Aalto University
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Engineering

MIKES

Luminous Efficacy Measurement Setup for Solid-State Lamps

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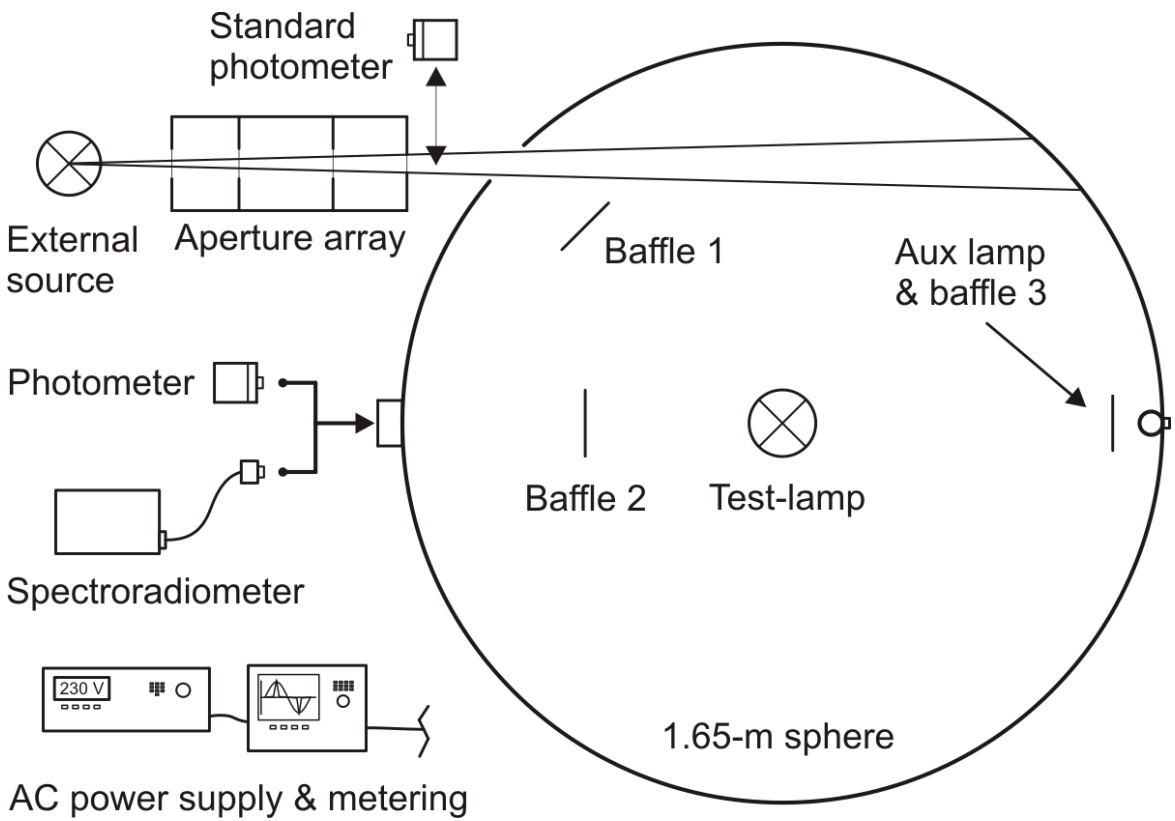
Introduction

- Luminous efficacy [lm/W], energy efficiency of light sources
- Solid-State Lamps (SSLs)
  - -E27 retrofit SSLs work with AC-voltage (230 / 110 V RMS)
  - -Consist of LEDs, built-in power supply, heatsink, optics
  - -Complicated optical and electrical properties

