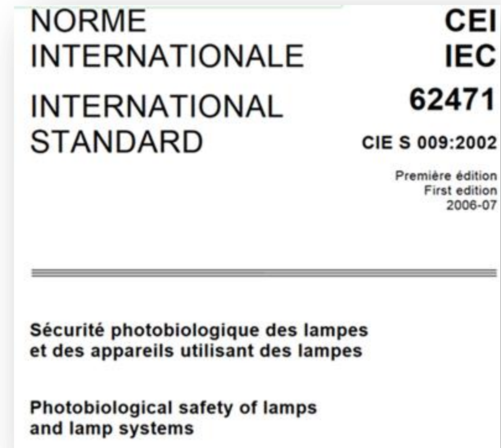

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→ E_{eff} of all tested lamps was measured with a deviation lower than 3% to a double monochromator reference

→ Measurement results suggest that UV hazard evaluations (ACGIH/ICNIRP) according to CIE S009/IEC 62471:2006 are possible with this approach

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→ Stray light corrected array spectroradiometer measurements down to 200 nm are possible for every type of light source