

# NMIJ Activities for Improving Measurement Reliability of LED Based Lighting and Accelerating that Dissemination

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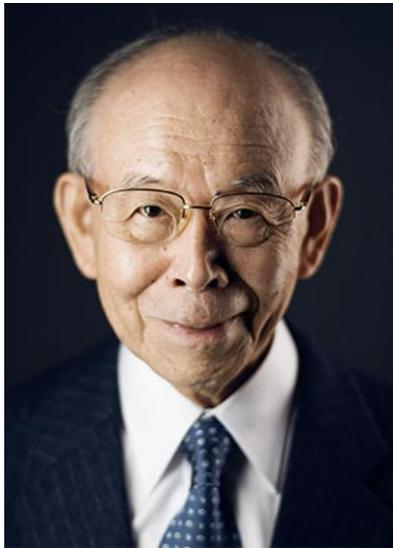
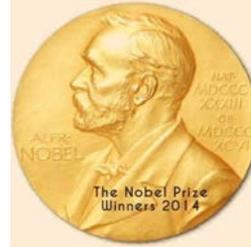
# Outline of this Presentation

- Introduction
- Photometry and Luminous Flux Measurement
- Problem of Traditional Luminous Flux Measurement Method
- New Method and Standard Appropriate to LED Measurement
- Evaluation of Integrating Sphere
- Proficiency Testing for LED Based Lighting

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# The Nobel Prize in Physics 2014



Dr. Isamu Akasaki



Dr. Hiroshi Amano



Dr. Shuji Nakamura

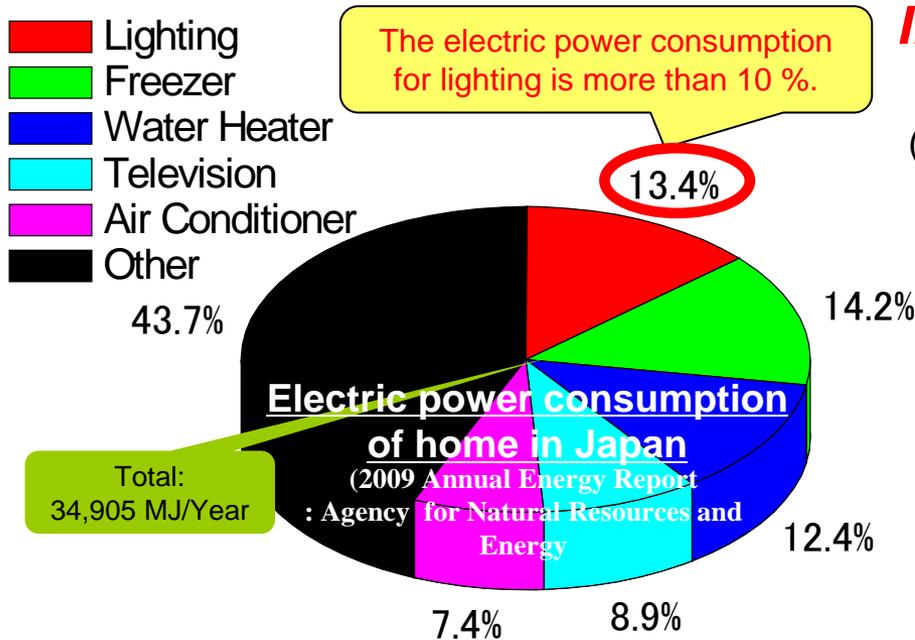
For the invention of efficient blue light-emitting diodes which has enabled bright and **energy-saving white light sources**

"The Nobel Prize in Physics 2014". *Nobelprize.org*. Nobel Media AB 2014. Web. 31 May 2016.  
<[http://www.nobelprize.org/nobel\\_prizes/physics/laureates/2014/](http://www.nobelprize.org/nobel_prizes/physics/laureates/2014/)>

# LED Based Lighting

– A key to realize energy-saving society –

● A considerable amount of energy is consumed by lighting



**Improvement of luminous efficacy is highly effective for saving energy**

(luminous efficacy = luminous flux / input power:  $lm/W$ )

- The luminous efficiency of LED based lighting (Solid State lighting: SSL) is expected to be further improved
- If the SSL get market acceptance, the SSL will penetrate market and the electric power consumption of home will be reduced.
- Consumer trust is indispensable for the market acceptance.
- Appropriate standard for LED measurement is necessary.



Candle  
~0.3  $lm/W$



Incandescent Lamp  
~20  $lm/W$



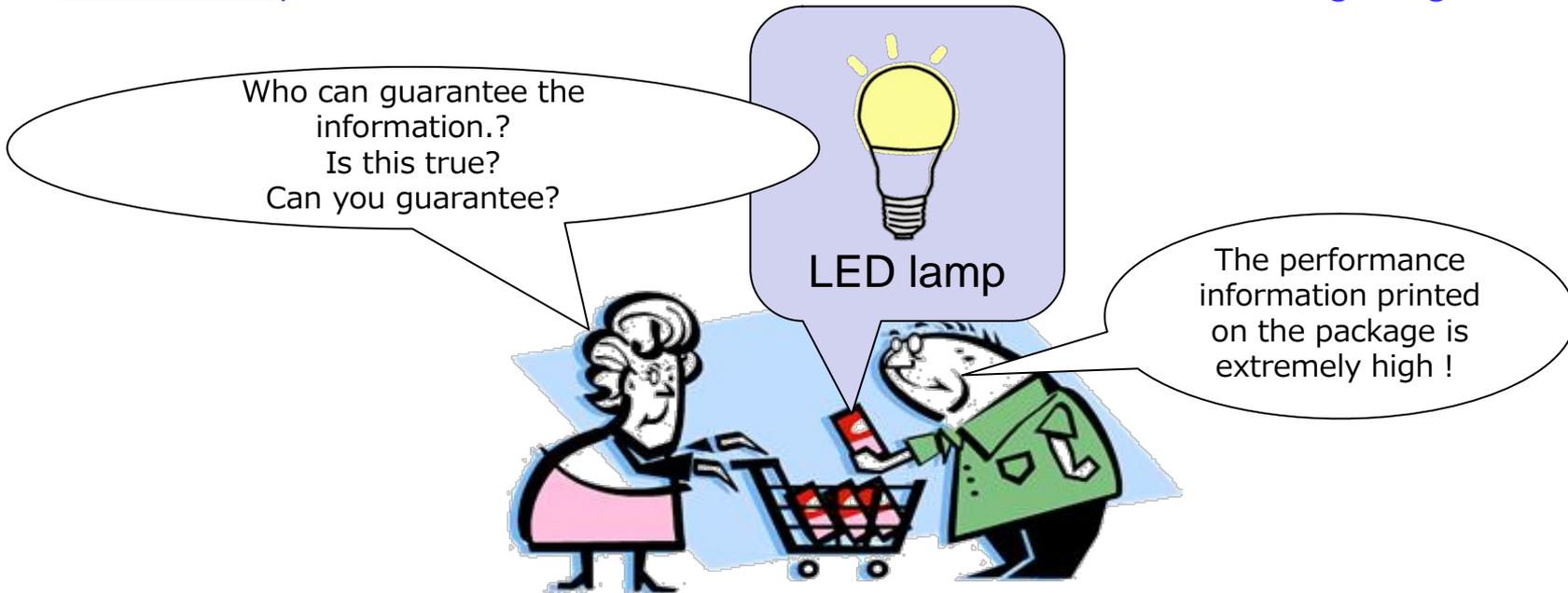
Fluorescent Lamp  
~100  $lm/W$



SSL, LED > 100  $lm/W$

# Potential Problems for LED Based Lighting Dissemination

- Reliable performance evaluation of LED are not so easy for manufacturers or testing laboratories
- If the product performance information of LED based lighting differ from the real performance (especially real performance is poorer than claimed performance information), does consumer want to introduce the LED based lighting?



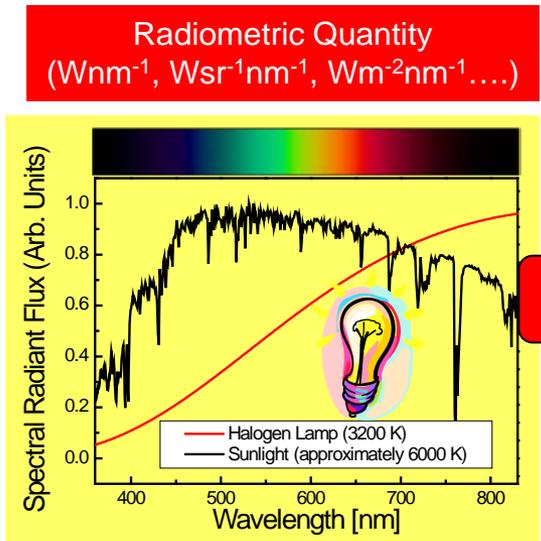
**If consumer doubt claimed performance information, the dissemination of LED based lightings into consumers will delay.**

