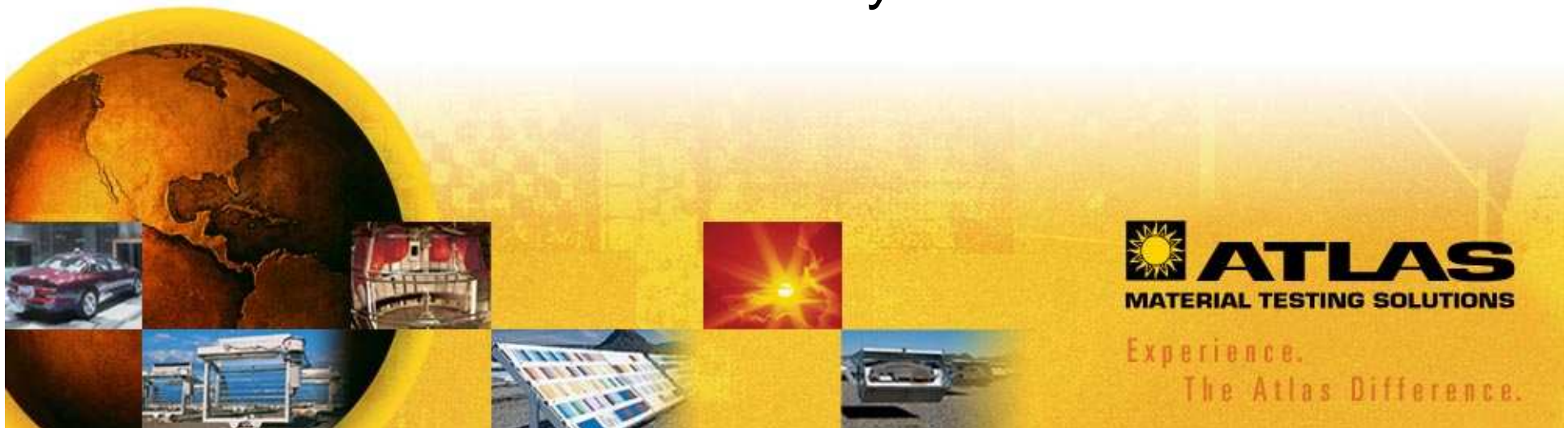


# Comparison of Measurements of Spectral Irradiance (UV/VIS) by an International Round Robin Test

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# Motivation



- Determination of the Deviation of Irradiance measured by different laboratories
  - Which are not from national metrology institutes but labs from
    - Commercial companies
    - Non profit institutes
    - ... *the field* ...
- In continuation of a further round robin (1993-1995) initiated by GUS (Gesellschaft für Umweltsimulation) conference 1992



# Participants



- ATLAS MTT GmbH, Linsengericht, Germany
- opto.cal GmbH, Movelier, Switzerland
- ATLAS MTT LLC, Chicago, USA
- Heraeus Noblelight GmbH, Hanau, Germany
- 3M, St. Paul, USA
- ATLAS DSET Laboratories Inc., Phoenix, USA
- Bundesanstalt für Materialforschung und -prüfung BAM, Berlin, Germany
- Fraunhofer Institut für Solare Energiesysteme, Freiburg, Germany
- Institut für Solartechnik, Hochschule für Technik, Rapperswil, Switzerland
- L'Oréal, Clichy, France



# Organisation and Realisation



- Not ruled by ISO/IEC Guide 43
- Process harmonized by all labs
- Equipment was shipped from lab to lab one after another
- Package included all except of voltage stabilizer and spectrometer
- Period of measurements from late 2003 to August 2005

