中国计量科学研究院
National Institute of Metrology,China

LED Sources in Photometry

Development of LED Filament Standard Lamp

National Institute of Metrology(NIM), China

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CCPR meeting

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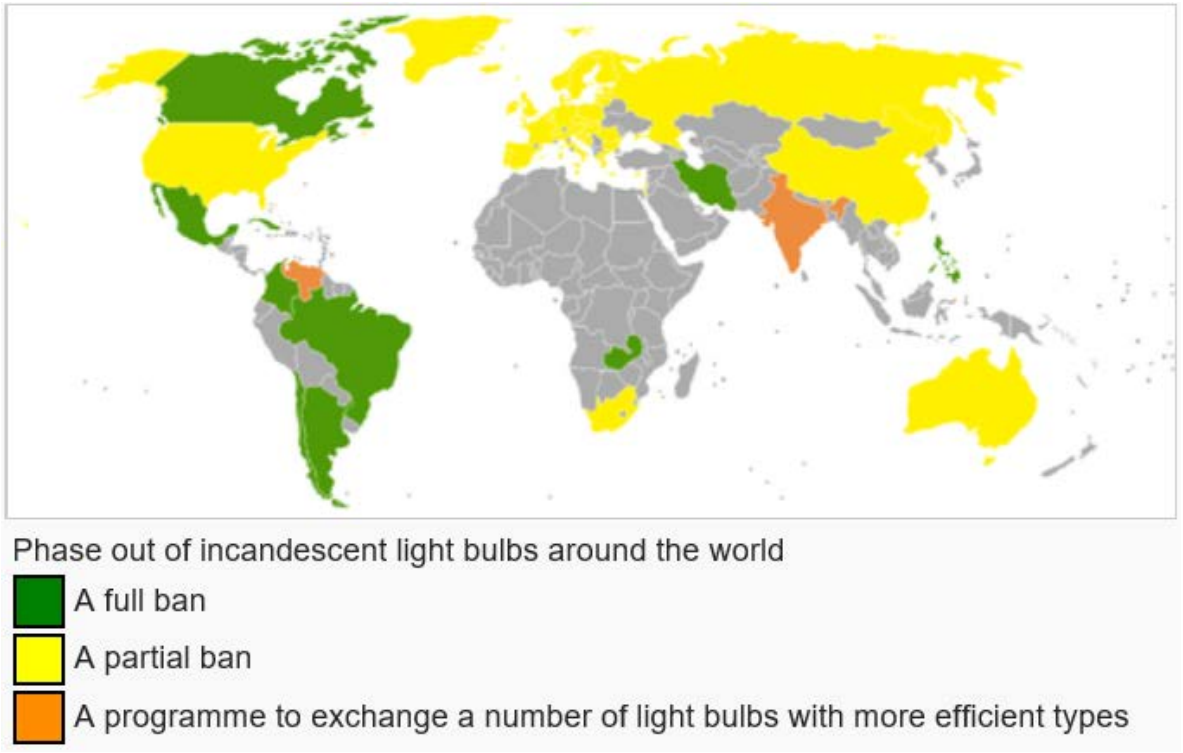
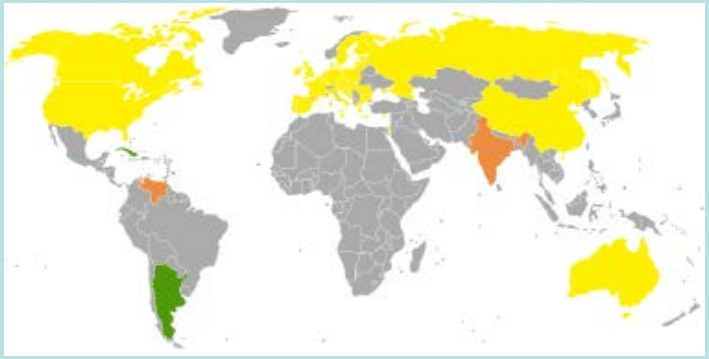
5 Summary

- Incandescent lamps are rapidly phasing out around the world.



Source: wikipedia 2016.9



Source: wikipedia 2016.3

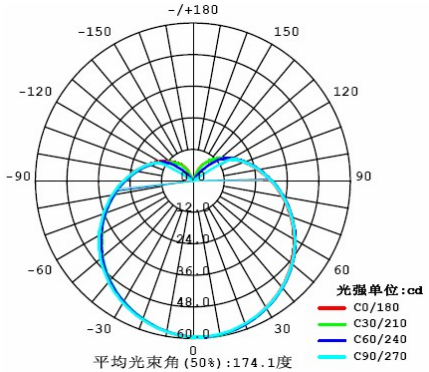
- LED lamps are widely used

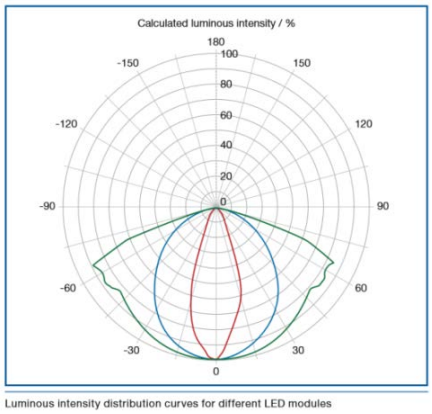
- Challenges for photometry:

  Light sources to be measured are significantly different from standard lamp

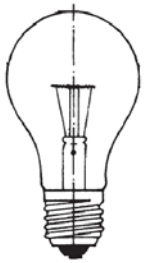
  – (1) Spatial distribution of luminous intensity: directional vs uniform