Integrating sphere setup

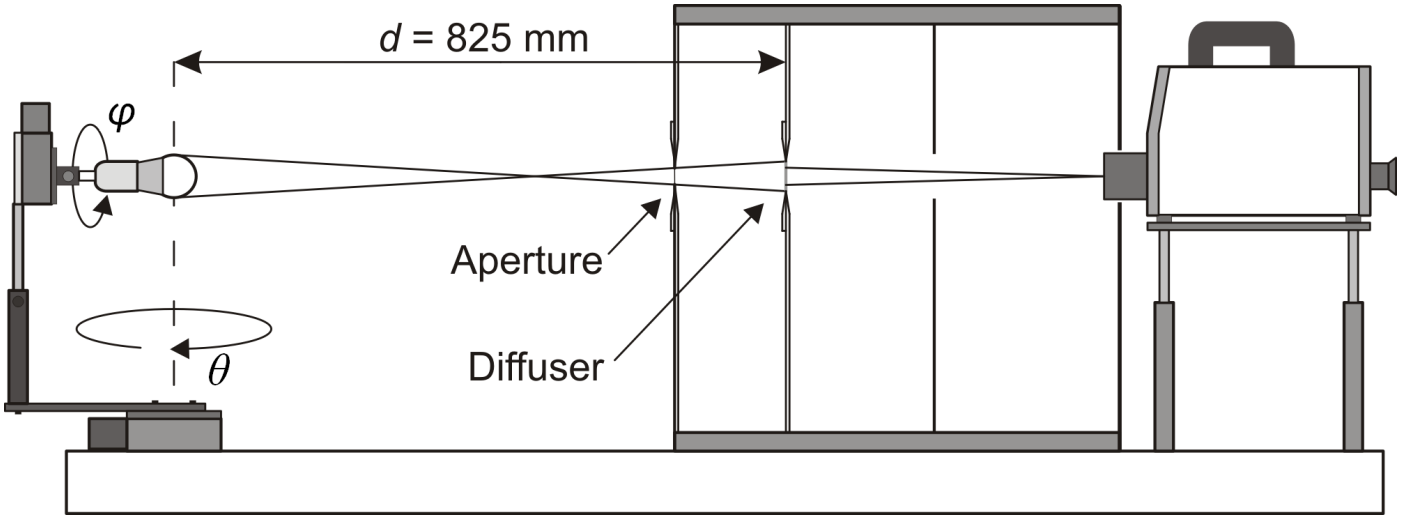
Luminous flux & Electrical power measurement



Goniospectrometer

Relative angular and spectral characterization

- Luminous intensity distribution of SSL -> Spatial correction
  -Spatial Responsivity Distribution Function (SRDF) of sphere is needed
- Spectral irradiance as a function of angle of observation



Test measurements

- 25 E27-base SSLs were measured after 100-h burn-in
- 23 C ambient temperature of room, 230 V, 50 Hz AC-voltage
- Lamps were allowed to stabilize 1–3 hours
- Luminous efficacy, spectral radiant flux, angular measurements
- Waveforms of luminous flux and electrical current