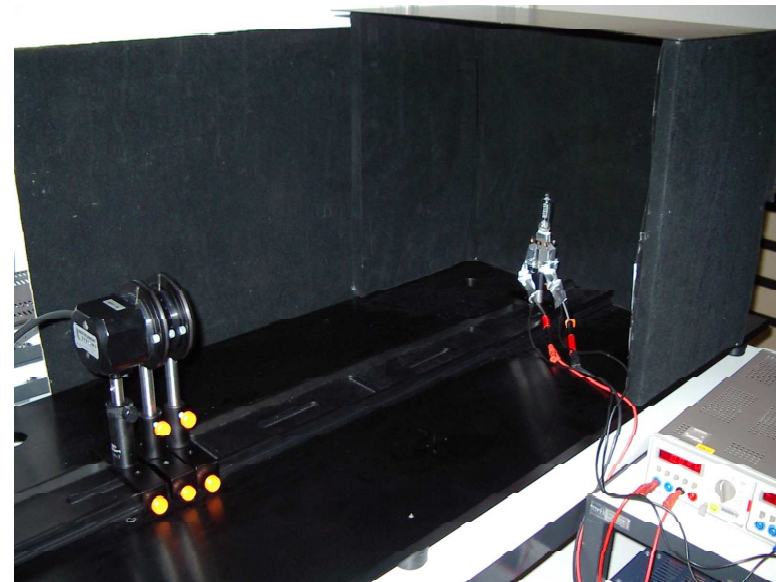


# Objects of interest -1-



- Halogen lamp (1000W)
  - GE Q1000CL/4CL
  - Ushio lamp #1000509 (in exchange)

- Smooth spectra
- No emission lines
- DC driven





## Object of Interest -2-



- Xenon discharge lamp
  - Heraeus NXe1500A driven in a modified ATLAS Suntest Device

- Spectra with emission lines
- AC driven i.e. 100/120 statistical light cycles a second
- Electrical power limited by a ballast

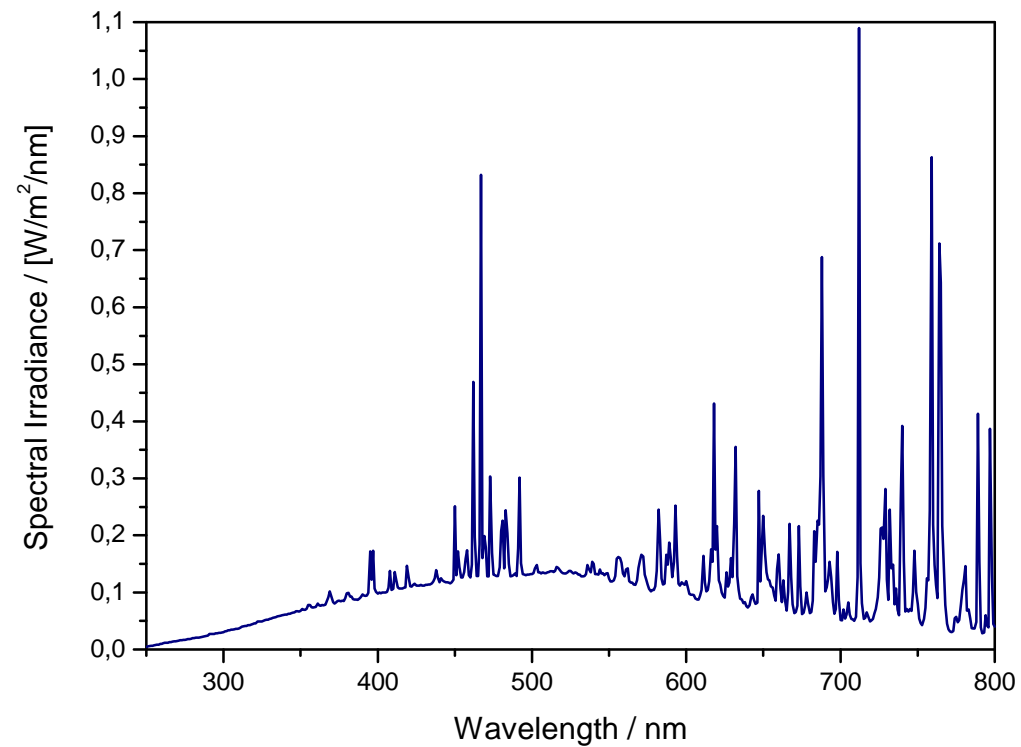




# Xe Spectrum



- Emission lines superposed with continuum





# Tasks



- Measuring spectral irradiance
  - In the range from 250 nm to 800 nm
  - Spectra in 1 nm steps
  - Without any additional edge filter and with WG280 and with WG335
  - Xe lamp at 50 and 60 Hz
- Also to be measured
  - Illuminance
  - Lamp Voltage, current



