



Traceable metrology as the foundation for reliable SSL performance testing

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Bits&Chips LED Summit 2012



To measure = to know?

- Performance claims should be based on measurements
- **But how to guarantee that measurements are reliable?**
- SSL more possibilities with respect :
 - Spectral composition
 - Spatial distribution
 - Temporal modulation
- Whereas classical metrology is based on a continuous, isotropical, broadband light source...



Reliable measurements

**Measured
parameter**

=

**Numerical
value**

×

Unit

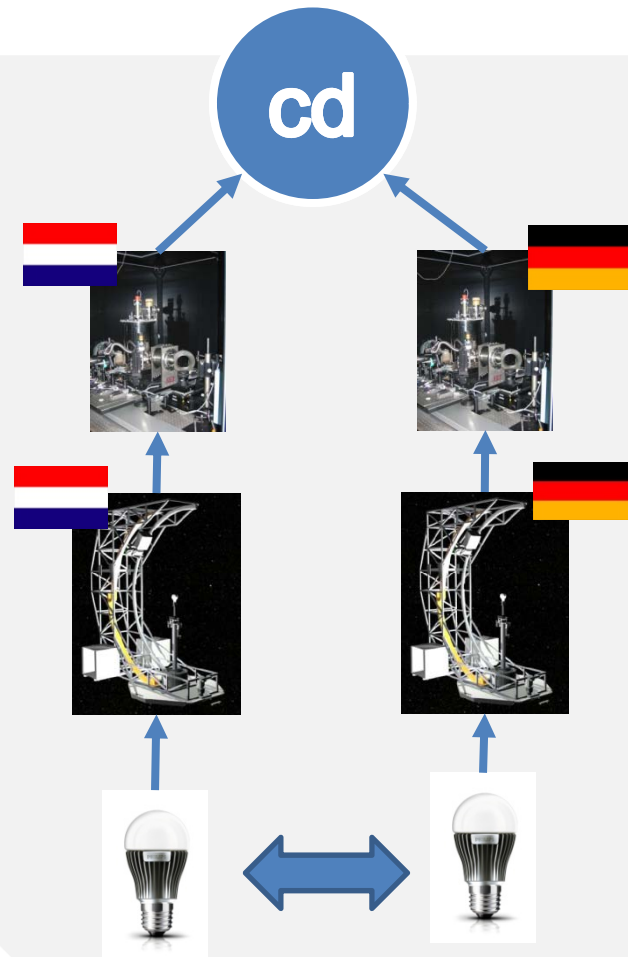
Well-defined,
common
meaning

Comparable to other
measurements
Known uncertainty

→ **Traceability**

Universal
(part of SI)

Traceability



- **Traceability** : unbroken chain of comparisons between object and reference
- Ending at primary standard: realisation of SI unit
- Each comparison has specified uncertainty



Taking care of traceability



- Global issue: comparable measurements between countries, vital for trade
- Regulated by Metre Convention
- Coordinated by **BIPM**
- In cooperation with national metrology institutes