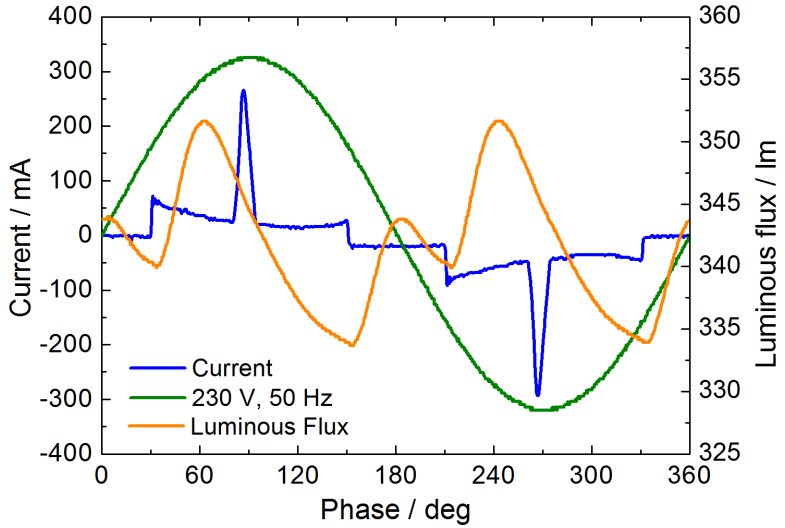
Combined measurement results

- Large differences between SSLs were found:
  - Luminous efficacy: 25 – 68 lm/W
  - [1]Ripple of luminous flux: 0.06 – 105 % (typically 100 Hz)
  - Power factor: 0.35 – 0.95
  - [2]THD of current: 30 – 280 %
- 5 lamps fully pulsed, 9 lamps with <10 % of ripple
- Large differences in the qualities of the built-in electronics
- Lamps with >200 % THD problematic in power measurements

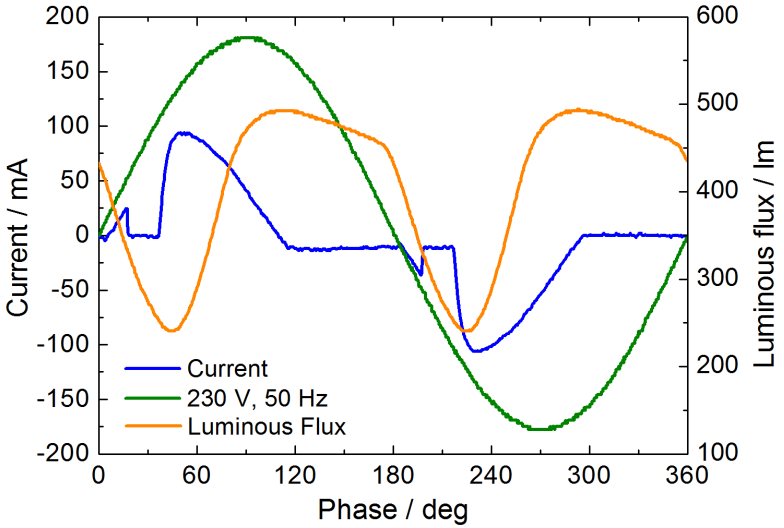
[1] Ripple was analyzed as the maximum deviation of the flux from its mean value

[2] THD = Total harmonic distortion, determined with Fast Fourier Transform method (FFT)