# Budget of Uncertainty



- Uncertainty of Measurement (k=1)
  - Lamp Voltage 0.06 %
  - Lamp Current 0.33 %
  - Illuminance 0.3 %
  - Distance Lamp – Sphere 0.5 %



# Spectrometers in use



Denomination	Type	Detector	Sphere	Stepping Grid
CAS140	single, array	CCD	40 mm	<1 nm
Zeiss	single, array	Si	75mm	0.9 nm
Zeiss	single, array	Si	70 mm	2,4 nm
DM150EC	double, scanning	PMT	plan	1 nm
DMc150	double, scanning	PMT	plan	1 nm
DTM	double, scanning	PMT	plan	3 nm
Gamma 4100B	double, scanning	PMT	6"	1 nm
Gamma NMH9	double, scanning	PMT	100 mm	3,5 nm
Macam 9910V7	double, scanning	PMT	63 mm	1 nm
Spectro 320D	double, scanning	Si+InGaAs	plan	1 nm
Spectro 320D	double, scanning	PMT	20 mm	2,5 - 3 nm
OL-754	double, scanning	PMT	6"	1 nm
OL-754	double, scanning	PMT	4"	<1 nm



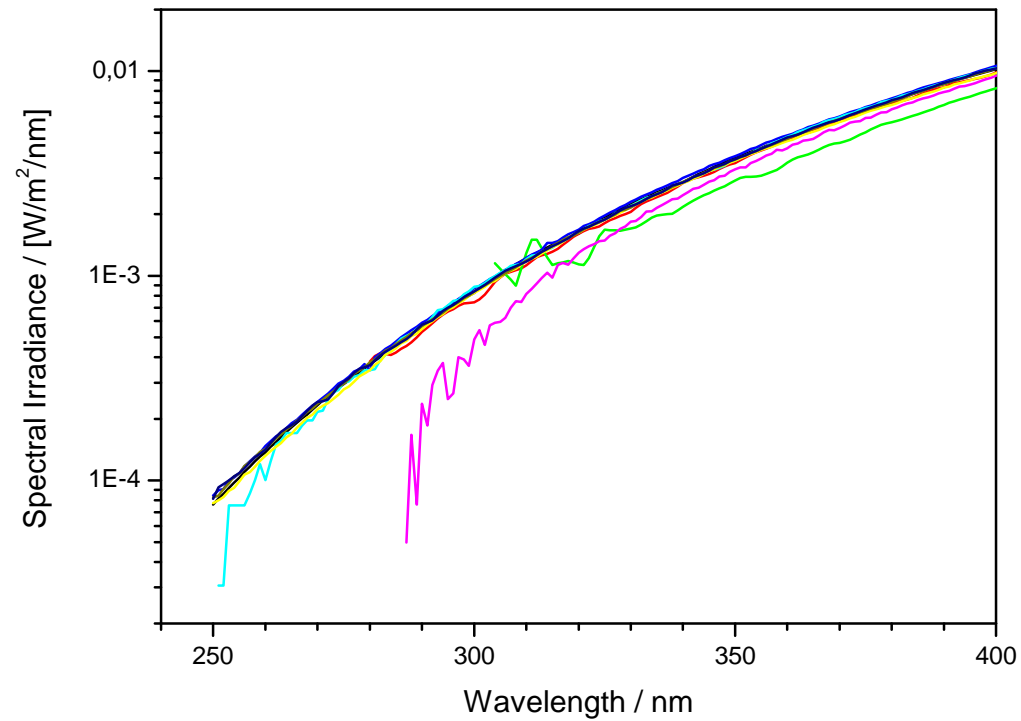
# (spectral) Irradiance



- Spectral range divided into several intervals  
20 (UV) – 100 nm (VIS)
- Comparison of the integrated Irradiance of that intervals
- Xe spectra consist of emission lines
  - Comparison “pixel by pixel” not reasonable due to
    - Different spectral resolution of different spectrometer
    - Uncertainties of wavelength calibrations
    - Uncertainties of repositioning of grating