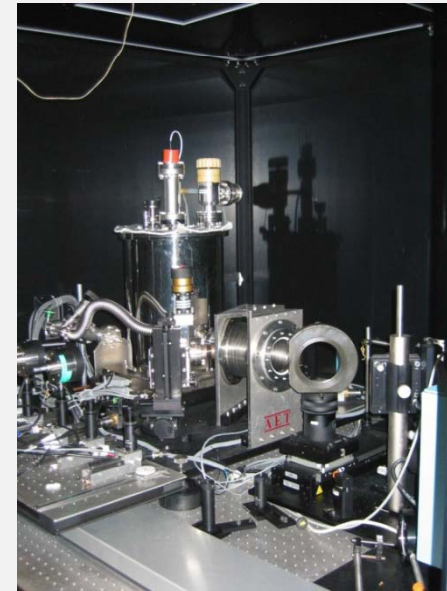
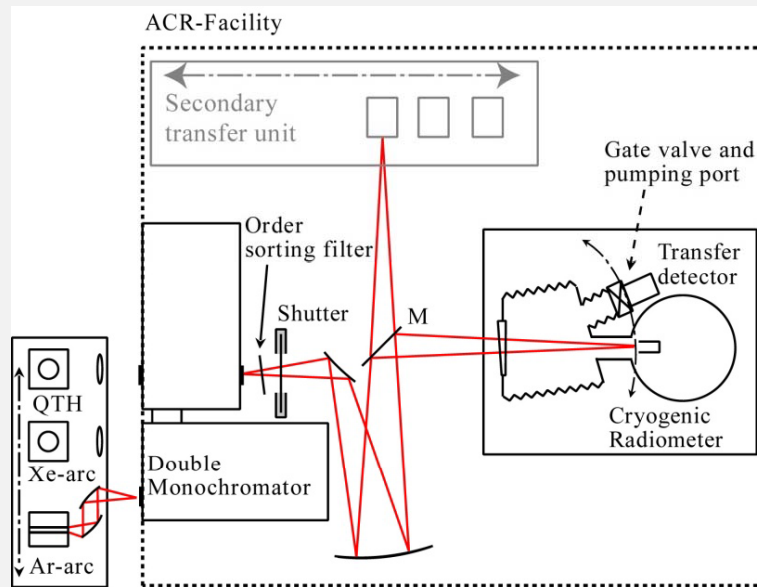


VSL



- **National metrology institute of the Netherlands**
- Maintains national measurement standards
- Represent Netherlands in international metrological infrastructure
- Metrology research
- Provide traceability to customers