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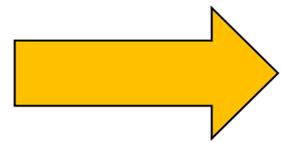
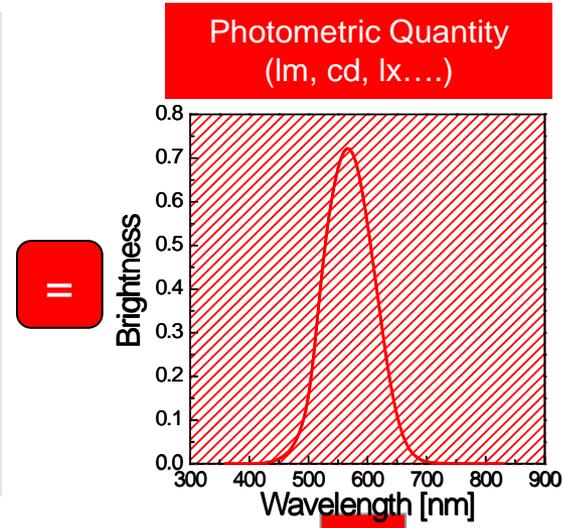
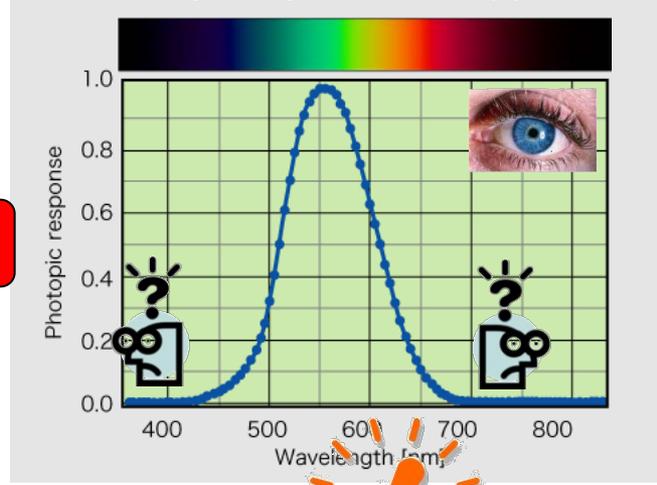
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# Performance Evaluation for Lighting-Photometry

- It is necessary for lighting to measure amount of light based on human visual response.
  - Photometry is indispensable for the performance evaluation for lighting
- Radiometry: Measurement of optical radiation from vacuum ultraviolet to far infrared with power or energy (base unit: W)
  - **Photometry**: Measurement of visible optical radiation in terms of **perceived brightness to the human eye** (base unit: **cd, lm, lx**)



Spectral luminous efficiency function for photopic vision:  $V(\lambda)$



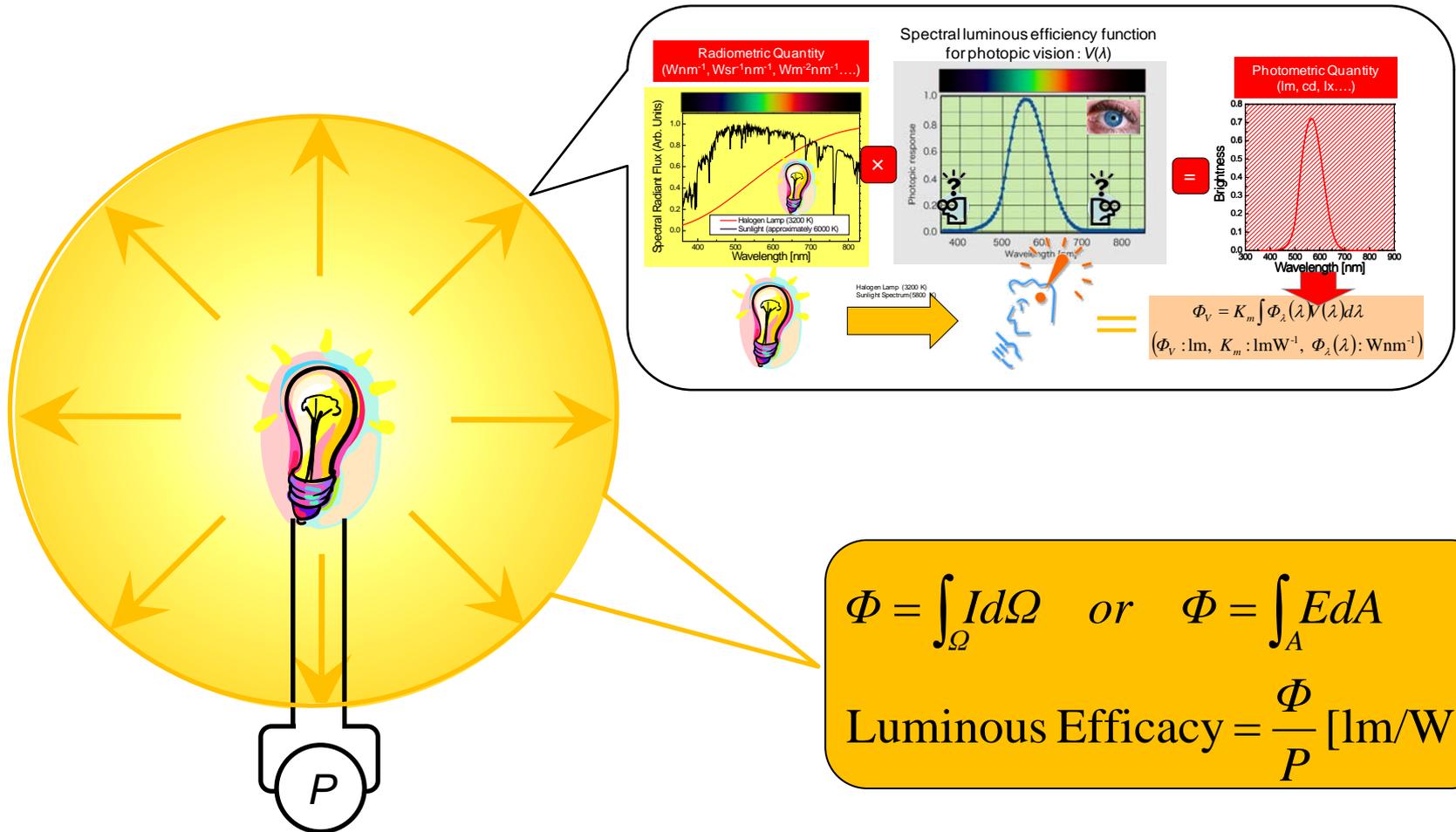
$$\Phi_V = K_m \int \Phi_\lambda(\lambda) V(\lambda) d\lambda$$

( $\Phi_V$  : lm,  $K_m$  :  $lmW^{-1}$ ,  $\Phi_\lambda(\lambda)$  :  $Wnm^{-1}$ )

# Luminous Efficacy

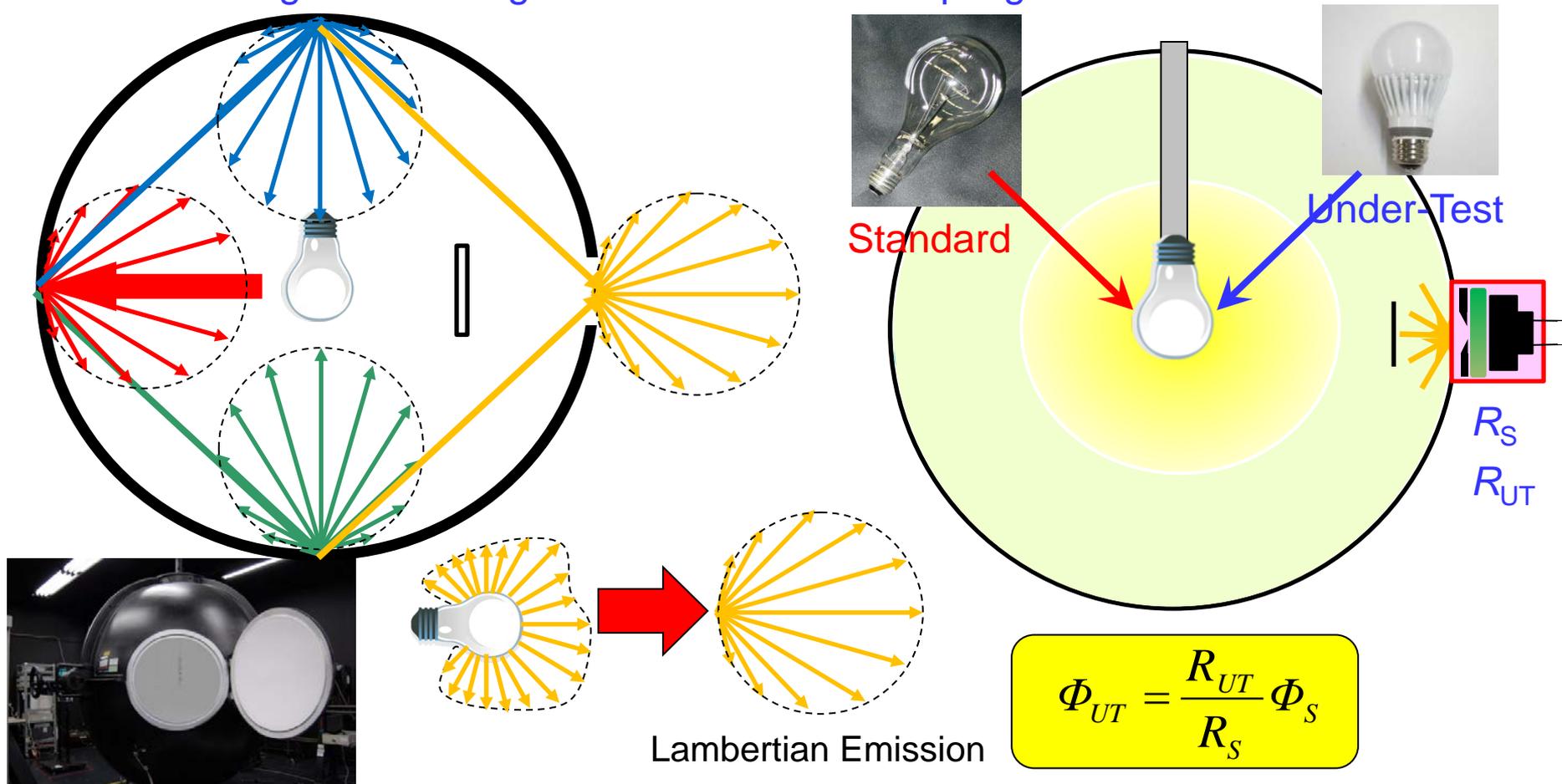
## -Key Parameter for Energy Saving Performance-

- Luminous Efficacy = Total luminous flux / Input electrical power: lm/W.
- Total luminous flux  $\Phi$  is given by the spatial integration of luminous intensity  $I$  or illuminance  $E$ .