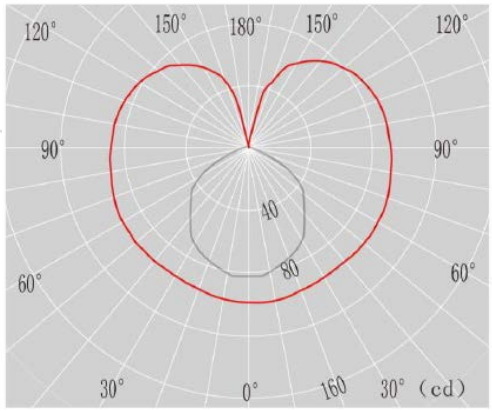
LED Bulb



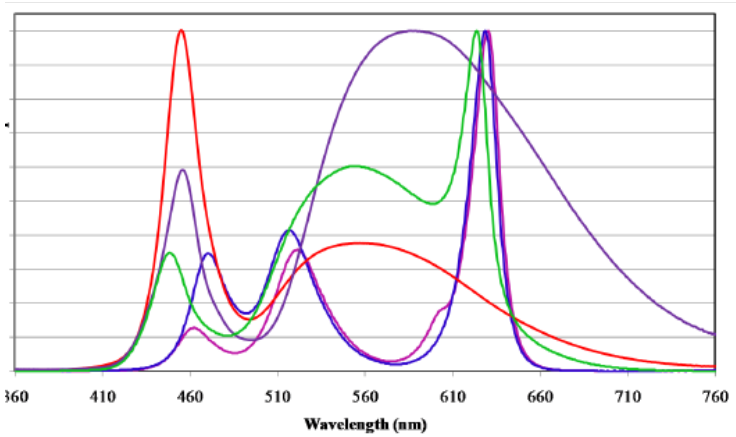


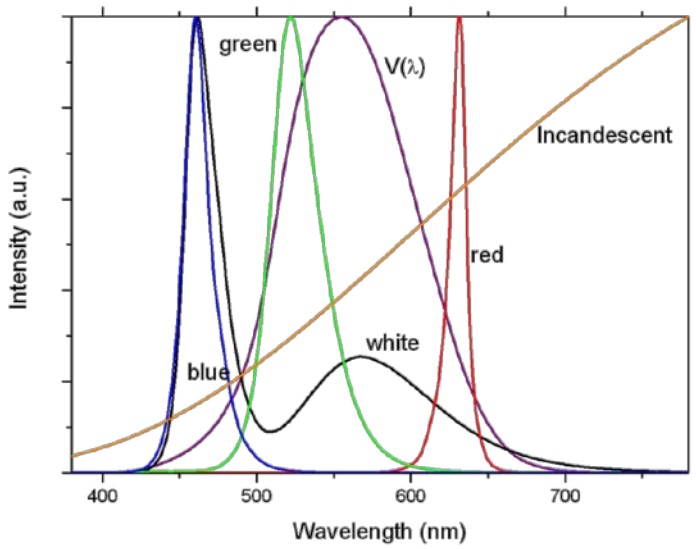
Incandescent Lamp

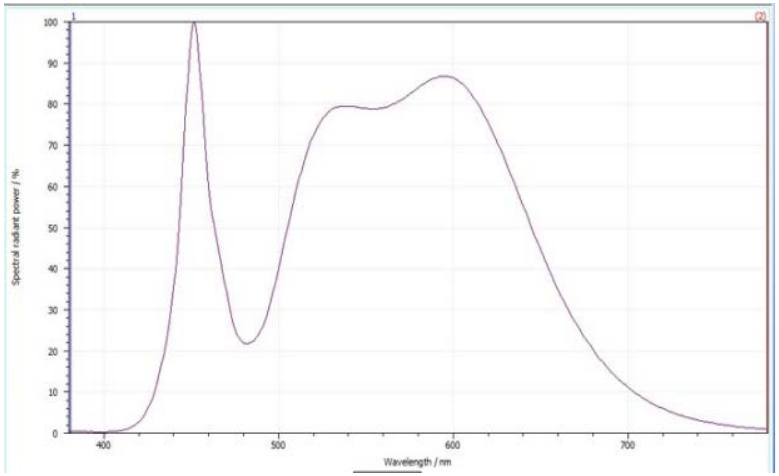




- Challenges for photometry
  - (2)Spectral power distribution:
    - Large deviation from CIE illuminant A
      - Spectral shape
      - narrowed band







- This presentation mainly focus on **Luminous flux** (Luminous intensity, illuminance, luminance)
- Solutions: measurement facility or standard artifact
- 1. To set up a goniophotometer or a high quality integrating sphere measurement facility and make spatial distribution corrections
  - **Pros:** Suitable to all kinds of LED lamps
  - **Cons:** High cost for each measurement facility
    - Goniophotometer: less efficient
    - integrating sphere: not easy for users at different level of lab to make the corrections
- 2. **To establish a set of standard LED lamps** for the maintenance and dissemination of photometric quantities
  - **Pros**:
    - Easy to disseminate and keep the accuracy
    - Low cost for the whole traceability system
  - **Cons:** How many kinds of LED lamps are necessary?

- **Characteristics of standard lamp:**
  - Spatial luminous intensity distribution
  - Stability: short term and long term
  - Reproducibility
  - Robust: transportation
  - Warm-up time: short
  - ------

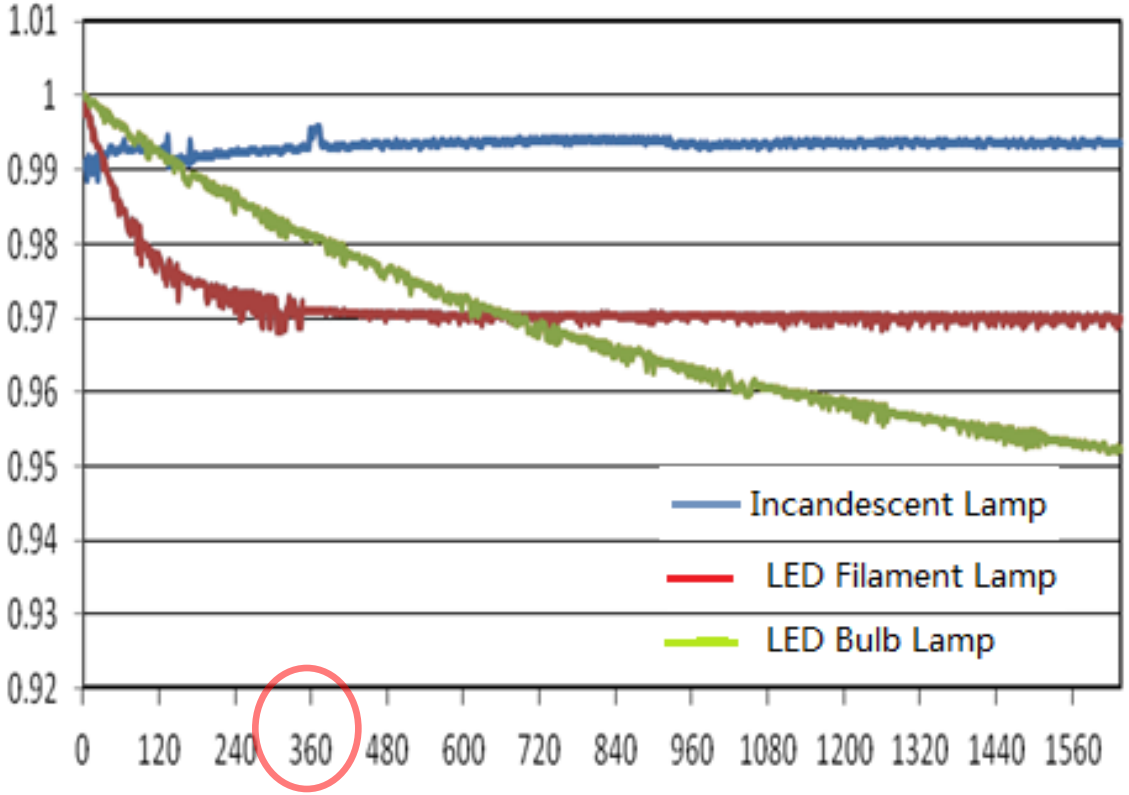
- A good candidate of standard lamp:
  - LED Filament Lamp