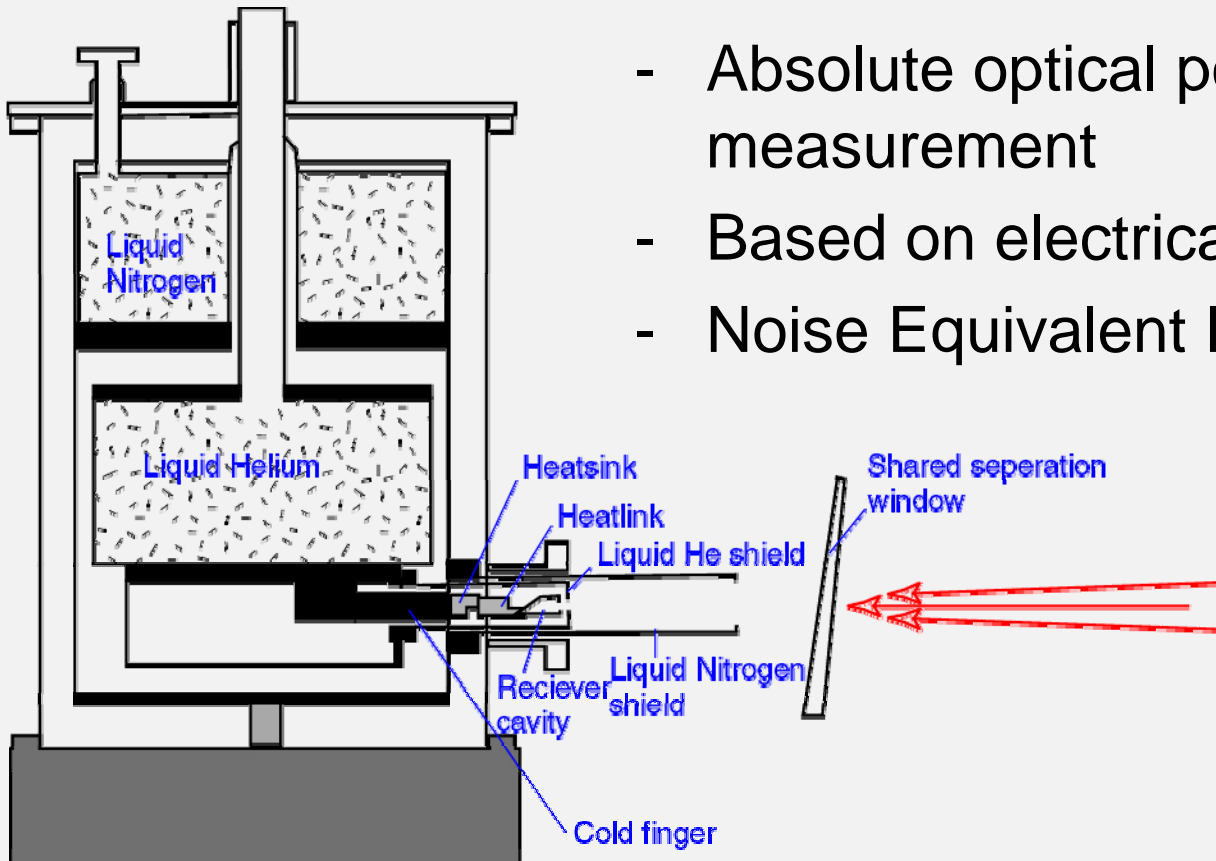
Primary standard for radiometry



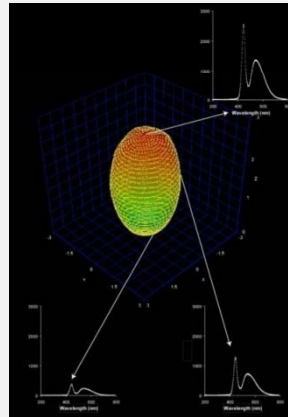
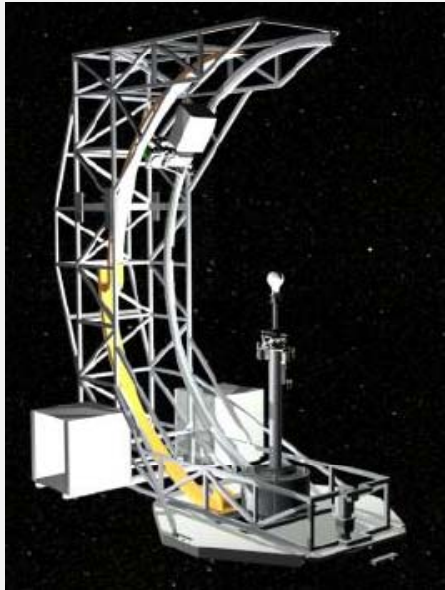
- Provides absolute flux with tunable wavelength
- Wavelength range: 190 nm – 20 μm
- Calibration of spectral responsivity of detectors

Absolute Cryogenic Radiometer

- Absolute optical power measurement
- Based on electrical substitution
- Noise Equivalent Power ≈ 9 nW



3D measurement of light sources



- 3m goniometer
 - Movable detector platform
 - Spectrometer and tristimulus meter
- Spatially resolved measurements
- Integrated measurements (virtual integrating sphere)
- **Great for SSL!**

Traceable luminous flux

- Traceable measurement of **total luminous flux for SSL** realised at VSL (ISO 17025 accredited)



3m virtual integrating sphere
(most accurate, spatially resolved)

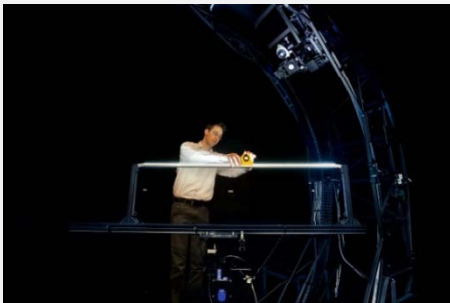
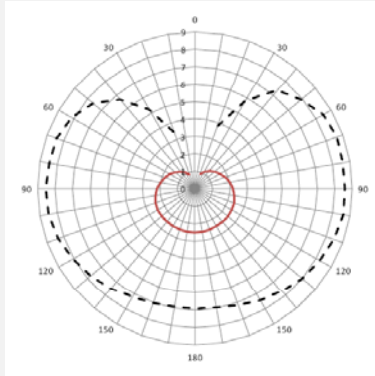


Traceability
using LED
transfer
standards



3m conventional integrating sphere
(fastest)

Successful use



- Public awareness campaign using off-the-shelf lamps (2009)
 - Real luminous flux 10-30% of suggested luminous flux
 - Power consumption up to 150% of specified value
 - Claimed equivalence 25-40 W; reality << 15W
- Customer measurements
- IEA Annex 4^E European lead (with US, China and Japan)



Extending the possibilities

- Traceability for basic parameters covered:
 - Luminous flux and efficacy
 - Spectrum, color coordinates and color temperature
- But what about:
 - Power quality?
 - Uncertainty in ray files?
 - Color quality indices?
 - Pulsed LEDs?
 - Environmental influences?
 - Lifetime prediction?