# Halogen Lamp Spectra





# Attendant Evaluations



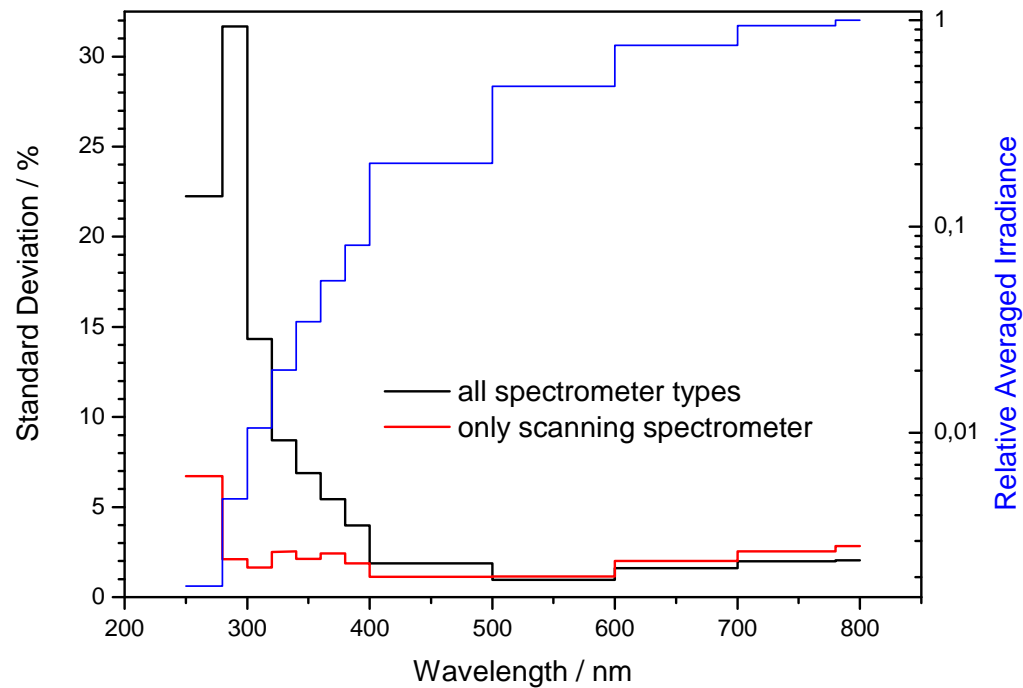
- Operating data (Voltage)
  - Q1000  $\sigma < 0.1\%$
  - Ushio  $\sigma < 0.2\%$
- Color temperature
  - Q1000: 3111 K ( $\sigma = 0,6\%$ )
  - Ushio: 3094 K ( $\sigma = 1\%$ )
- Calculated (from spectra) illuminance
  - Q1000 3.91 klx ( $\sigma = 1,1\%$ )
  - Ushio 3.83 klx ( $\sigma = 4.0\%$ )



# Standard Deviation Halogen



- Q1000 (n = 6)