-Results of LED Filament Standard Lamps

Warm up time

Comparable to incandescent lamp,

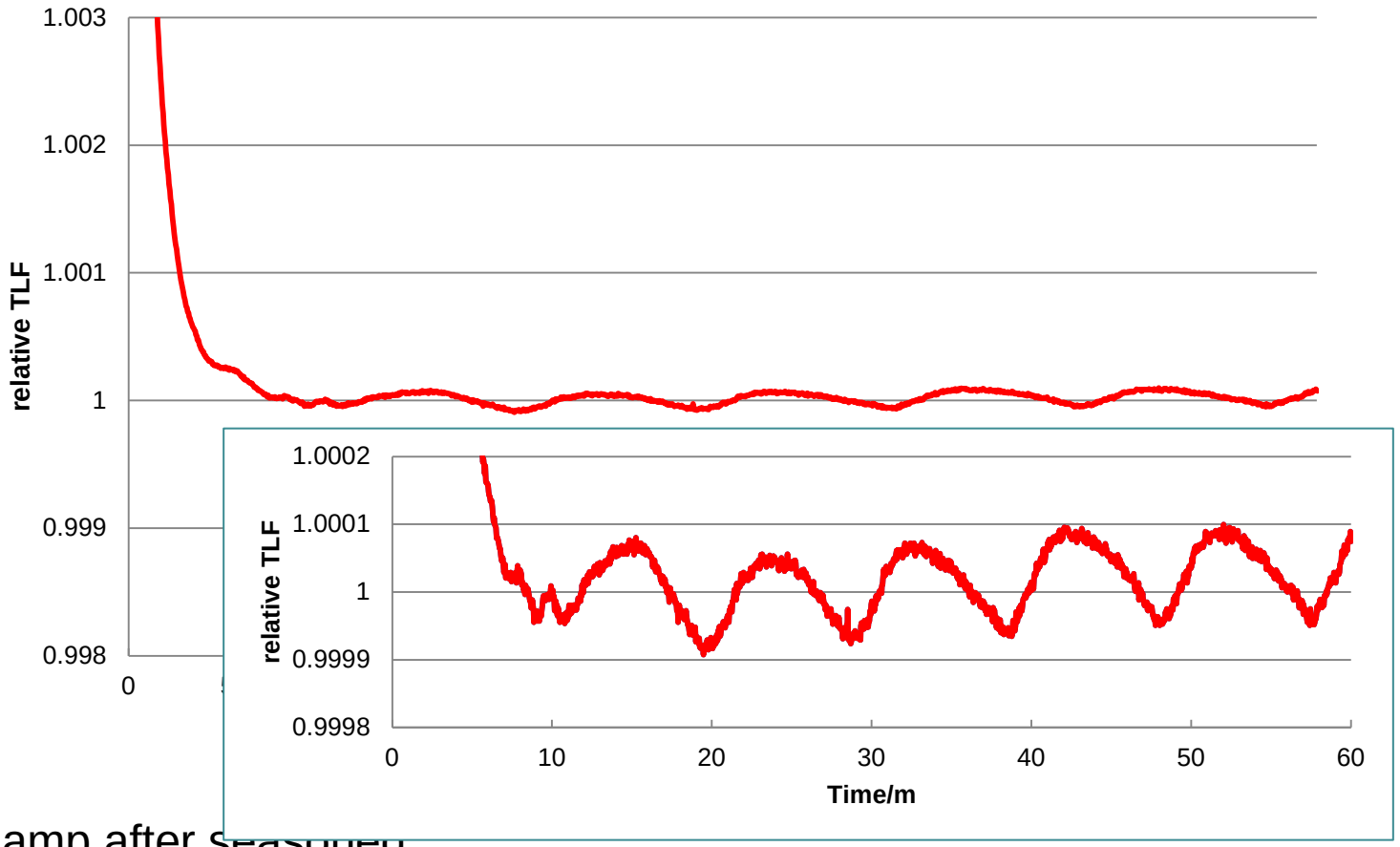
much shorter than normal LED lamps



Luminous Flux Vs. time (s)