JRP Metrology for SSL



- Goal: traceable metrology for SSL
 - Spatial, spectral and temporal effects
 - Photometric and electrical quantities
 - Human perception aspects
 - General and application-specific
- 17 partners from 14 European countries
- Coordinated by VSL





EMRP



- Combined research program for national metrology institutes
- 50% EU / 50% national funding
- Managed by EURAMET
- Duration : 2009-2016
- Total budget : 400 M€



Project pillars

Traceable measurement facilities

- Electrical measurement systems
- Time-resolved measurements
- Mesopic photometers
- Spectral effects in measurement systems
- Near-field goniometry
- Environmental influences

Measurement methods

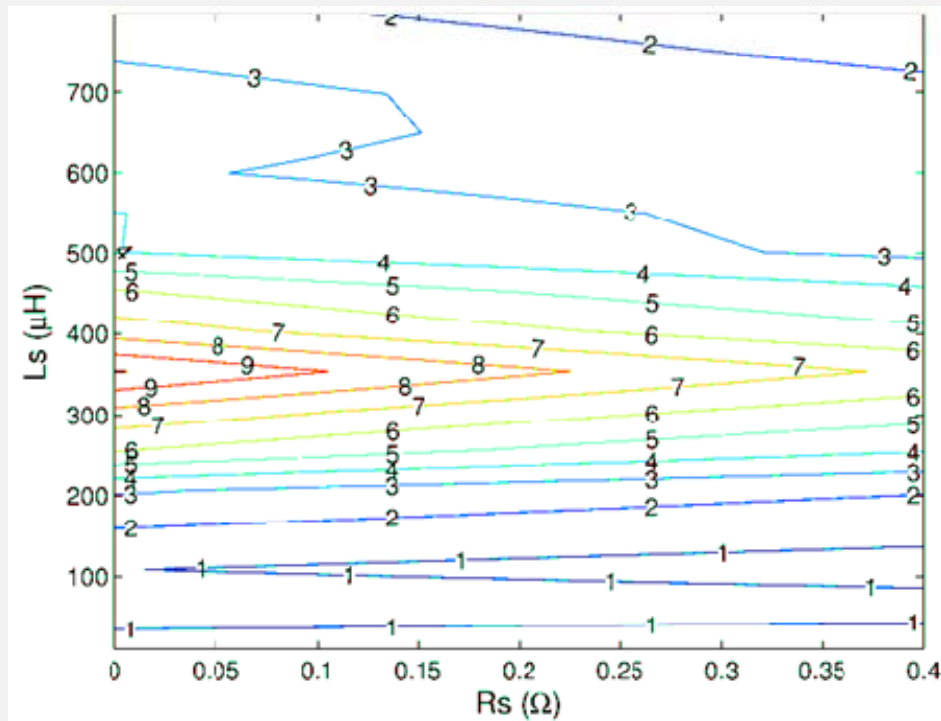
- Electrical characterisation
- Efficacy
- Goniometric measurements
- Lifetime