# Traditional Method for Luminous Flux Evaluation

- Introducing sphere photometer consists of an integrating sphere and a photometer.
- Introducing a total luminous flux standard lamp calibrated by NMI.
- The total luminous flux of under-test light source is calibrated from the ratio of the under-test light source signal to the standard lamp signal.

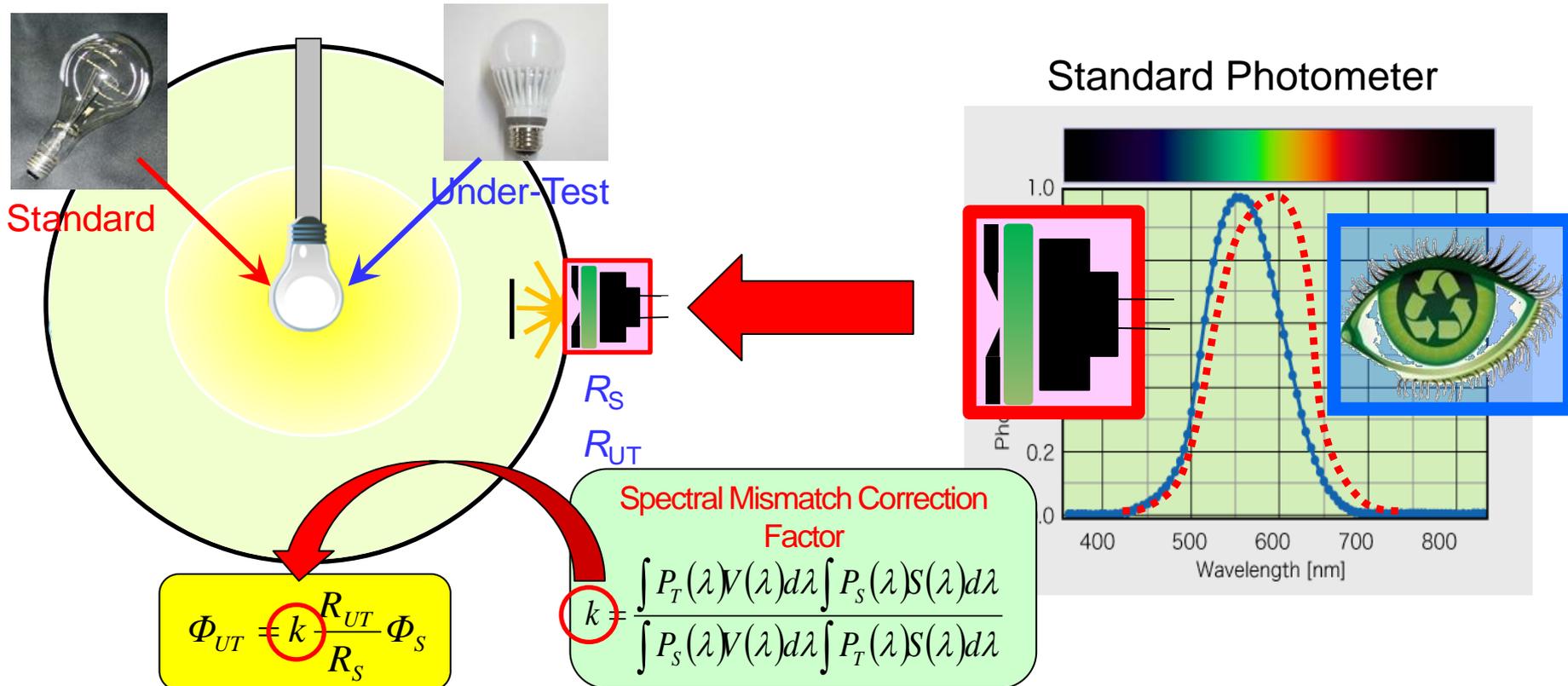


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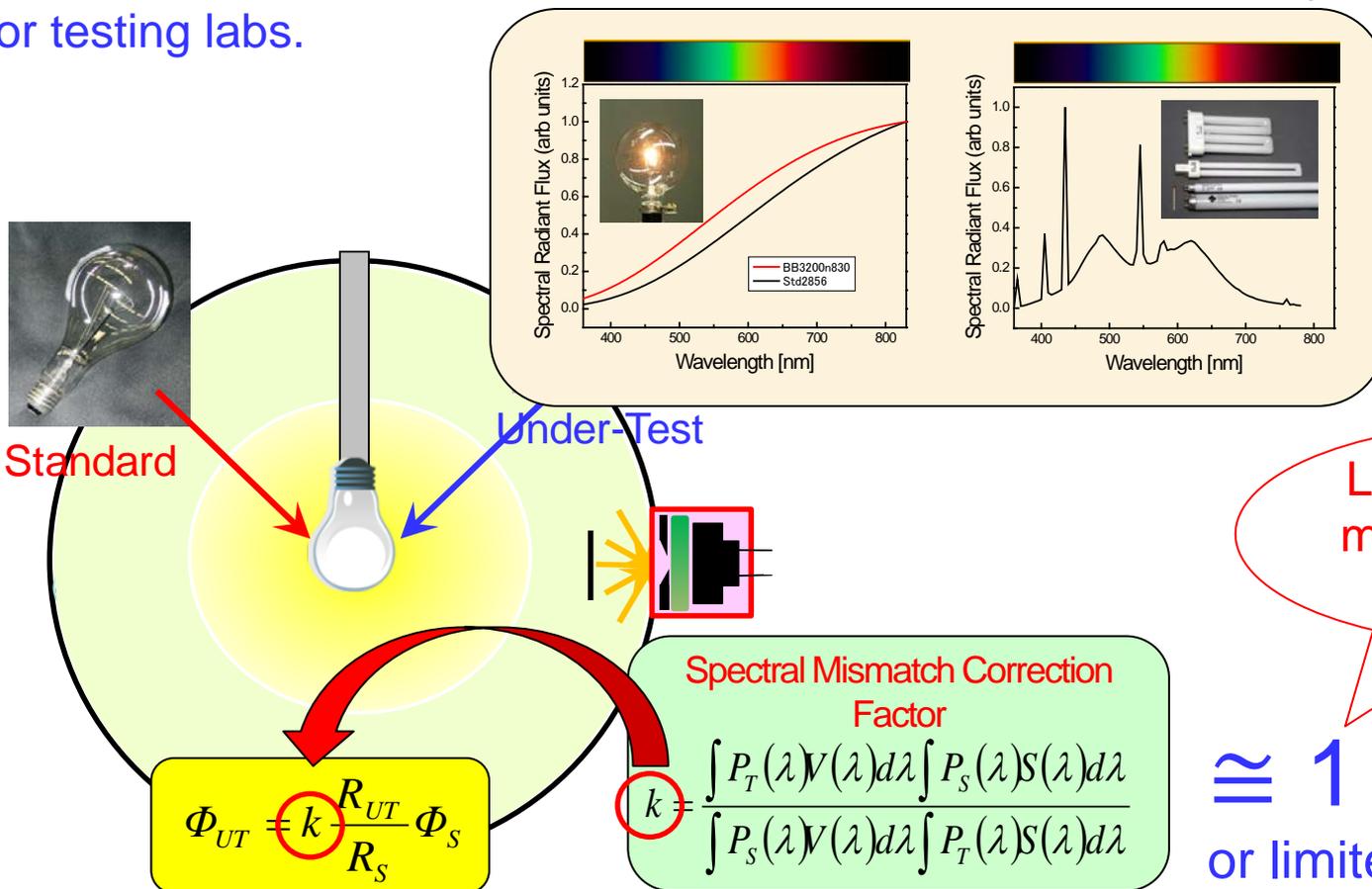
# A Problem on Traditional Method

- It is difficult (impossible) to match the relative spectral responsivity of photometer to the human visual response (Spectral luminous efficacy for photopic vision:  $V(\lambda)$ )
- Spectral Mismatch Correction Factor is required if the spectral distribution difference between the standard lamp and the under-test lamp is significant.
- The relative spectral responsivity evaluation is not easy especially for combined photometric measurement instrument, such as sphere photometer.
- The responsivity evaluation gives a heavy burden to the manufactures or testing labs.