- Results of LED Filament Standard Lamps

Short term stability



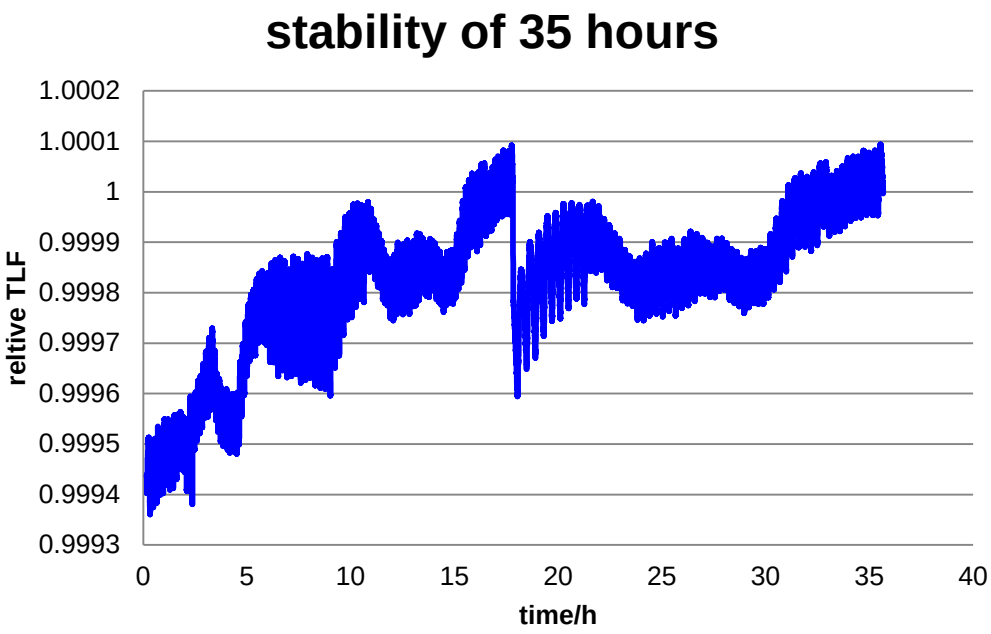
lamp after seasoned

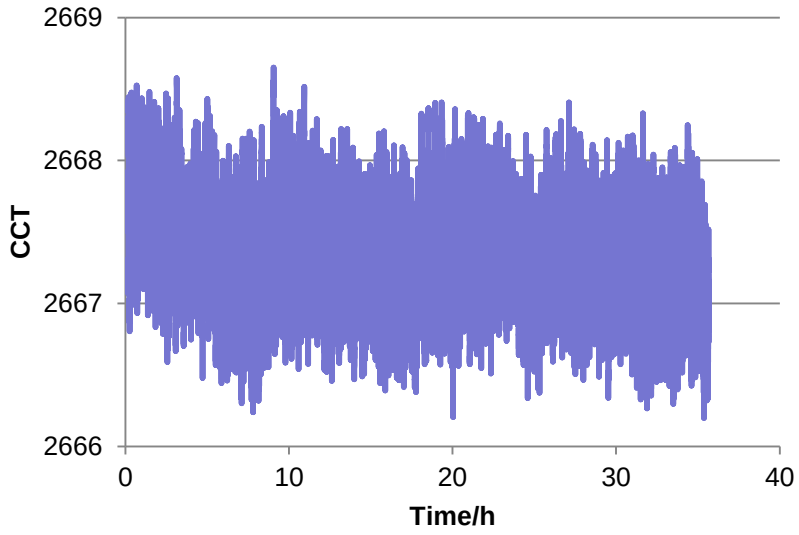
Stability in 53min after 6.5 min warm-up:
The fluctuation is 192ppm(peak-peak), 45 ppm(stdev).

- Results of LED Filament Standard Lamps

Stability

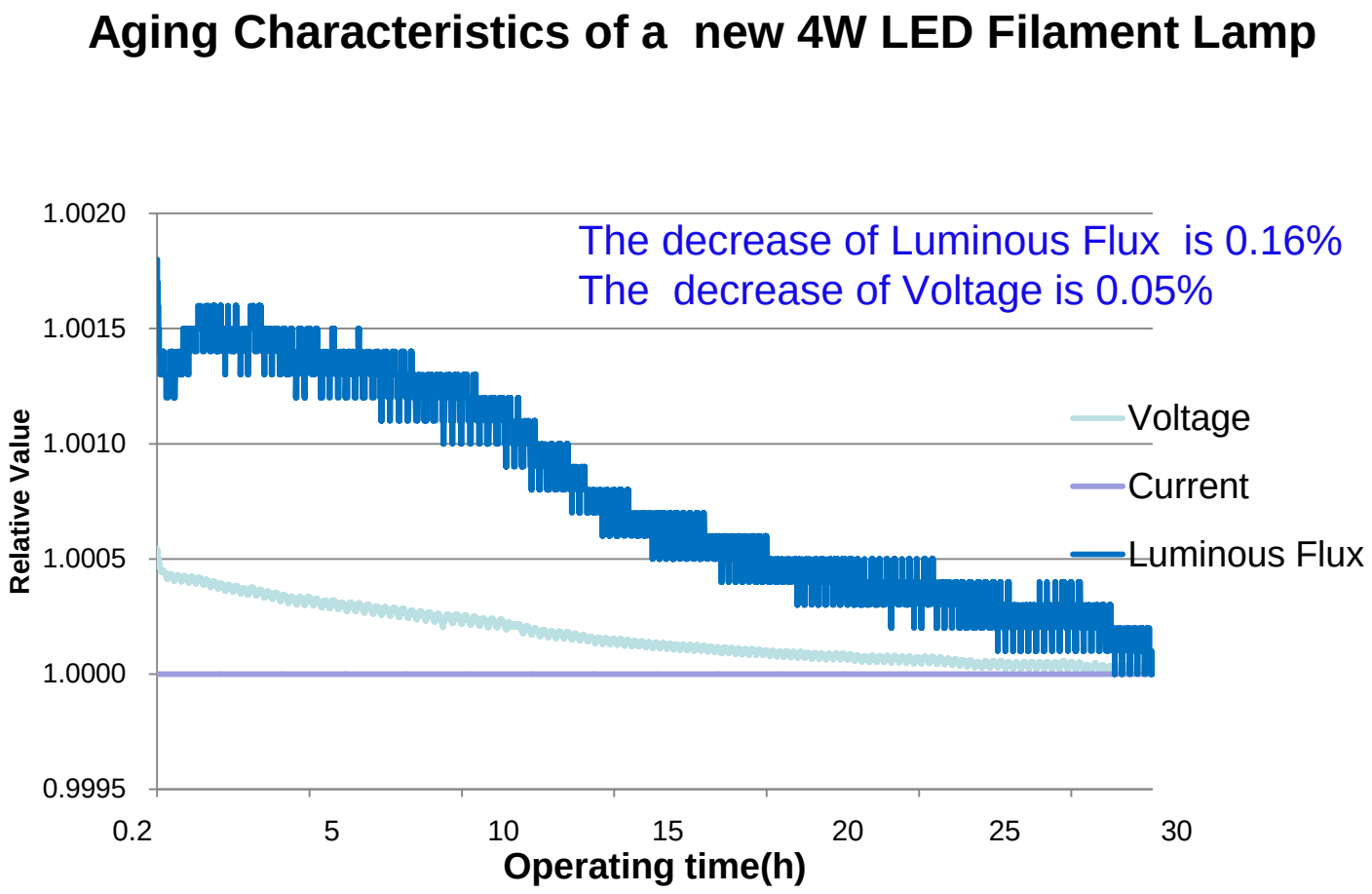
4W LED Filament Lamp after 2000 h seasoning