Human perception

- Colour quality
- Visual comfort
- Mesopic and scotopic vision

Application specific quality metrics

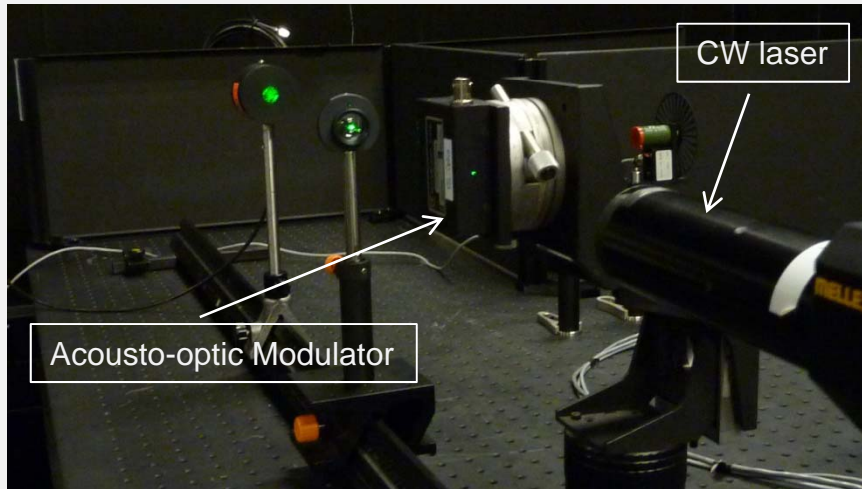
- Measurement equipment
- Indoor lighting
- Road lighting
- Greenhouses
- Art



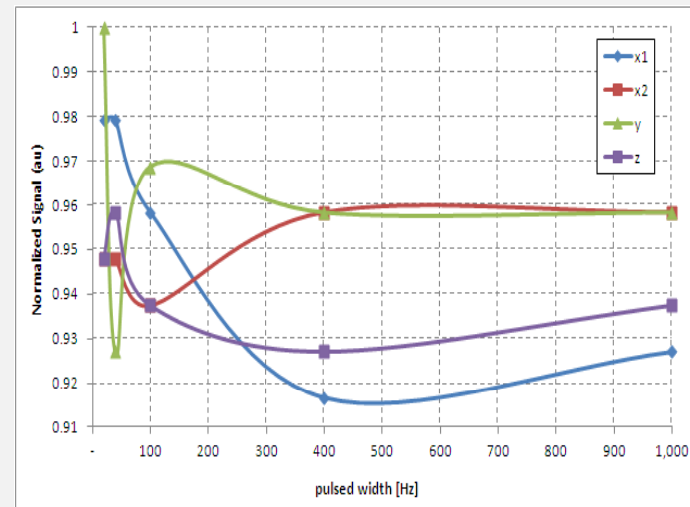
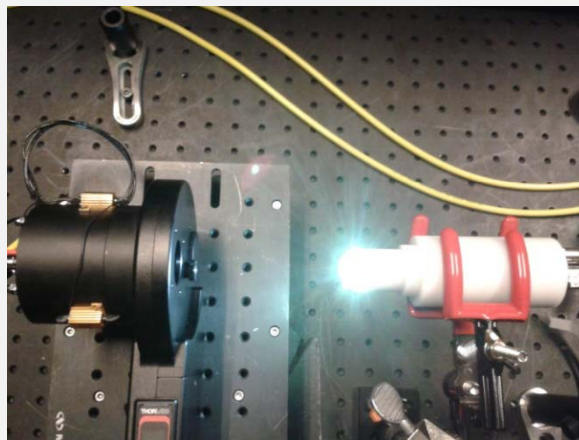
Contour of the relative deviation (percentage) in RMS current value

- Source impedance interferes with accurate electrical power measurements
- Solution : specially designed **stabilization network**
- With stabilisation: **less than 0.02%** deviation