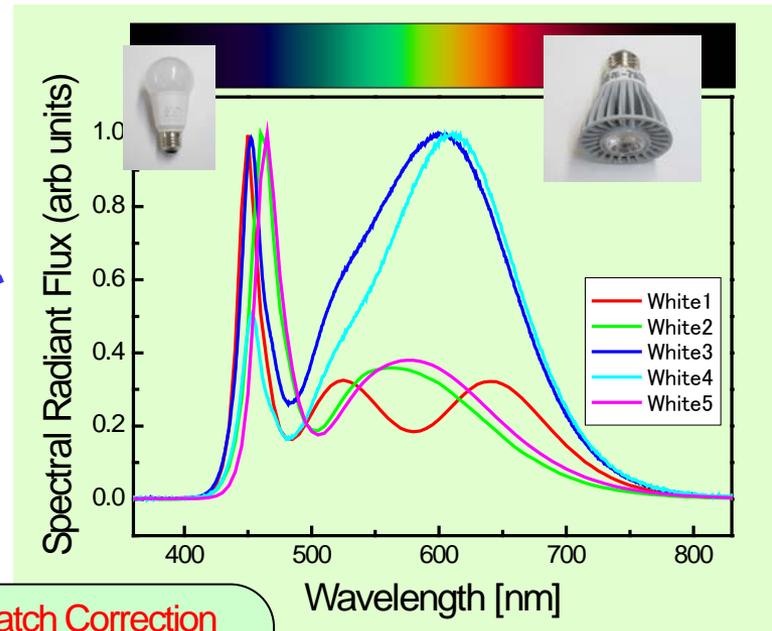
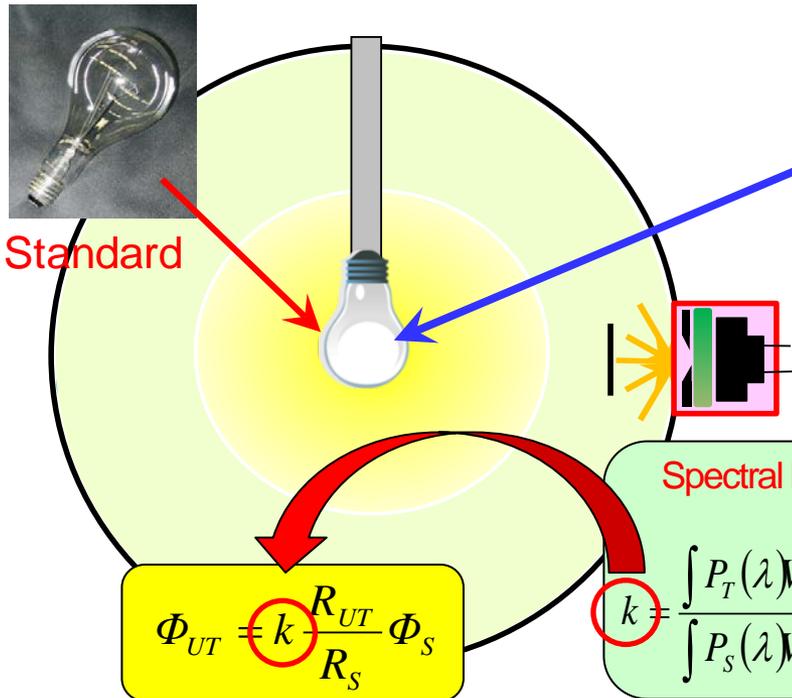
# Traditional Lighting–Problem is not Serious

- The spectral distribution of the traditional lighting does not differ greatly from that of the standard lamp or the variety of the distribution is limited.
- Spectral Mismatch Correction Factor is nearly equal to 1 or the variety of the Correction Factor is limited.
- The burden due to Correction Factor evaluation is not so heavy for the manufactures or testing labs.



# LED Based Lighting–Problem is Serious

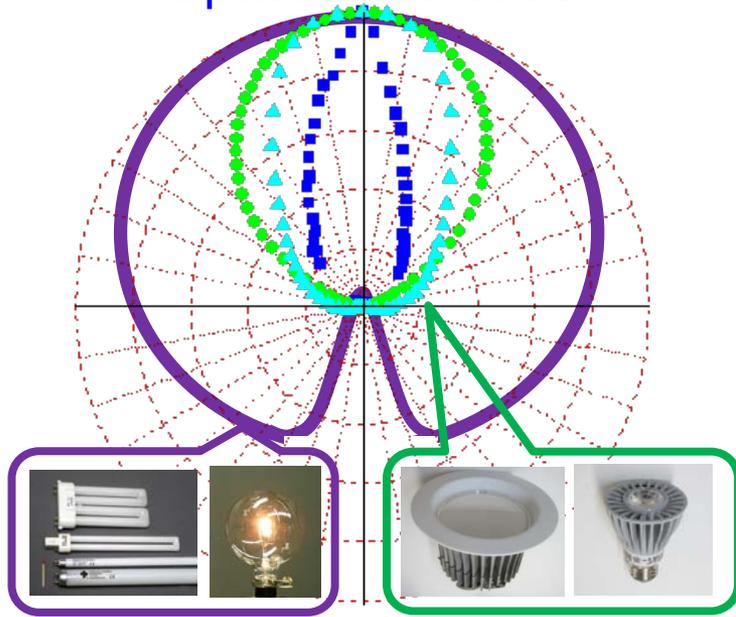
- The spectral and the special distributions of the emitted radiation are completely different from the traditional light source and the distributions have wider variety.
- Spectral Mismatch Correction Factor is larger than traditional light source so the relative spectral responsively evaluation of the sphere photometer is more important.
- The responsively evaluation gives a heavy burden to the manufactures or testing labs.
- It is difficult to reduce the measurement error.
- Easier measurement method is required by the manufactures or testing labs.



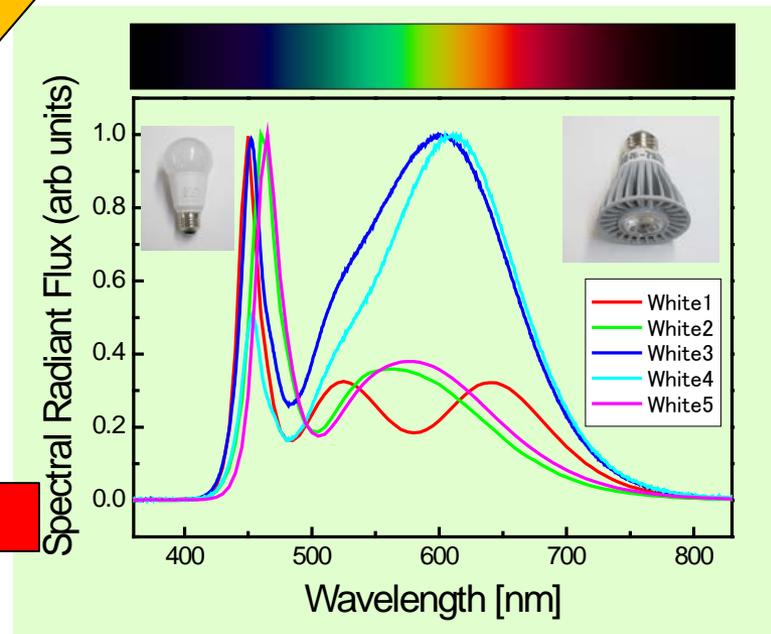
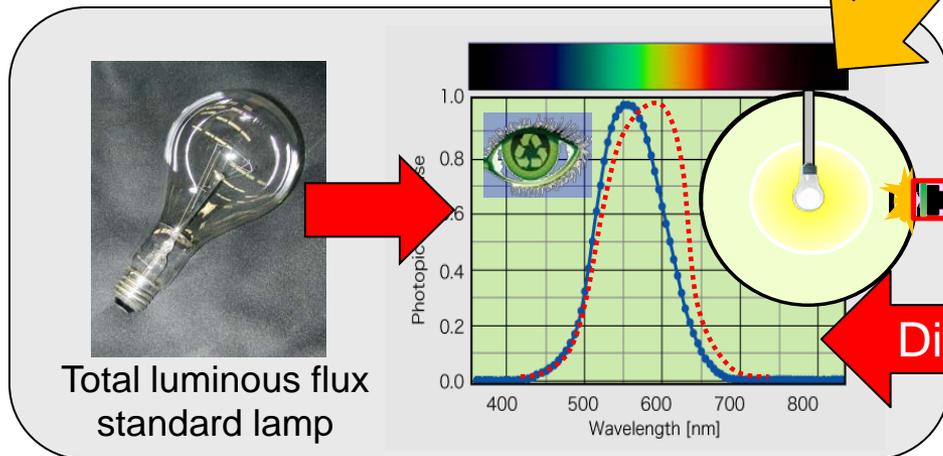
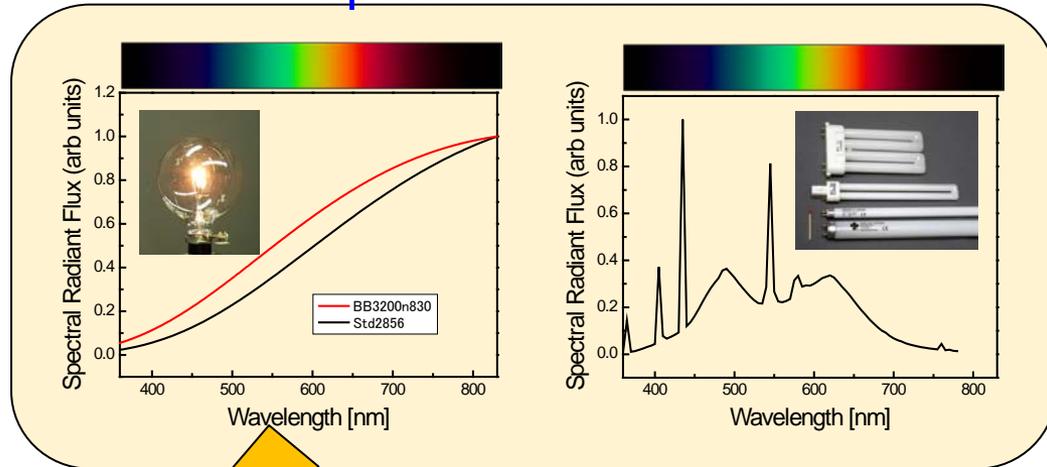
Under-Test  
Wider Variety