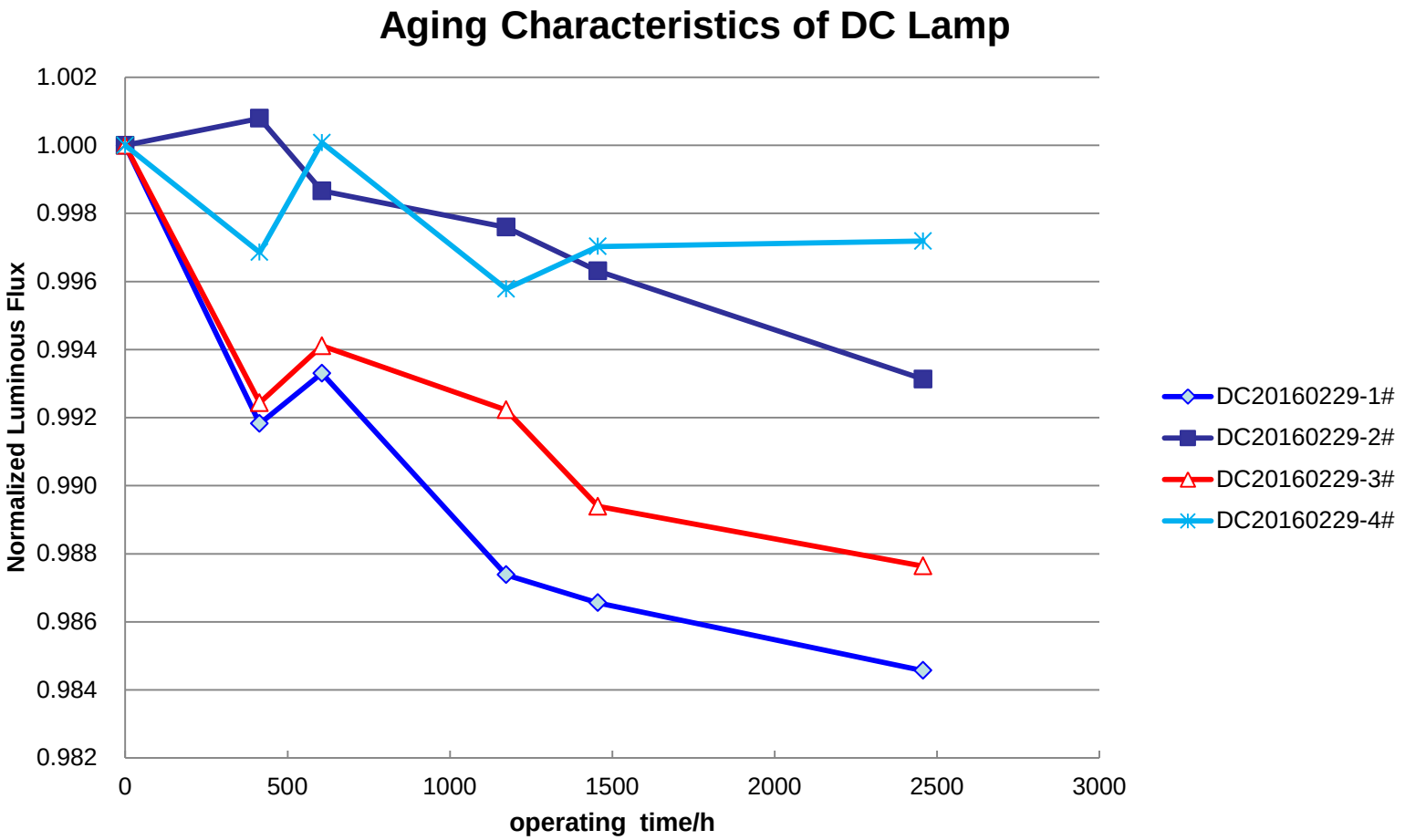
- Results of LED Filament Standard Lamps

Aging



- Results of LED Filament Standard Lamps

Aging (2475h)



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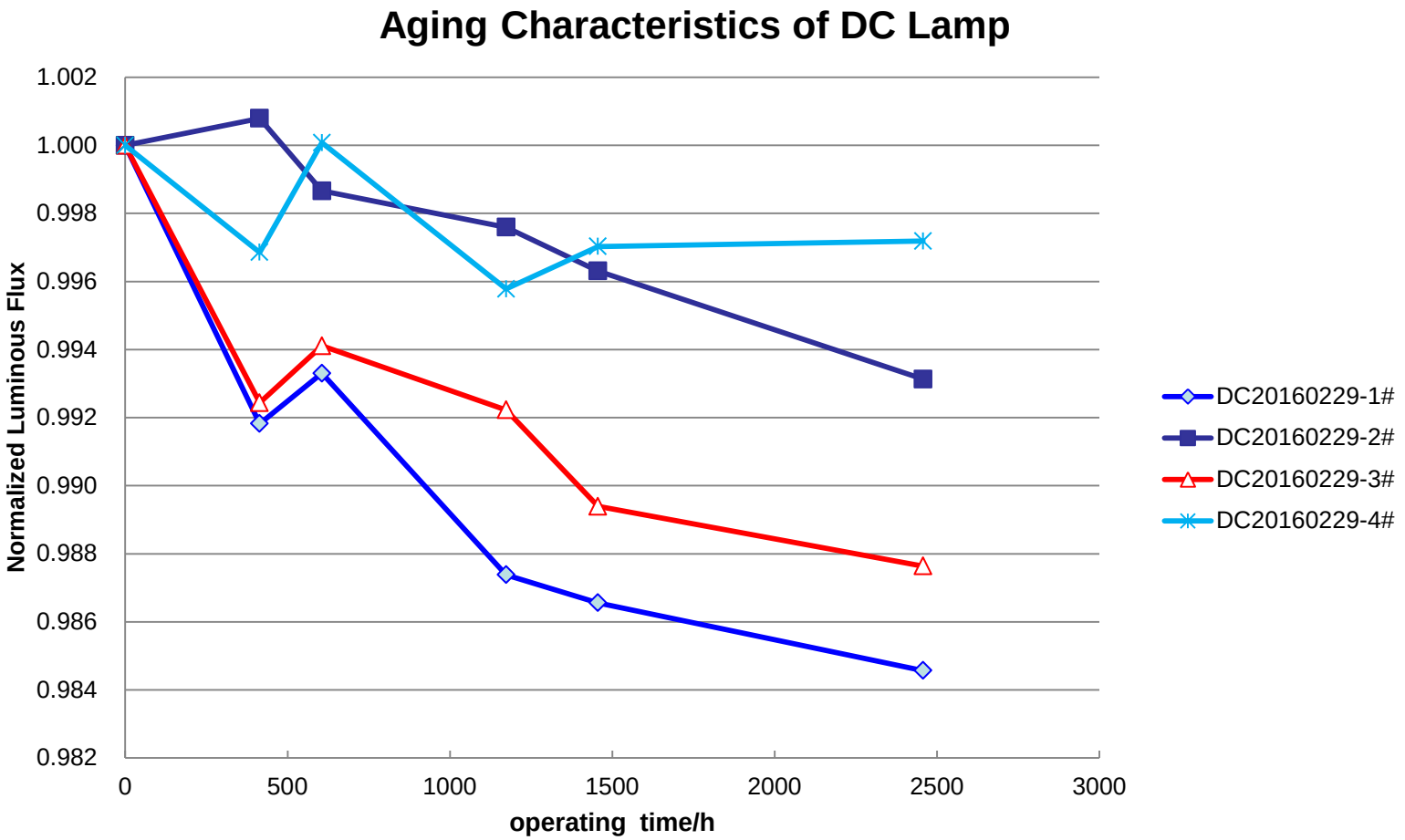