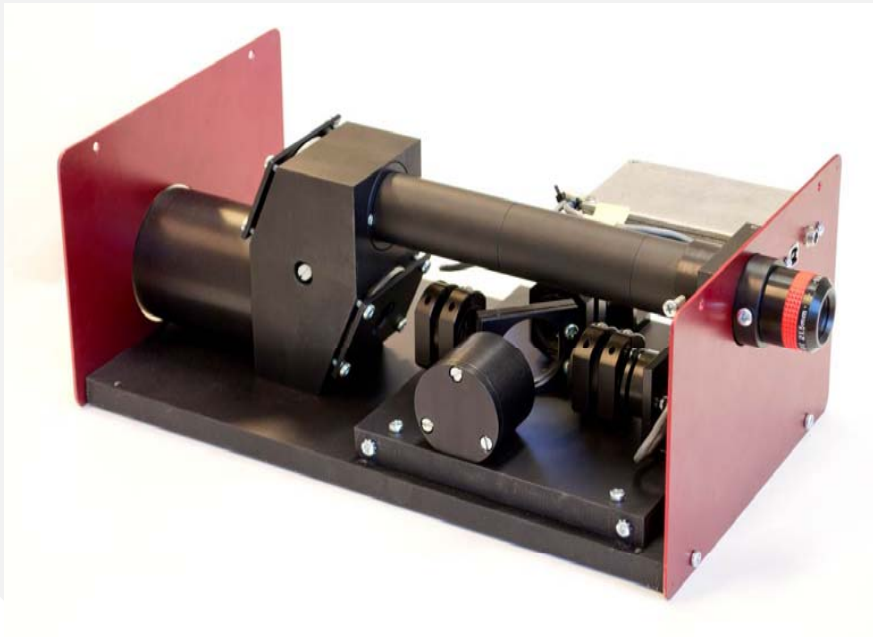
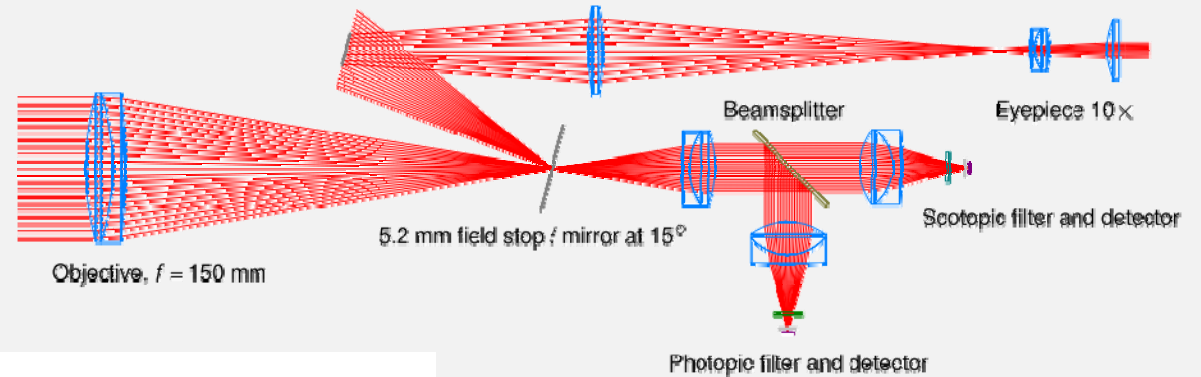
Pulsed LEDs



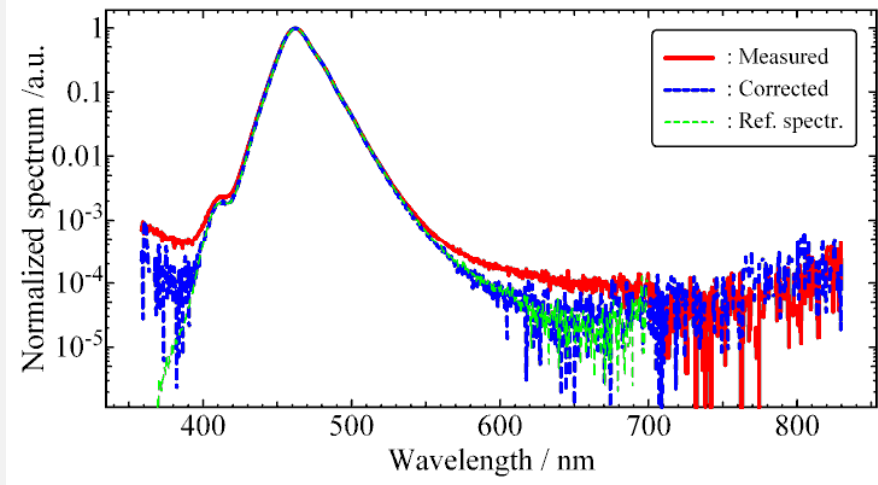
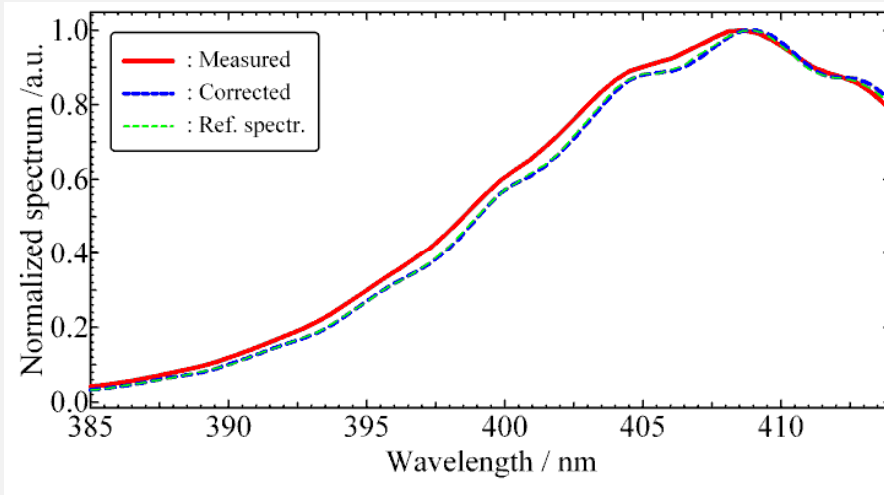
- Step 1 : calibration of frequency response of tristimulus meter
- Step 2 : measurement of color change in pulsed LED