Waveforms of SSLs

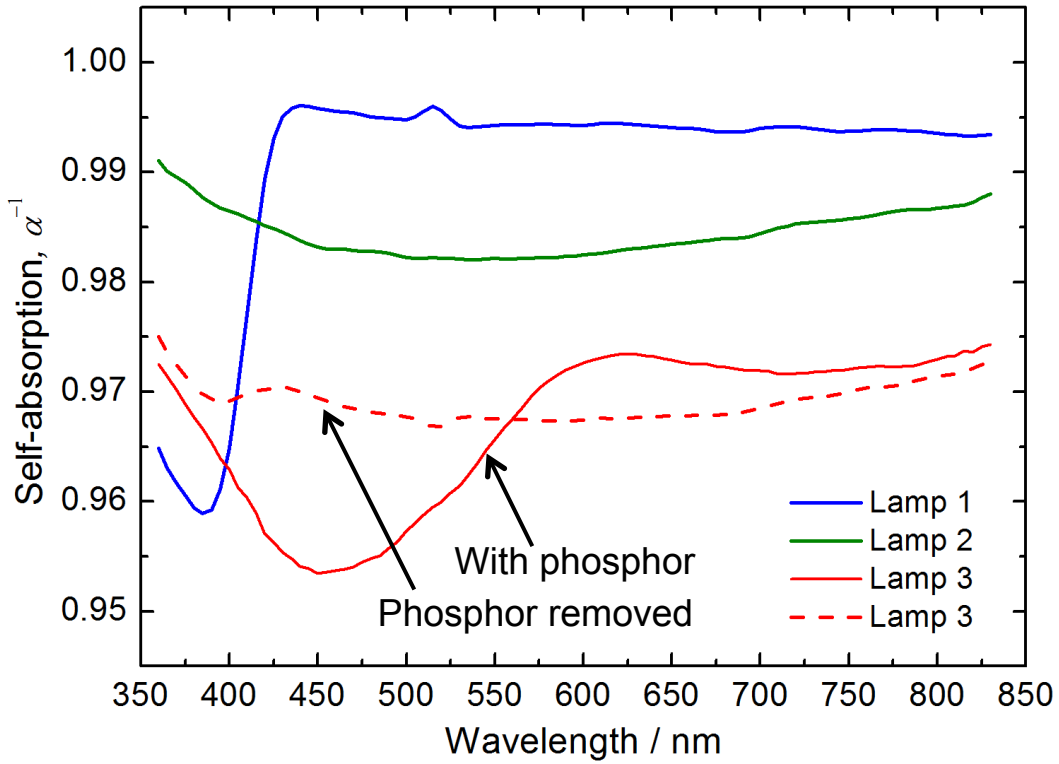


- Luminous efficacy: 33.2 lm/W
- Ripple of flux: 2.6 %
- Power factor: 0.72
- THD of current: 90 %



- Luminous efficacy: 53.9 lm/W
- Ripple of flux: 31.4 %
- Power factor: 0.70
- THD of current: 72.2 %

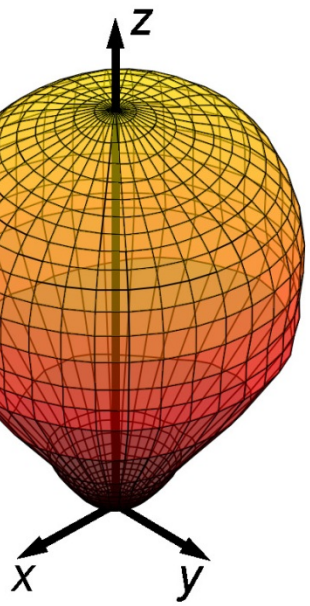
Spectral self-absorption



- Contribution to luminous efficacy small & less than 17 K in CCT
- May have significant contribution with small integrating spheres