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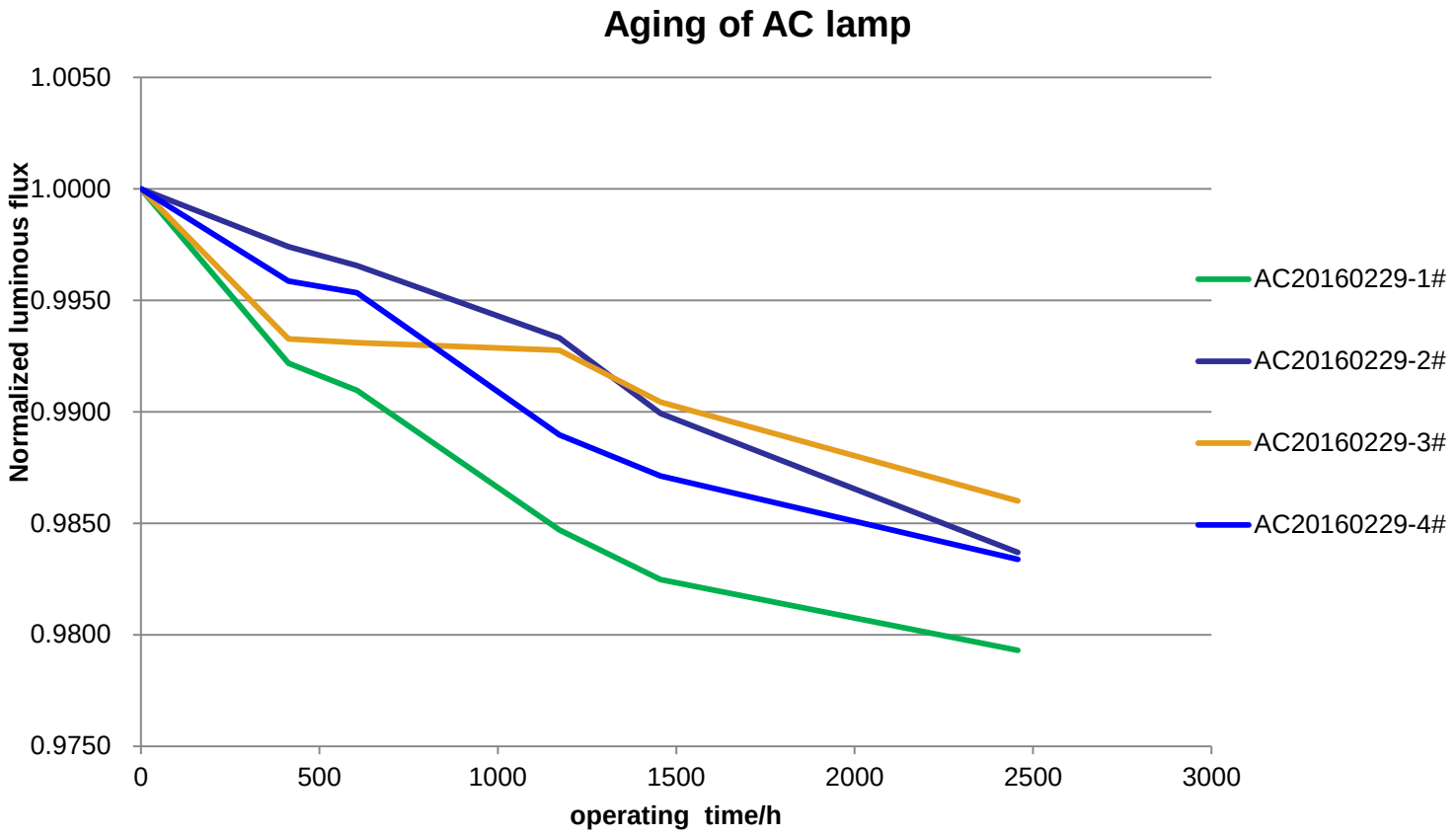
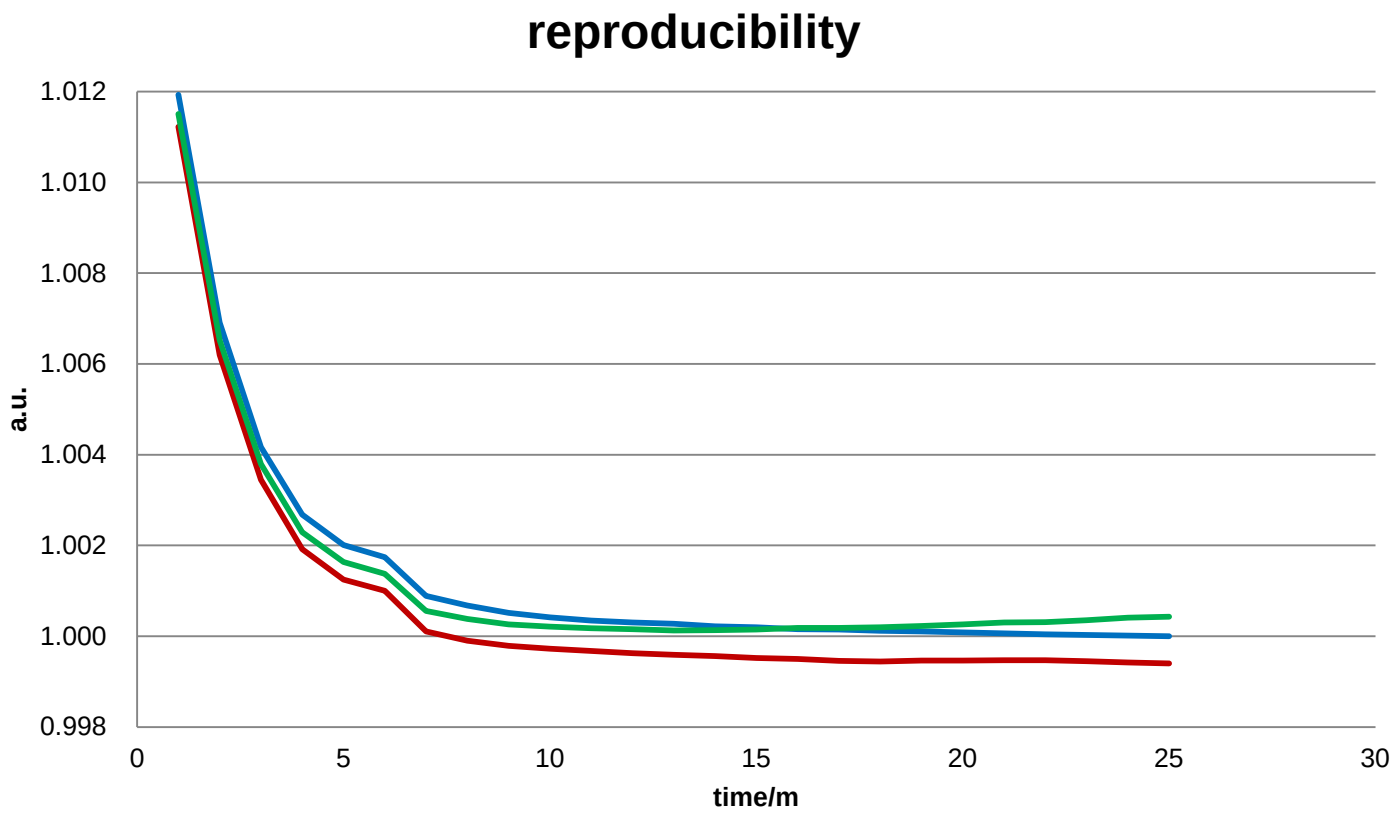