Mesopic photometer

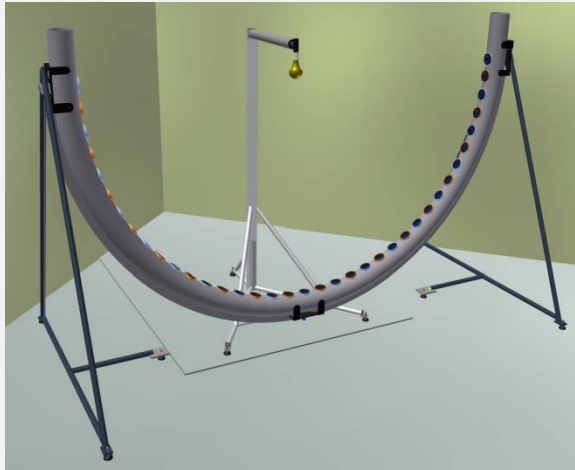


Spectroradiometer calibration

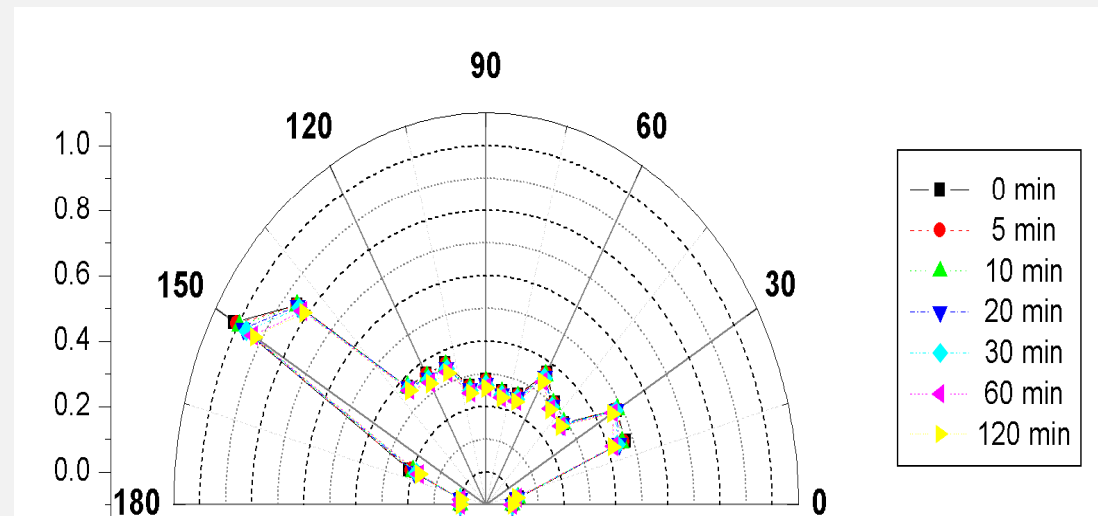


- Measure response of array spectrometer to tunable laser
- Special correction algorithm for band-pass and stray light