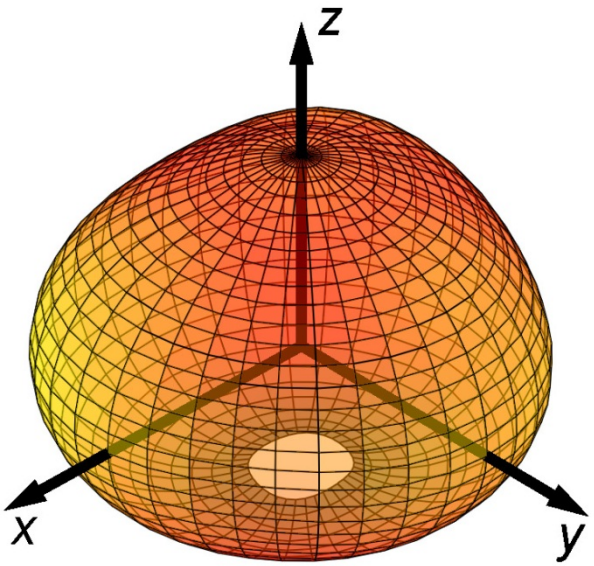
Angular characterization

Luminous intensity distribution



-Type of SSL: Spot

-Spatial correction: 1.013



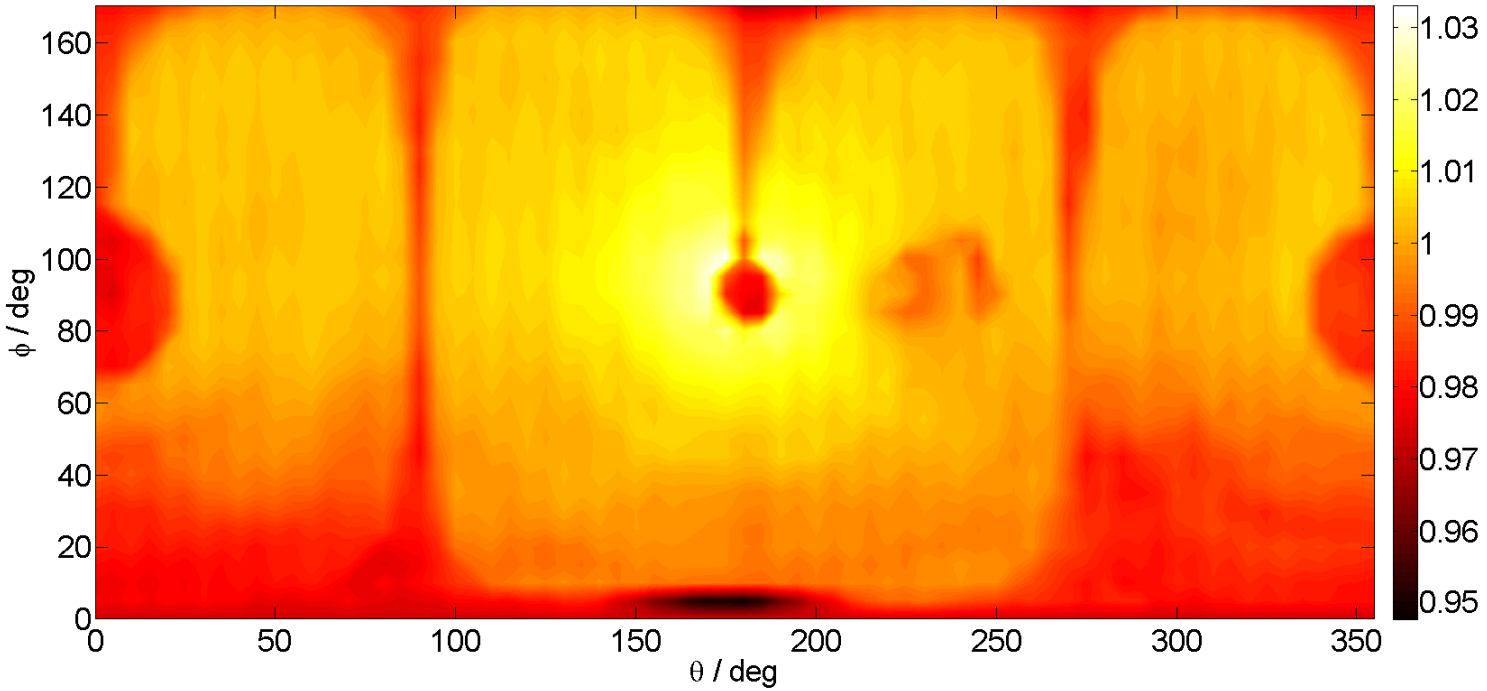
-Type of SSL: Bulb

-Spatial correction: 1.001

- Spatial correction is <u>needed for both types of SSLs</u>

Angular characterization

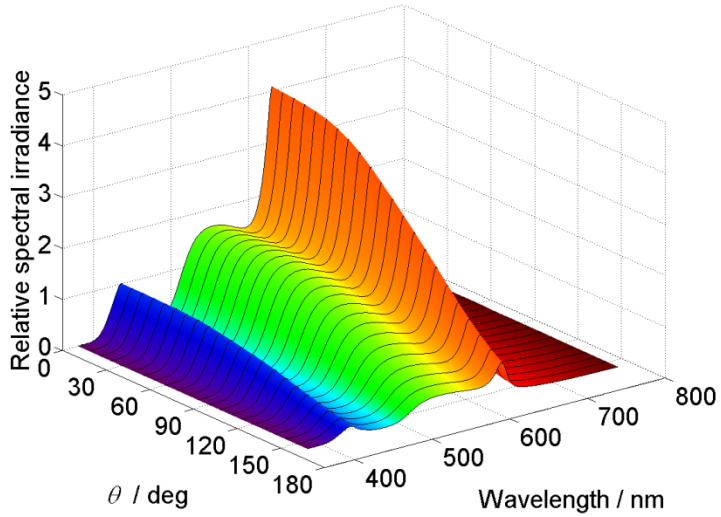
Spatial responsivity distribution function (SRDF)