- Results of LED Filament Standard Lamps

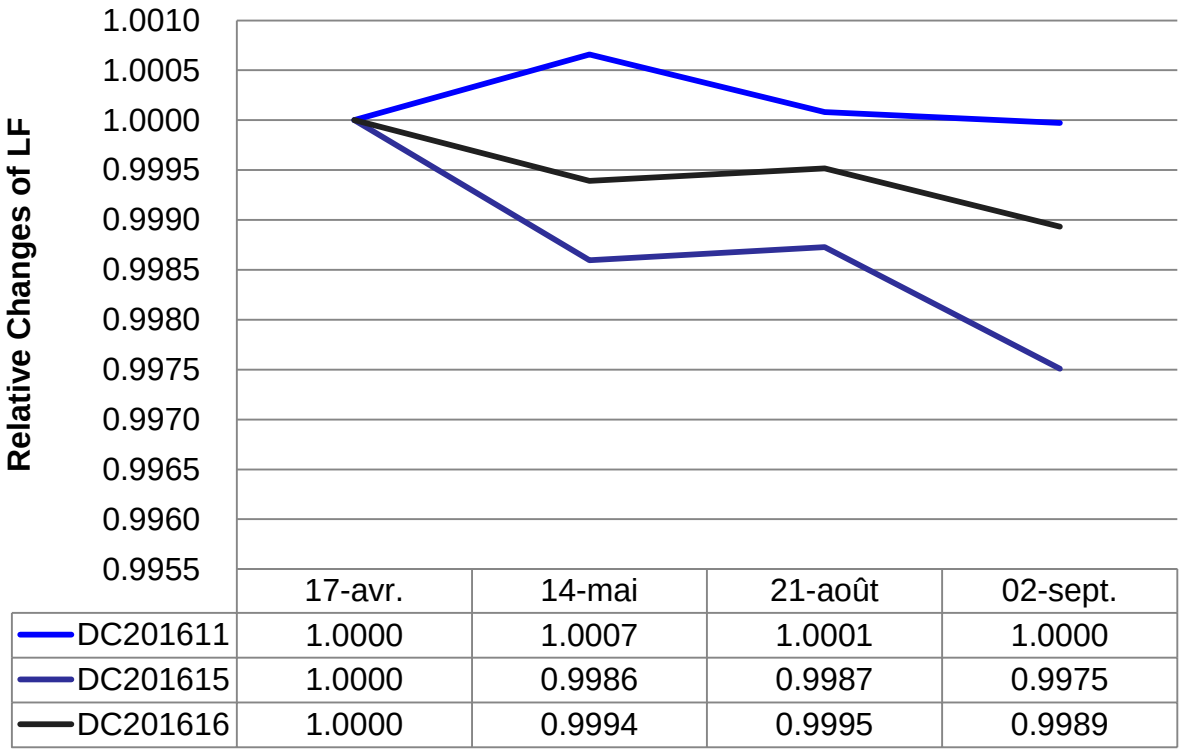
Short-term reproducibility: Within 0.1%



1)Turning on ;2) Burning 24 min;3) Turning off 30 min 4) Turning on…Repeat for 3 rounds

- Results of LED Filament Standard Lamps

Long-term Reproducibility (5 months)



	17-avr.	14-mai	21-août	02-sept.
DC201611	1.0000	1.0007	1.0001	1.0000
DC201615	1.0000	0.9986	0.9987	0.9975
DC201616	1.0000	0.9994	0.9995	0.9989

After 500h burning

Stored in the laboratory without burning except for measurement.