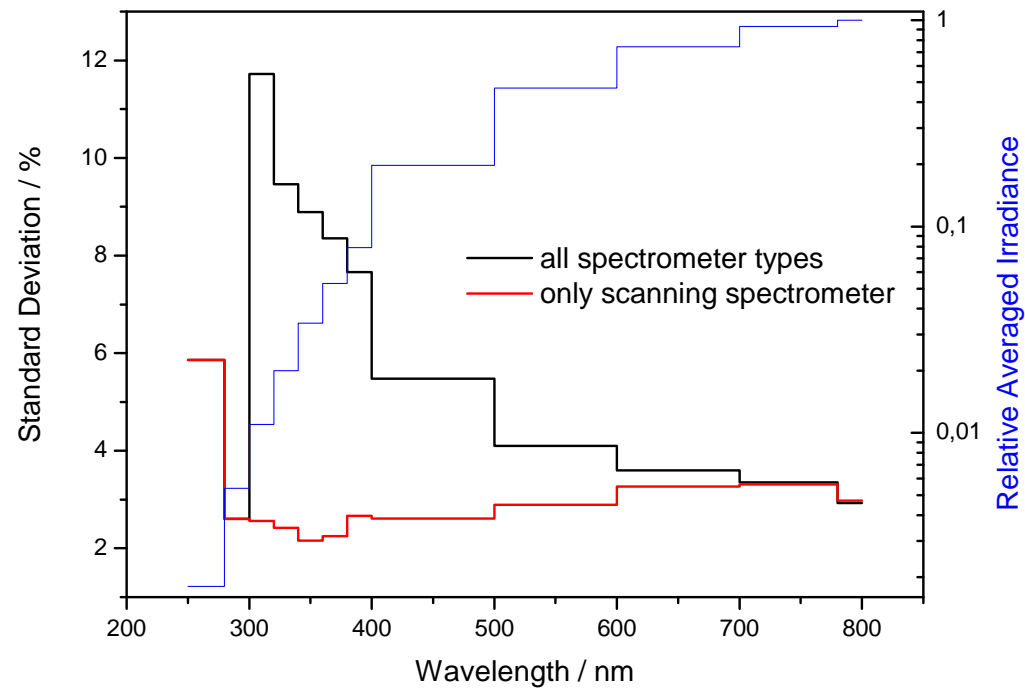
Dynamic range  
of FEL spectrum  
3 orders of  
magnitude



# Standard Deviation Halogen



- Ushio (n = 9)