Fast C-plane profiles

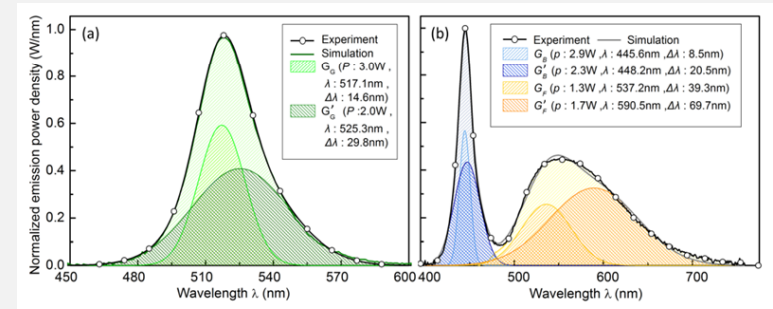
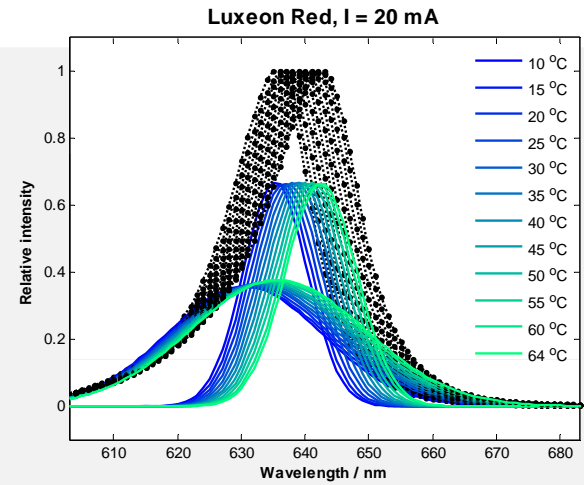


- Multiple detectors in parallel
- Illumination profile under changing conditions

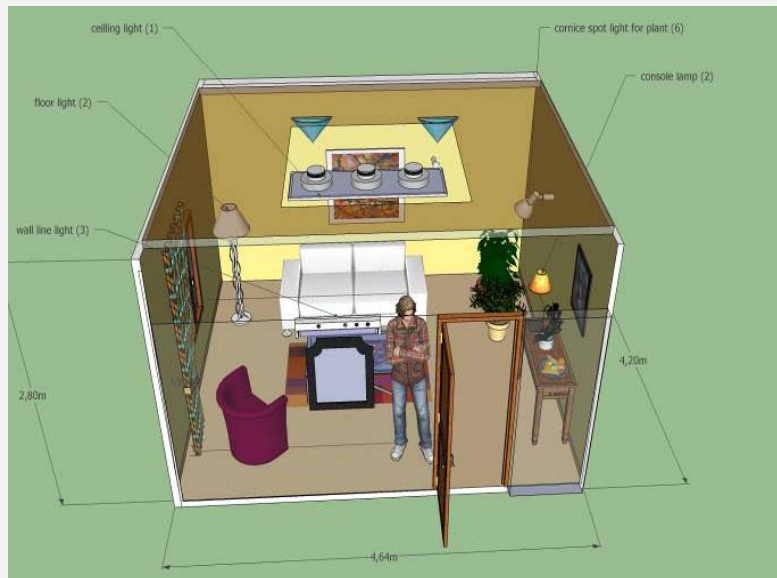


Junction temperature

Junction Temp T_j



Human perception



- Comprehensive comparison between various color quality indices and subjective evaluation in specially constructed test room



Summary



- Reliable SSL characterisation is founded on traceable metrology.
- New traceable metrology needs to be developed to take into account spatial, spectral and temporal properties of SSL.
- EMRP JRP Metrology for SSL combines expertise from European national metrology institutes to realise this.
- Website: <http://www.m4ssl.npl.co.uk>



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The research leading to these results has received funding from the European Union on the basis of Decision No 912/2009/EC.

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Metrology
Institute