# Traditional and LED Based Lighting Difference

Spatial distribution



Spectral distribution

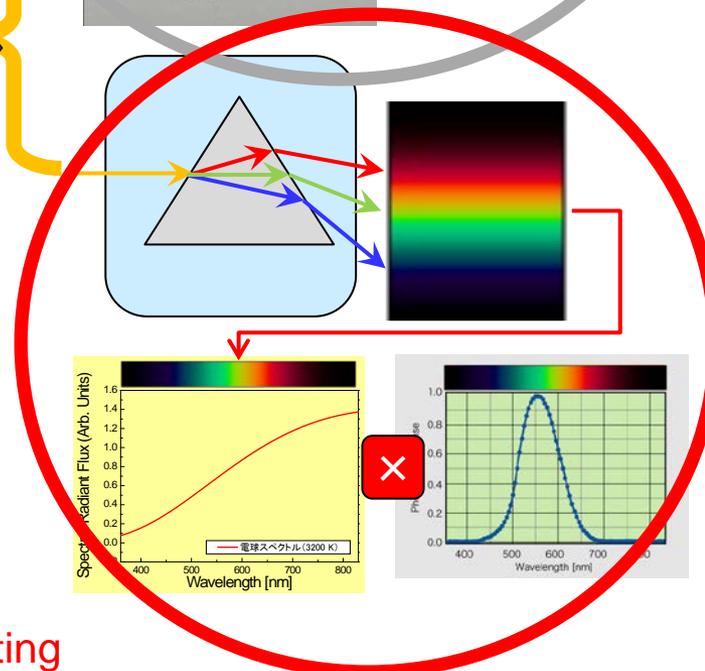
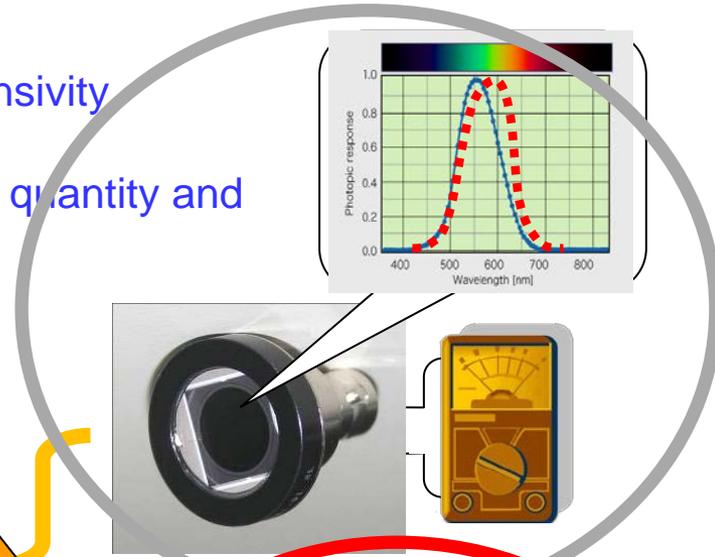
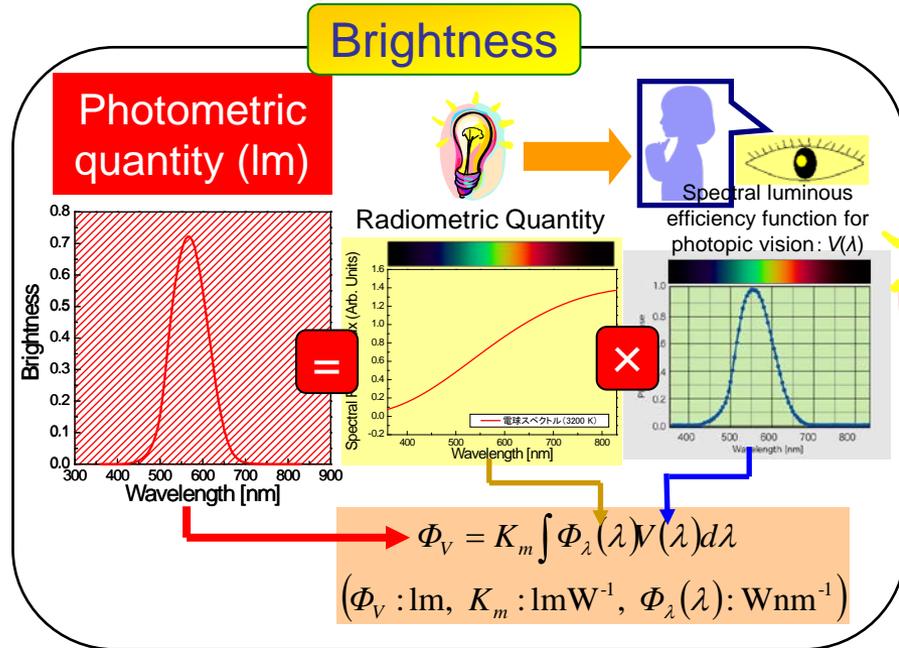


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# Easier Measurement Method

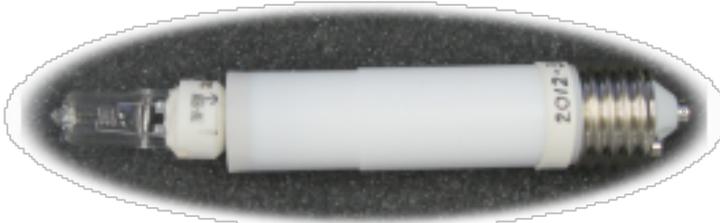
- There are two kinds of measurement methods
  1. Introducing a detector whose relative spectral responsivity approximates the human visual response.
  2. Introducing a spectroradiometer, measuring spectral quantity and evaluating photometric quantity by calculation.



1. The measurement method based on sphere photometer is appropriate for traditional light source measurement.
2. The measurement method based on sphere spectroradiometer which consists of an integrating sphere and a spectroradiometer is appropriate for LED based lighting

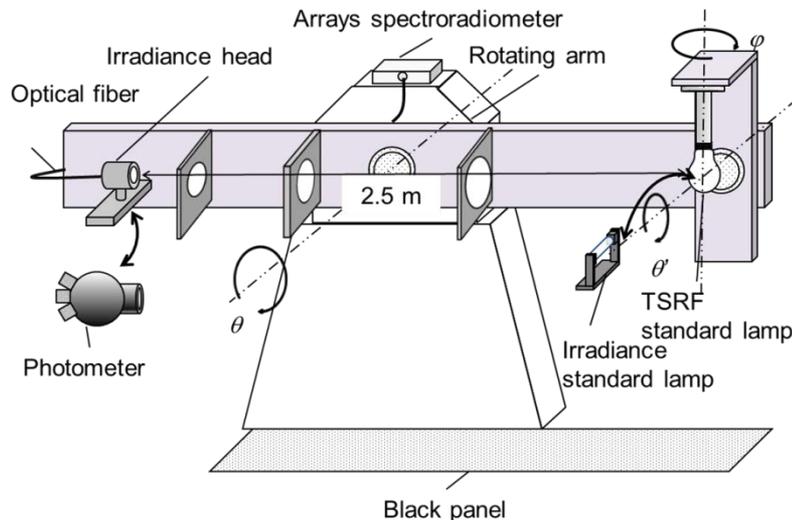
# Establishment of Total Spectral Radiant Flux Standard for $4\pi$ Geometry

- Total spectral radiant flux (TSRF) standard in visible range (360 nm to 830 nm) was established by using a gonio-photometer and a gonio-spectroradiometer.
- A halogen lamp, which has sufficiently high CCT and stable optical power, was selected as the transfer standard lamp for TSRF calibration.

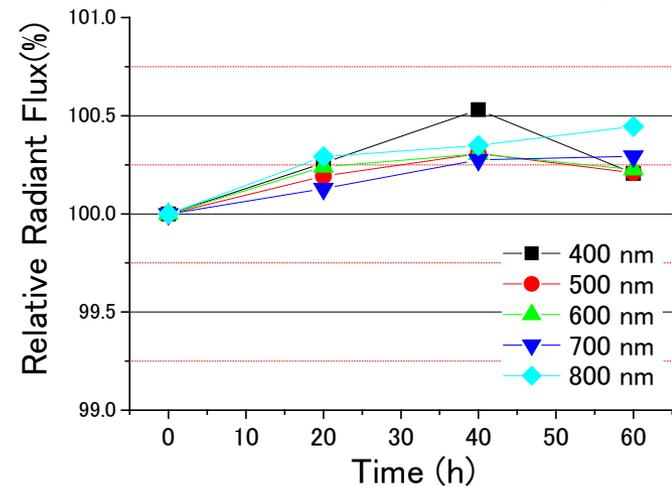


- A 24V-150W QH lamp
- Total luminous flux: approximately 3 000 lm
- CCT: approximately 3 100 K

- Relative Expanded Uncertainty ( $k=2$ ): 4.0 % to 3.1% (varied with wavelength)