- SRDF of the integrating sphere scanned using an LED-scanner

Angular characterization

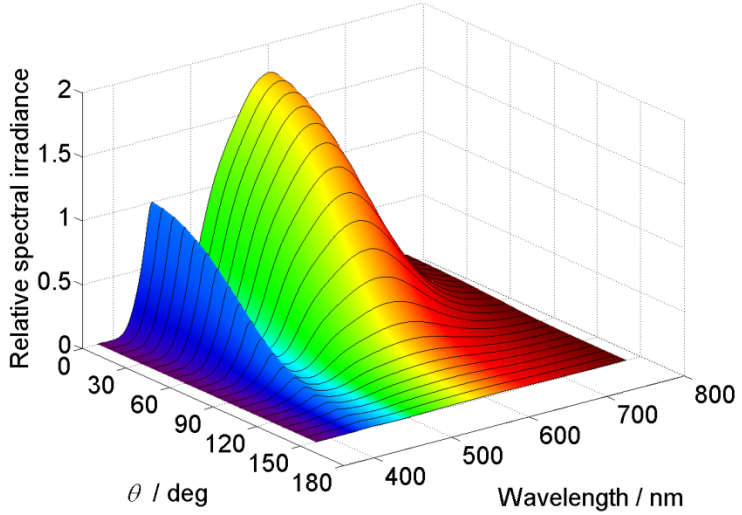
Spectral irradiance as a function of angle of observation