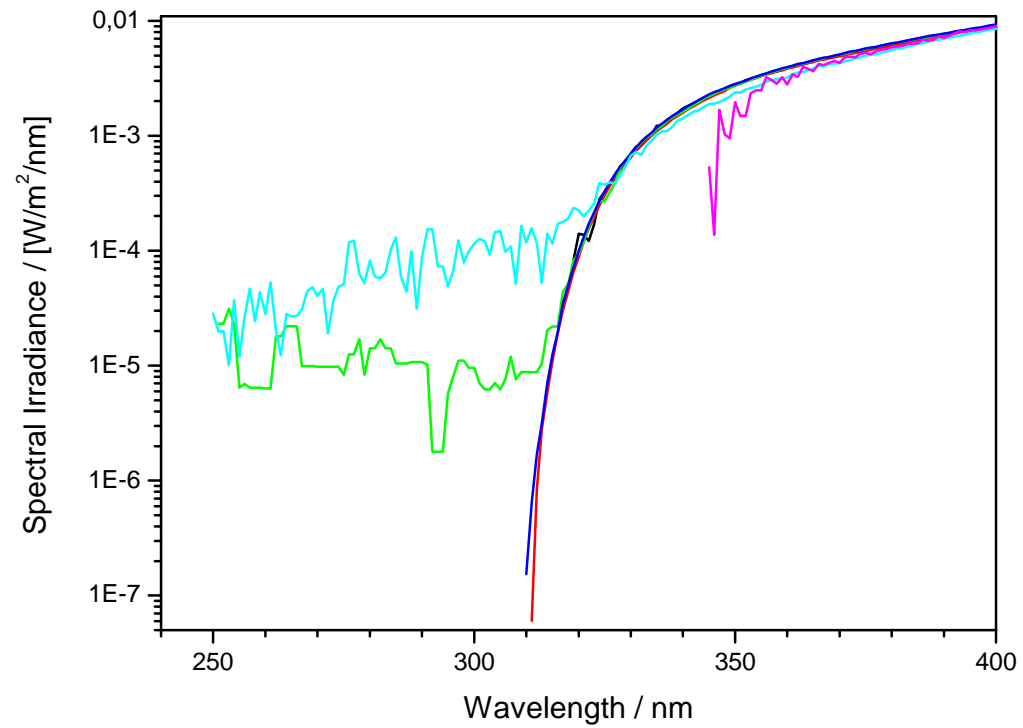




# Edge Filter WG335

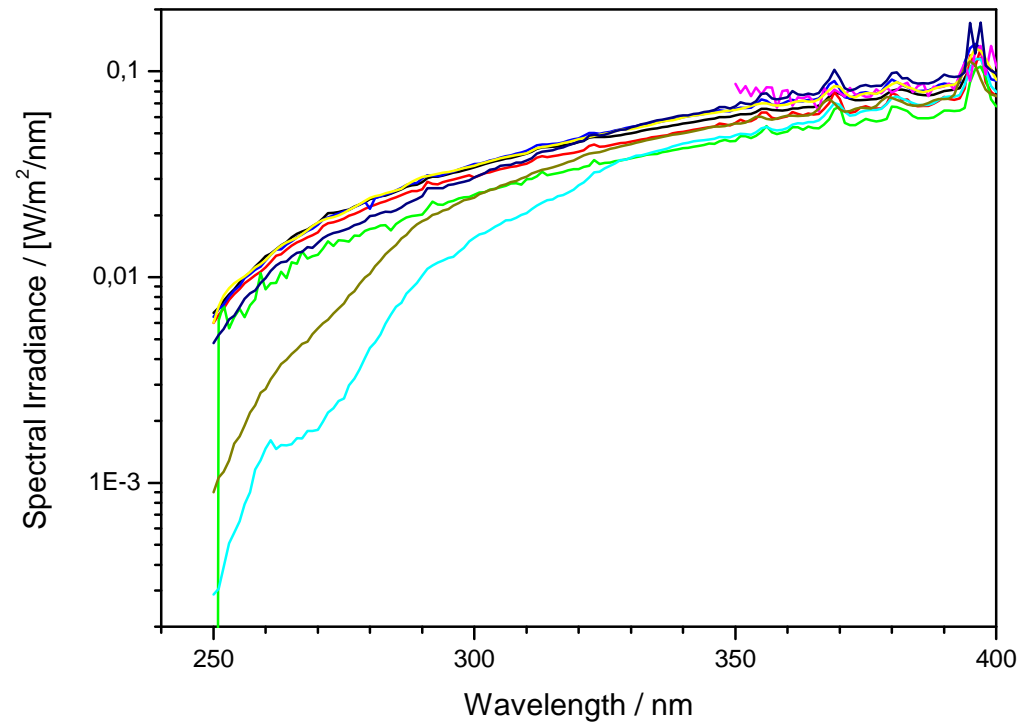


- Check of dynamical range in UV





# Xe Spectra (50Hz)





# Attendant Evaluations



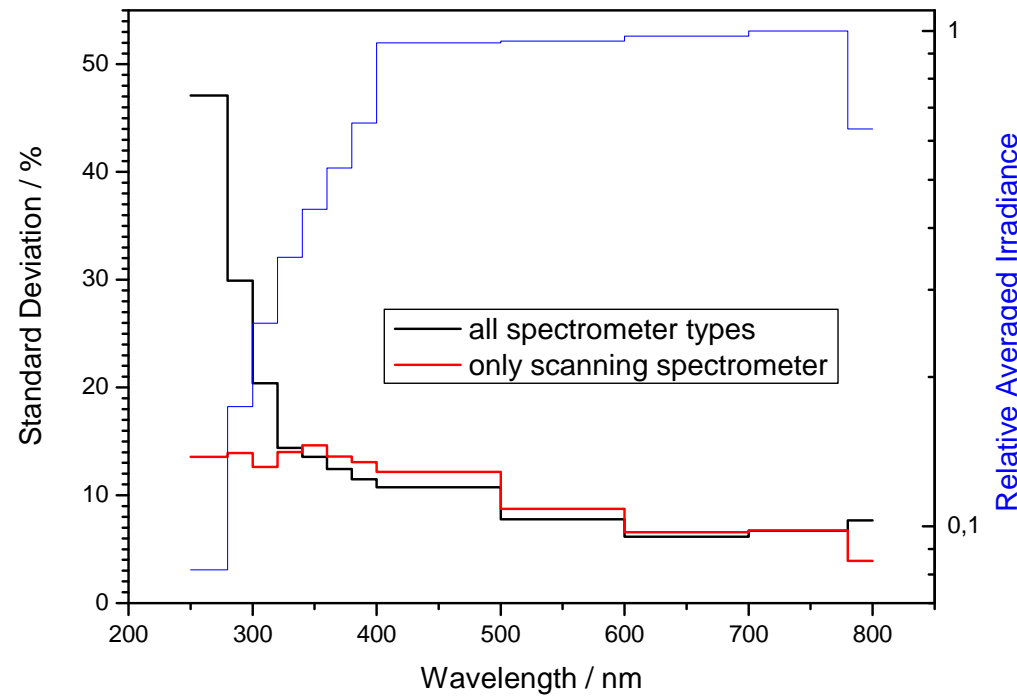
- Operating data
  - Voltage  $\sigma = 0.7\%$
  - Current  $\sigma = 2.6\%$
- Calculated illuminance
  - $\sigma = 7.6\%$