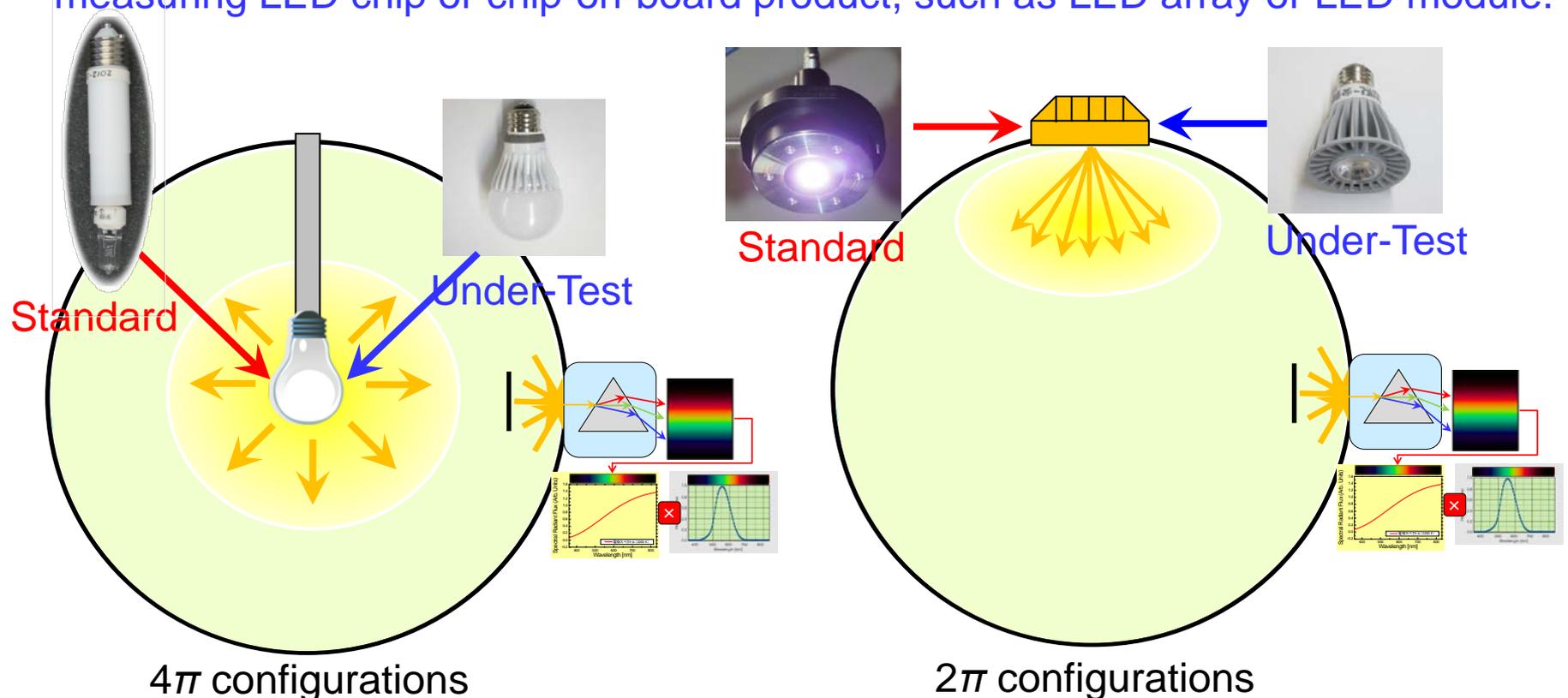
NMIJ gonio-photometer/spectroradiometer



Spectral ageing trend of the TSRF standard lamps after the 100 h pre-seasoning

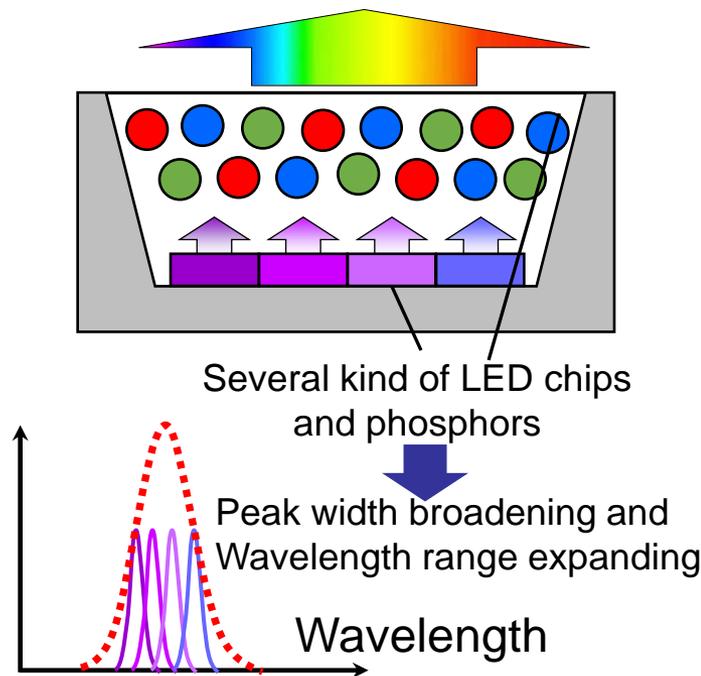
# Two Kinds of Measurement Configurations

- Integrating sphere has two kinds of measurement configurations, such as  $4\pi$  and  $2\pi$ , different in light source setting.
- $4\pi$  and  $2\pi$  configurations are appropriate for omni-directional and directional light sources, respectively.
- LED is principally directional light source, so  $2\pi$  configuration is appropriate for measuring LED chip or chip-on-board product, such as LED array or LED module.

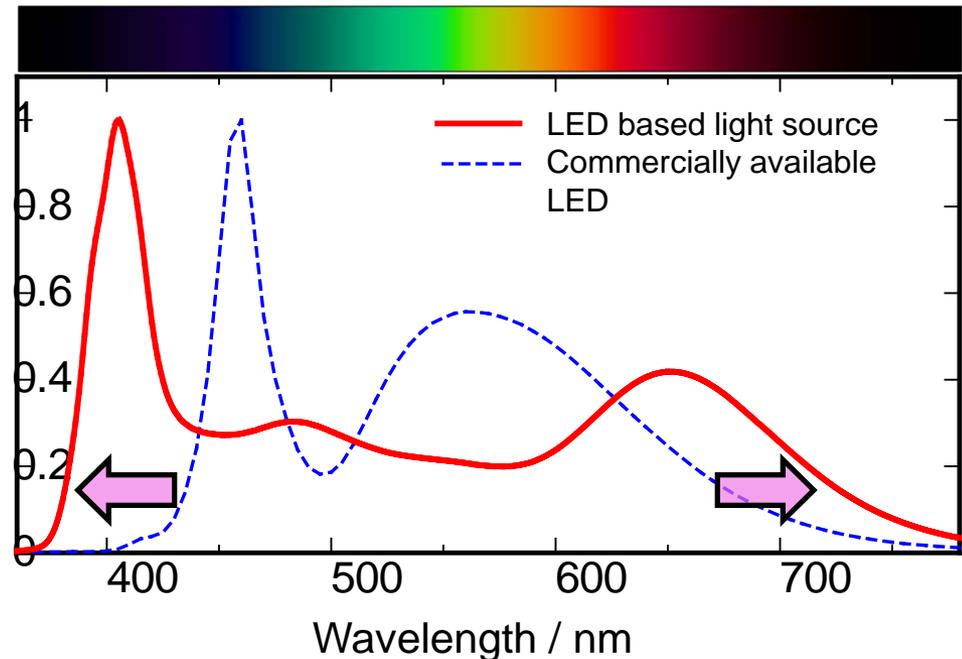


# Development of LED based Light Source Appropriate for Total Spectral Radiant Flux Standard for $2\pi$ Geometry

- NMIJ and Nichia Corporation have developed a LED based light source which is appropriate for spectral radiant flux standard for  $2\pi$  Geometry
- The spectrum of the light source is broader than that of the commercially available LED in wavelength The radiation spectrum covers the wavelength of 380 nm to 780 nm.
- The wavelength range in which spectrum does not have steep peaks or valleys is much wider than that of the commercially available LED.



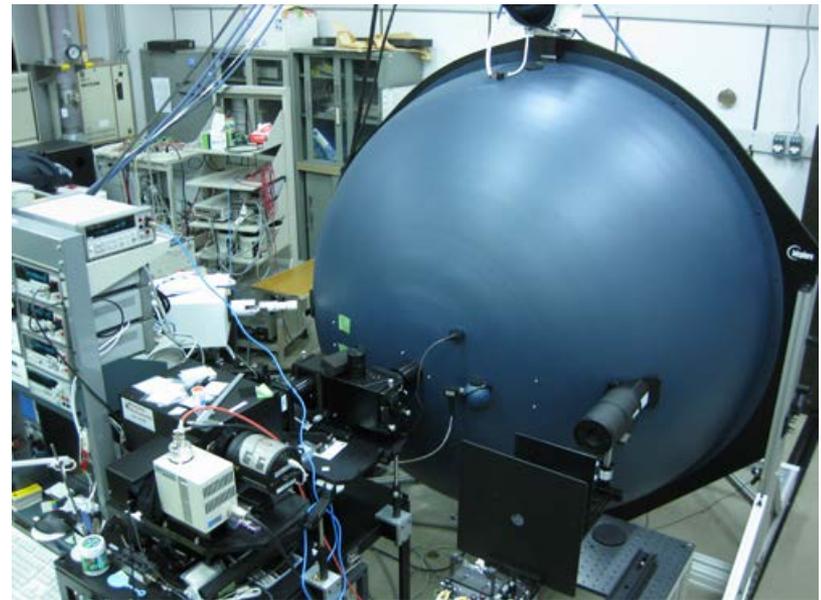
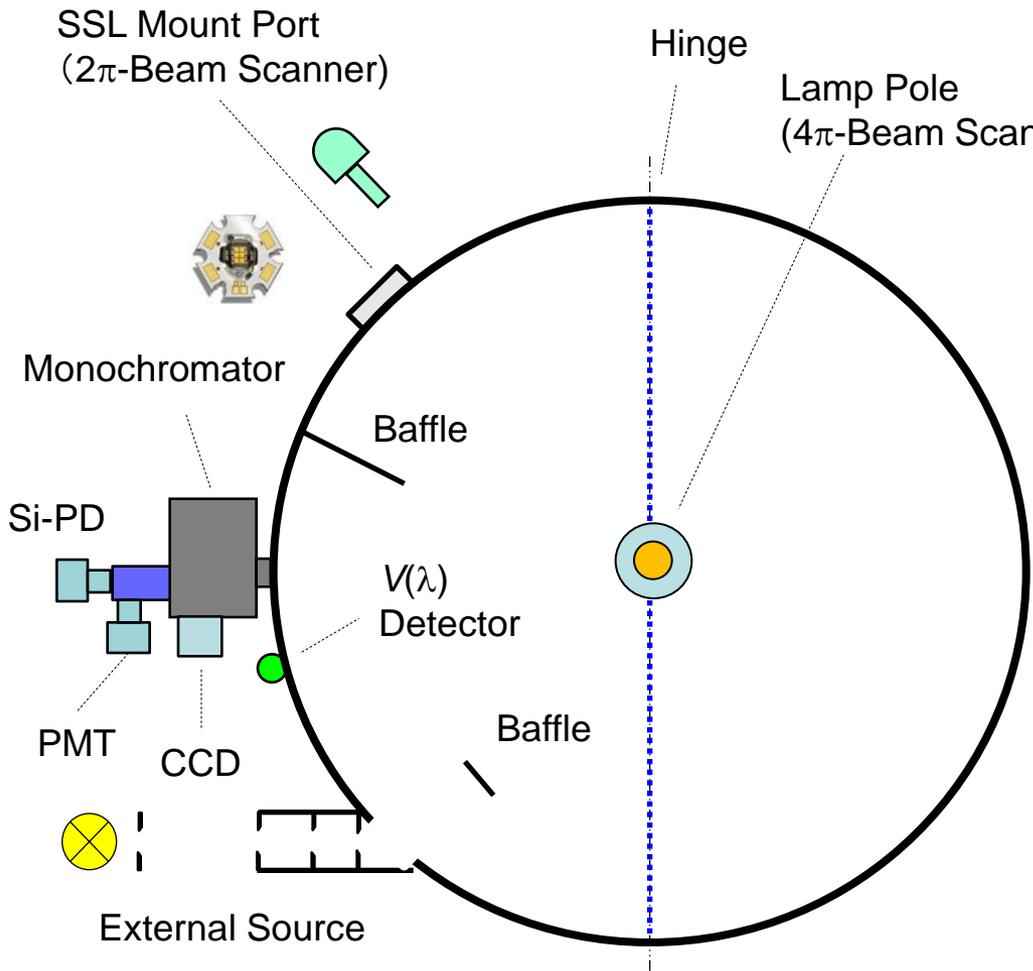
Spectral Radiant Flux (arb. units)