-CCT ($\theta = 0$ deg): 2970 K

-CCT ($\theta = 160$ deg): 3295 K

-Difference: 325 K



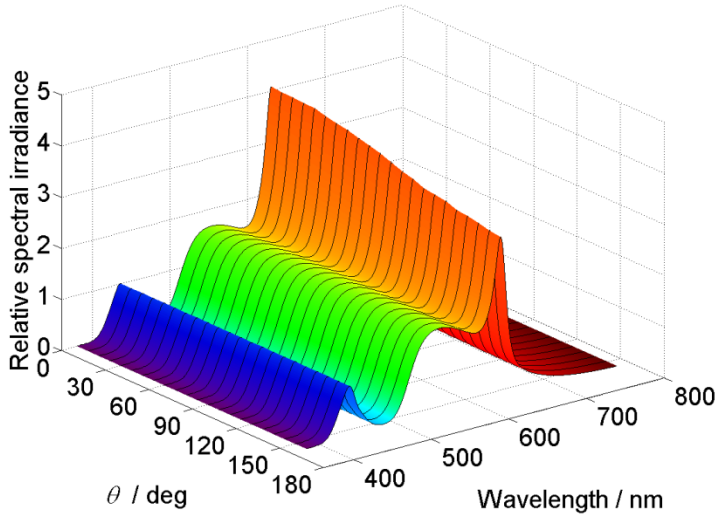
-CCT ($\theta = 0$ deg): 3029 K

-CCT ($\theta = 150$ deg): 3283 K

-Difference: 254 K

Angular characterization

Spectral irradiance as a function of angle of observation



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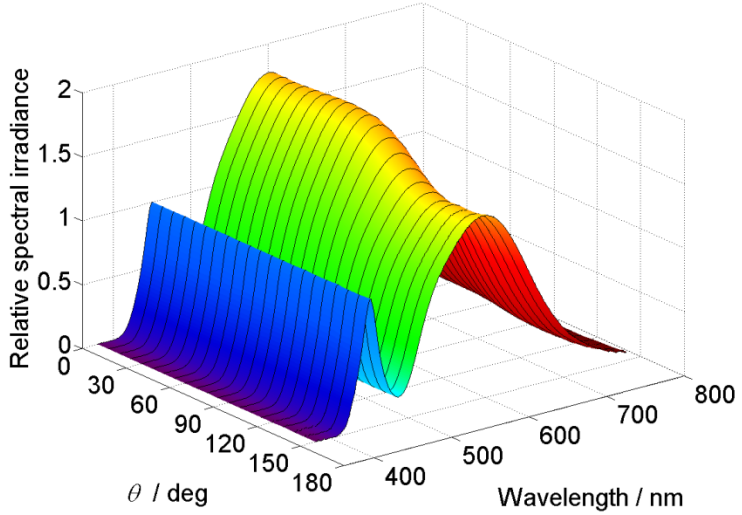

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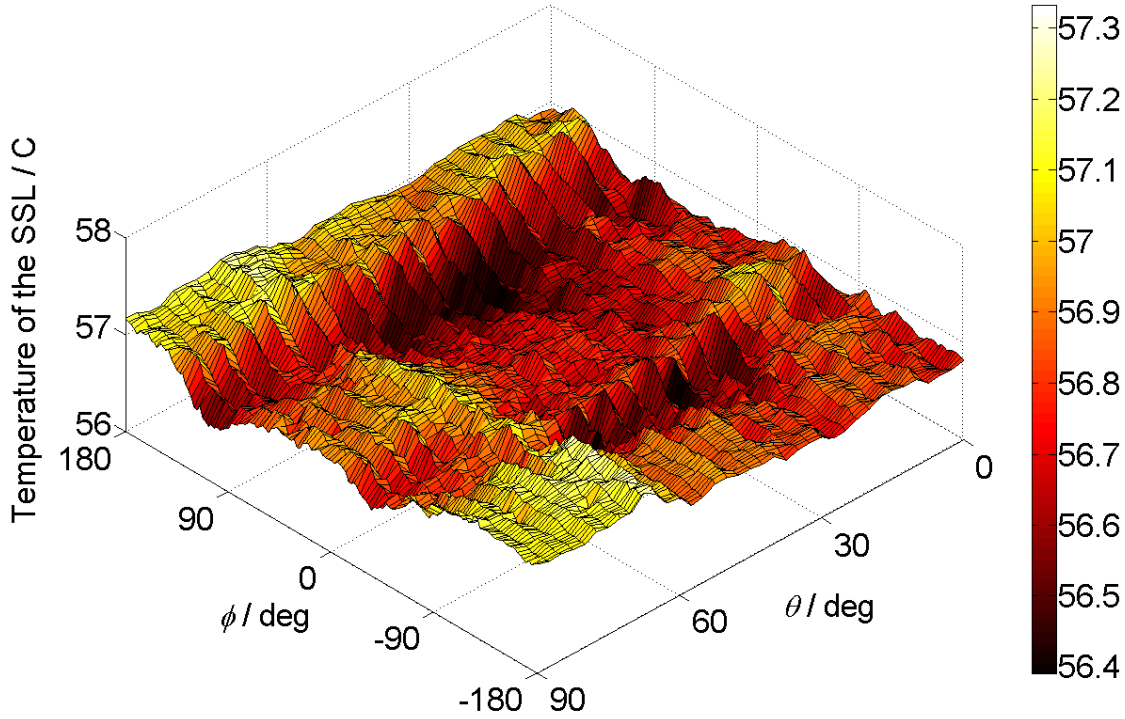
Angular characterization
Temperature variation of SSL



- Typical temperature variation in the goniometer measurement ±0.5 C

Conclusions

- Test-measurements were conducted for 25 SSLs
- Large differences were found between lamps
- Expanded uncertainty of luminous efficacy measurement is 1.2 % (k = 2) for a typical SSL with stable electronics
- All SSLs available cannot be measured with low uncertainty due to problematic built-in power supplies

Questions?