# Standard Deviation Xe(50Hz)



- $n = 9$  (european labs)



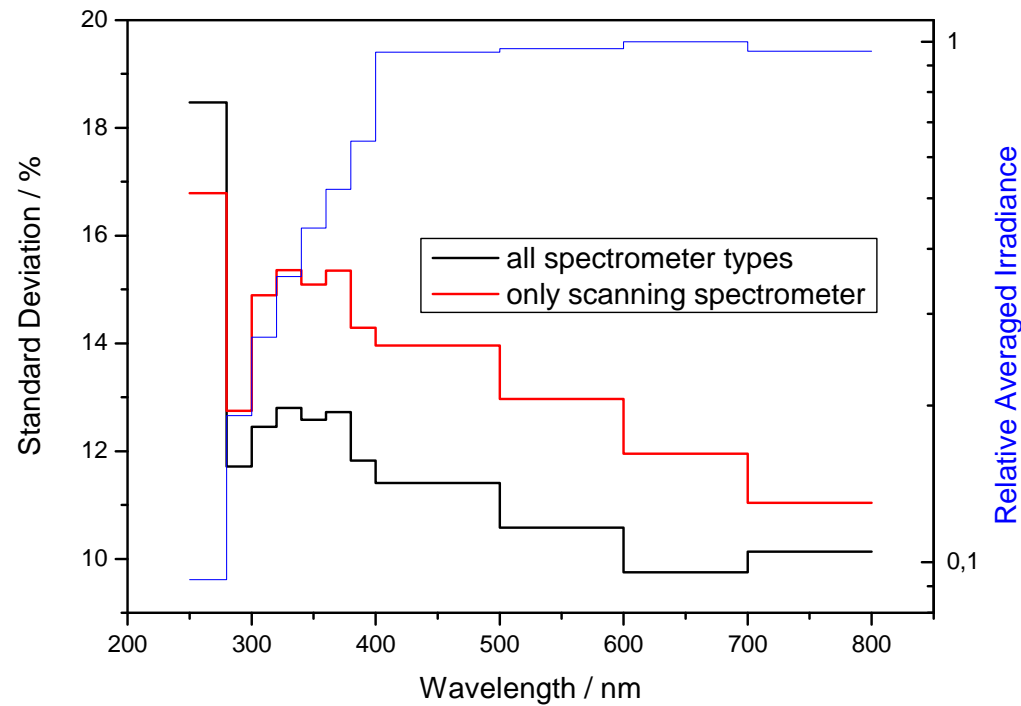
Dynamic range of  
Xe-spectrum only  
1 order of  
magnitude!



# Standard Deviation Xe (60Hz)



- Only 3-4 data sets! (2 US labs + 2 european)  
Value of sdev not really meaningful





# Summary



- Two classes of lamps were investigated
  - Halogen, Xe (AC, emission lines)
- SDevs in the range
  - Halogen 2-7% (250-400nm), 1-3% (400-800nm)
  - Xe 11-47%, 6-11%
  - SDevs much worse than of measurements with a single specrometer at same lamps
- Initial assumption about stability of lamps (especially exchange lamp Ushio and Xe) not confirmed



# Outlook



- Closing this round robin by finishing evaluation and by writing a detailed report
- Internal discussion about results and ...
- Arranging a further round robin
  - With tightened measuring/evaluation program
  - More effort on stabilization of the lamps  
new ideas / approaches wanted
  - New/more interested parties for participation are welcome