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# Sphere Spectroradiometer System for Total Spectral Radiant Flux Standard

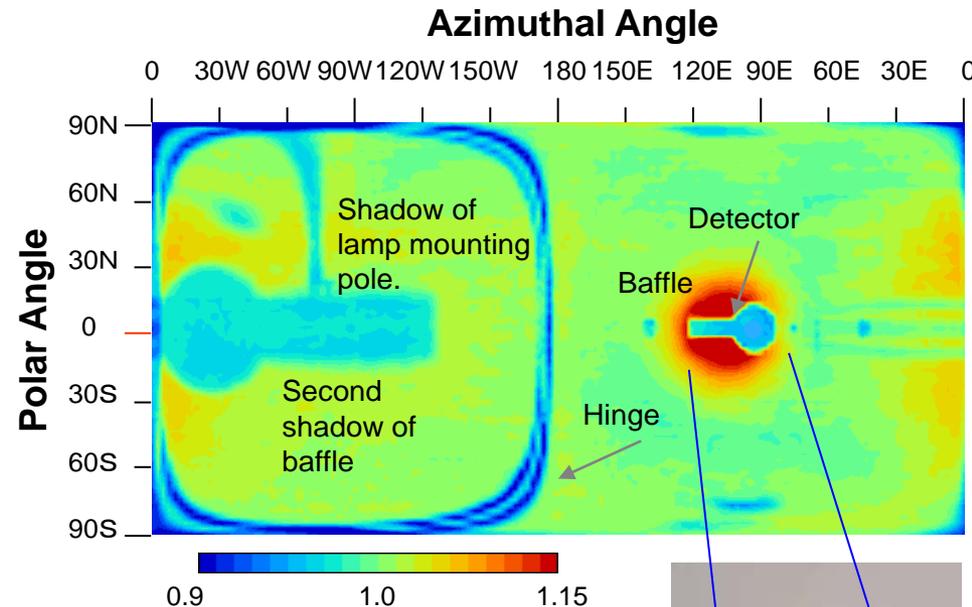


NMIJ 1.65 m sphere spectroradiometer system

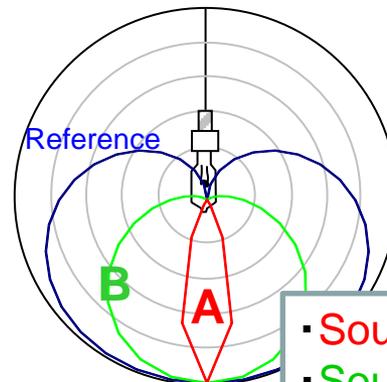
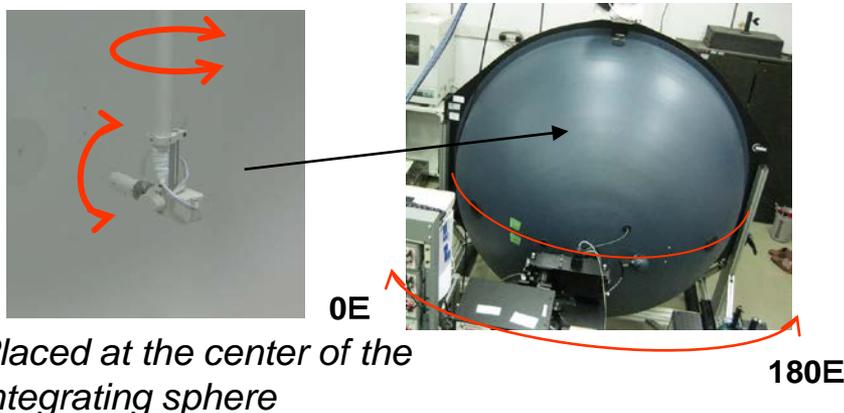
# Measurement of Spatial Response Distribution Function (SRDF)

- The SRDF of a integrating sphere was measured by using a newly designed LED beam scanner.
- The error of total luminous flux calibration, arisen from the SRDF non-uniformity, was evaluated.
- Several light sources which have different luminous intensity distribution were used for the error evaluation (In our evaluation, narrower intensity distribution caused larger error.)

## SRDF Plot as Cylindrical Projection



North pole

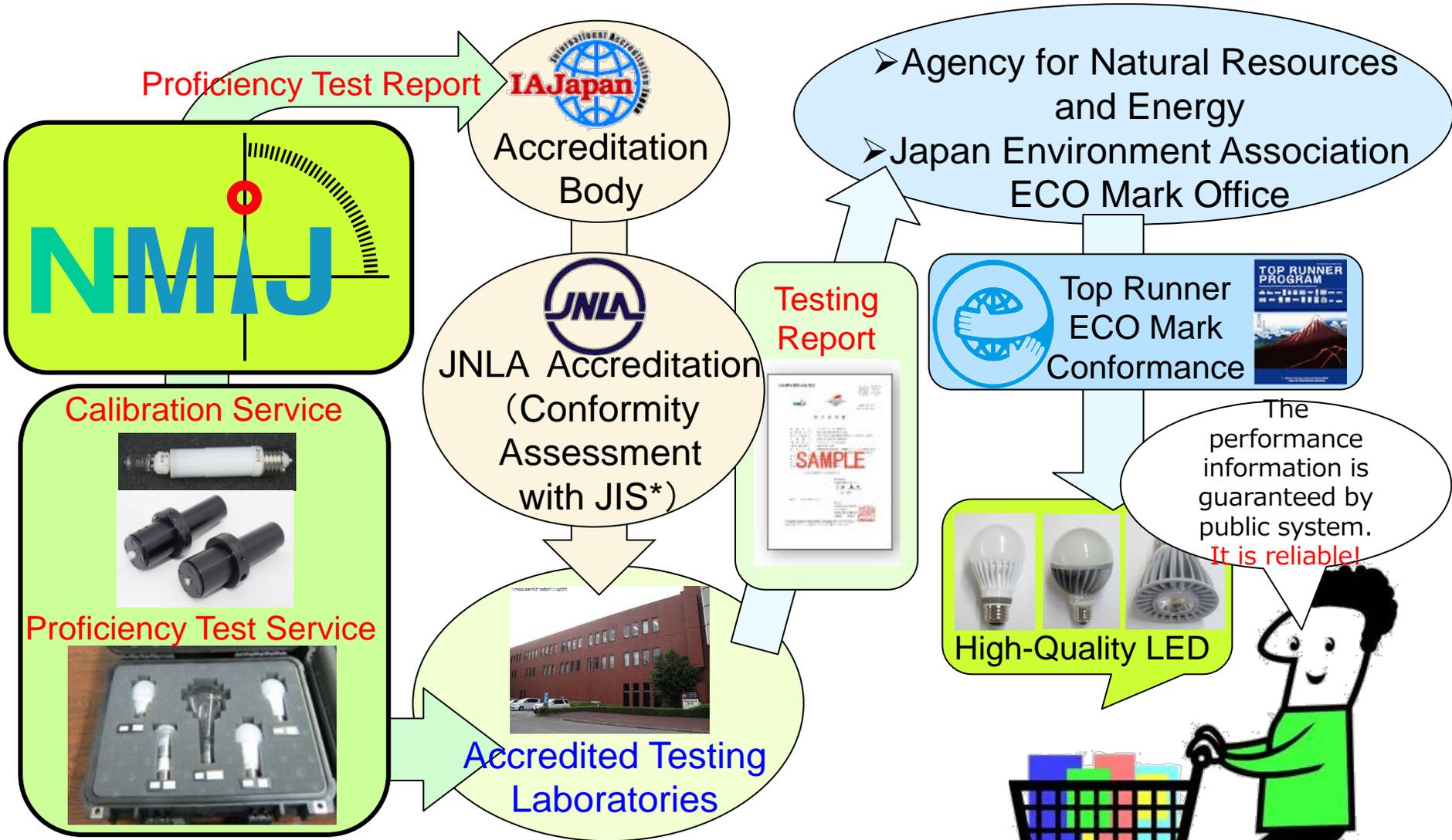


- Source (A) / Reference: 0.84 %
- Source (B) / Reference: 0.13 %

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# Conducting a Proficiency Testing for LED Based Lighting



\*JIS: Japanese Industrial Standards (Document Standard)

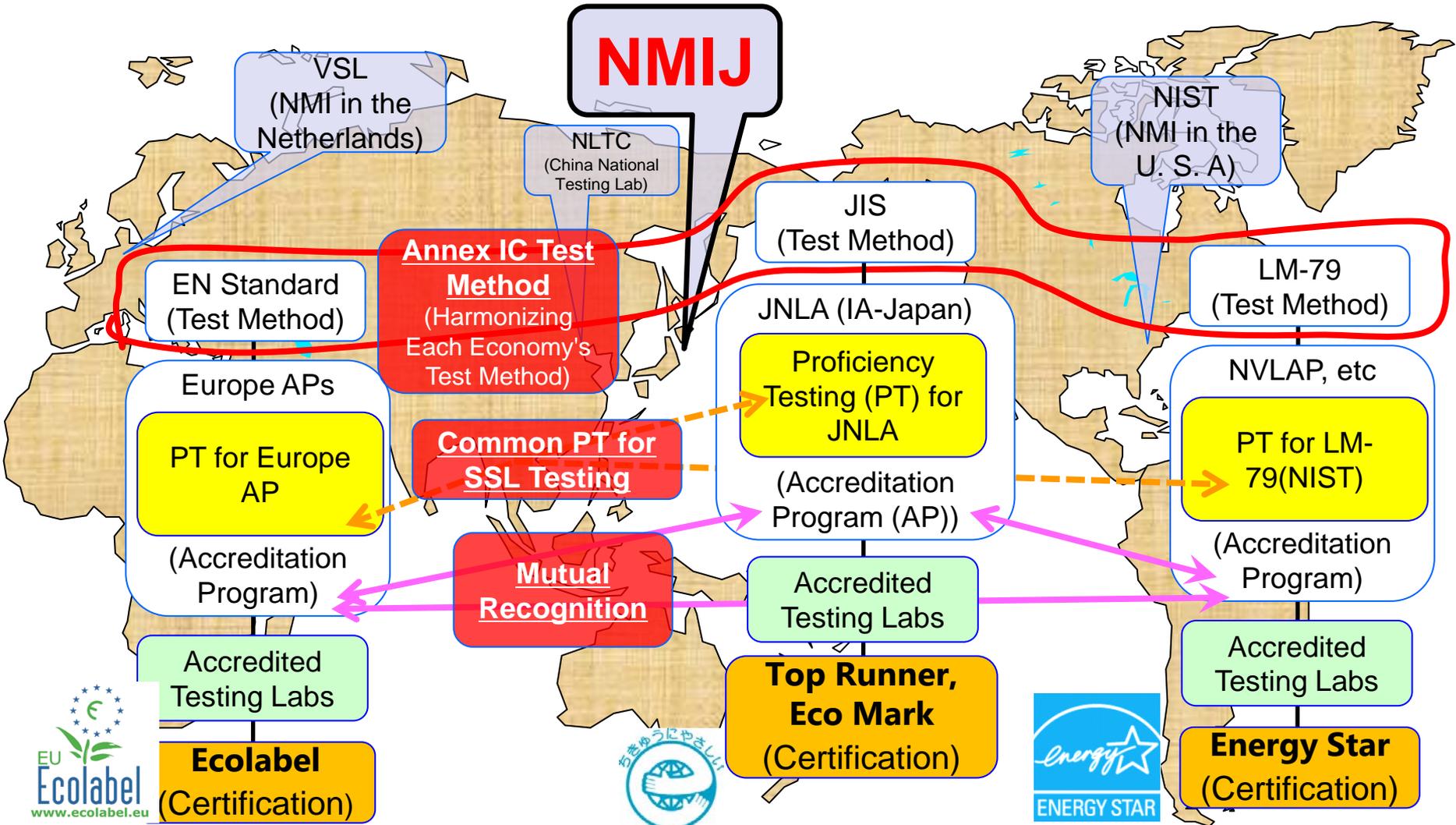
# Outline of the Proficiency Testing in Japan

- Number of the participant : 12 laboratories  
(3: public test laboratories, 9: manufactures)
- Artifacts  
5 types of artifacts were selected for the Proficiency Testing: 4 are LED lamps and one is an incandescent lamp
- Schedule: Nov 2012~Jun 2013  
The participant laboratories were divided into 4 groups.  
Until end of March, 10 participants finished their measurements.



The artifacts for the Proficiency Testing

# Worldwide Activity for Harmonizing Proficiency Testing by IEA-4E SSL Annex



# The Proficiency Testing Results

- 123 testing / calibration labs participated the activity
- [http://ssl.iea-4e.org/files/otherfiles/0000/0067/IC2013\\_Final\\_Report\\_final\\_10.09.2014a.pdf](http://ssl.iea-4e.org/files/otherfiles/0000/0067/IC2013_Final_Report_final_10.09.2014a.pdf)

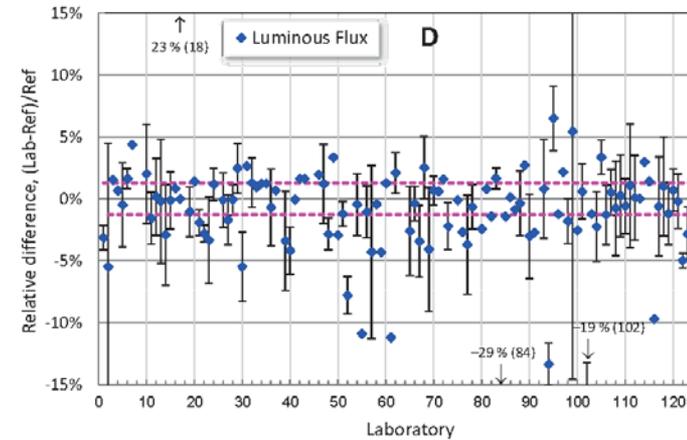
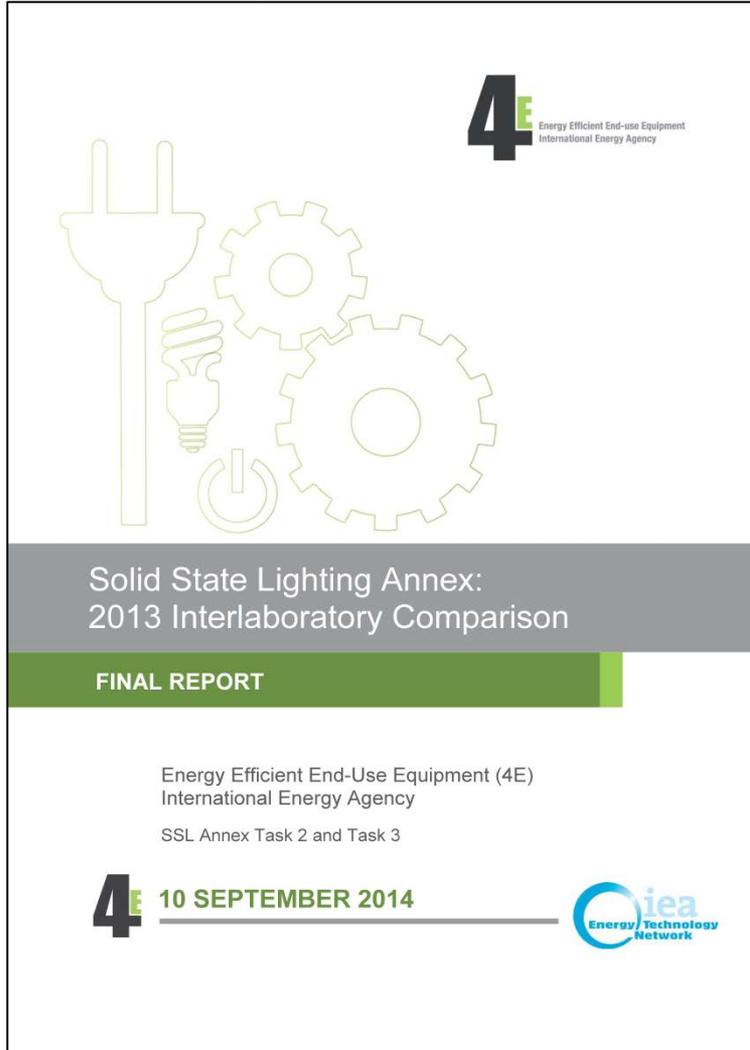


Figure 9-3. Relative differences of total luminous flux for directional LED lamp (D)

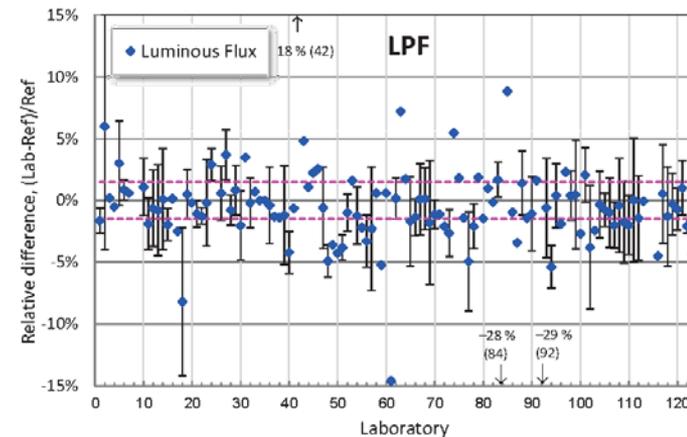


Figure 9-4. Relative differences of total luminous flux for low power factor lamp (LPF)

# Discussions with Stakeholders

- Government, Manufacturer, Accreditation Body, Standardization body, Consumer Associations
- Discussion (Conflict)
  - **Government:** Necessity of the activity and funding  
=> Energy Star Marking, International Organization Work
  - **Manufacturer:** Benefit introducing the system  
=> Better Standard, Government leadership
  - **Standardization body:** Benefit for the main user  
=> Better Document Standard, Government leadership
- **Contribution item from metrological side is different with different stakeholders!**

Thank you for your attention