- Results of LED Filament Standard Lamps

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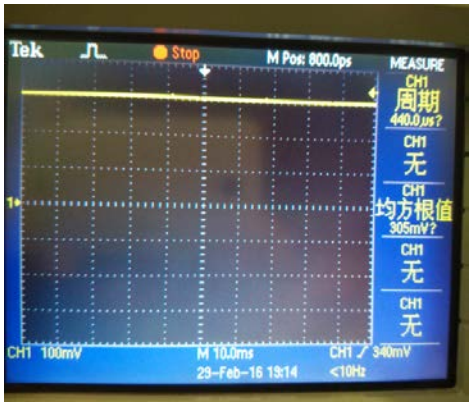
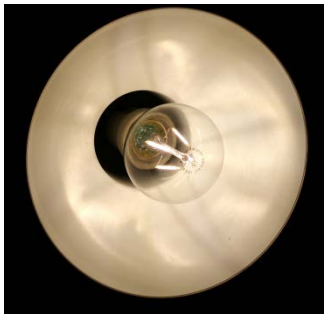
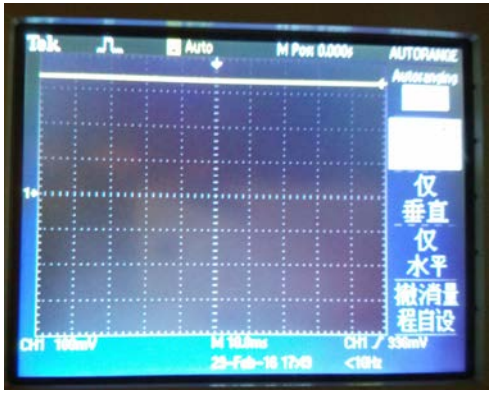
Flicker

Standard AC driven LED filament lamp

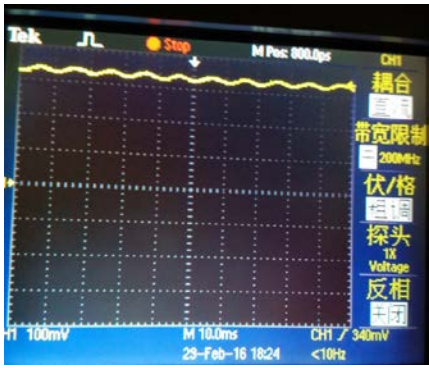


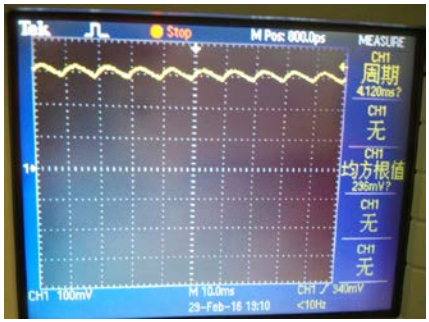


Standard DC driven LED filament lamp



AC incandescent lamp





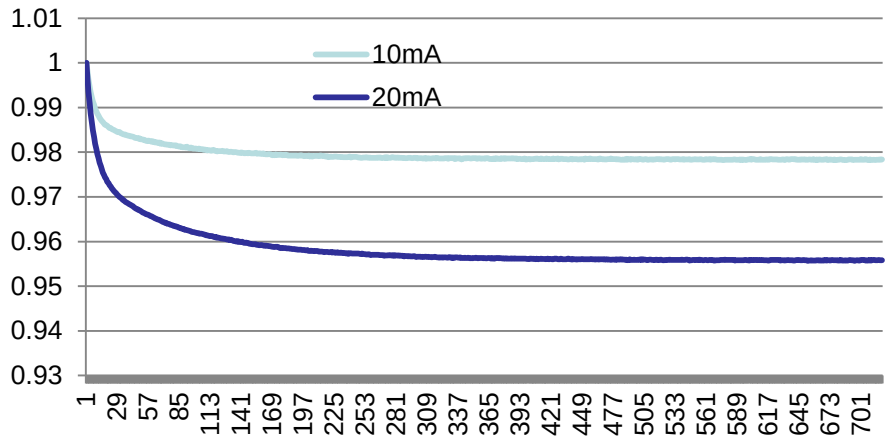
Commercial LED filament lamp

There is no flicker for LED filament standard lamp.

- Results of LED Filament Standard Lamps

Burning at different current of lamp AC20160229-7#

Current		TLF/lm	x	y	CCT/K
10mA	Initial	245.38	0.4684	0.4190	2649
	End	240.49	0.4682	0.4189	2650
20mA	Initial	486.94	\	\	\
	End	465.37	0.4664	0.4179	2667



Relative TLF Vs. time(s)

-Results of Standard Filament LED Lamps

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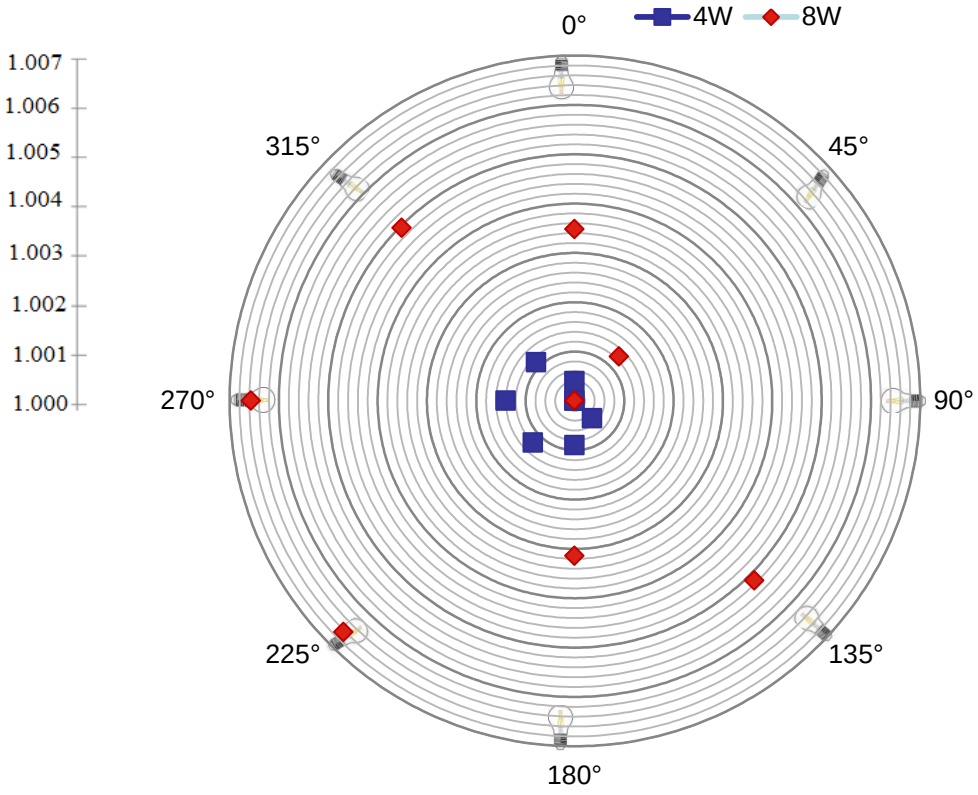
Burning position



4W lamp is not sensitive to burning position, while 8W shows sensitive to burning position.

4 W LED Filament Lamp

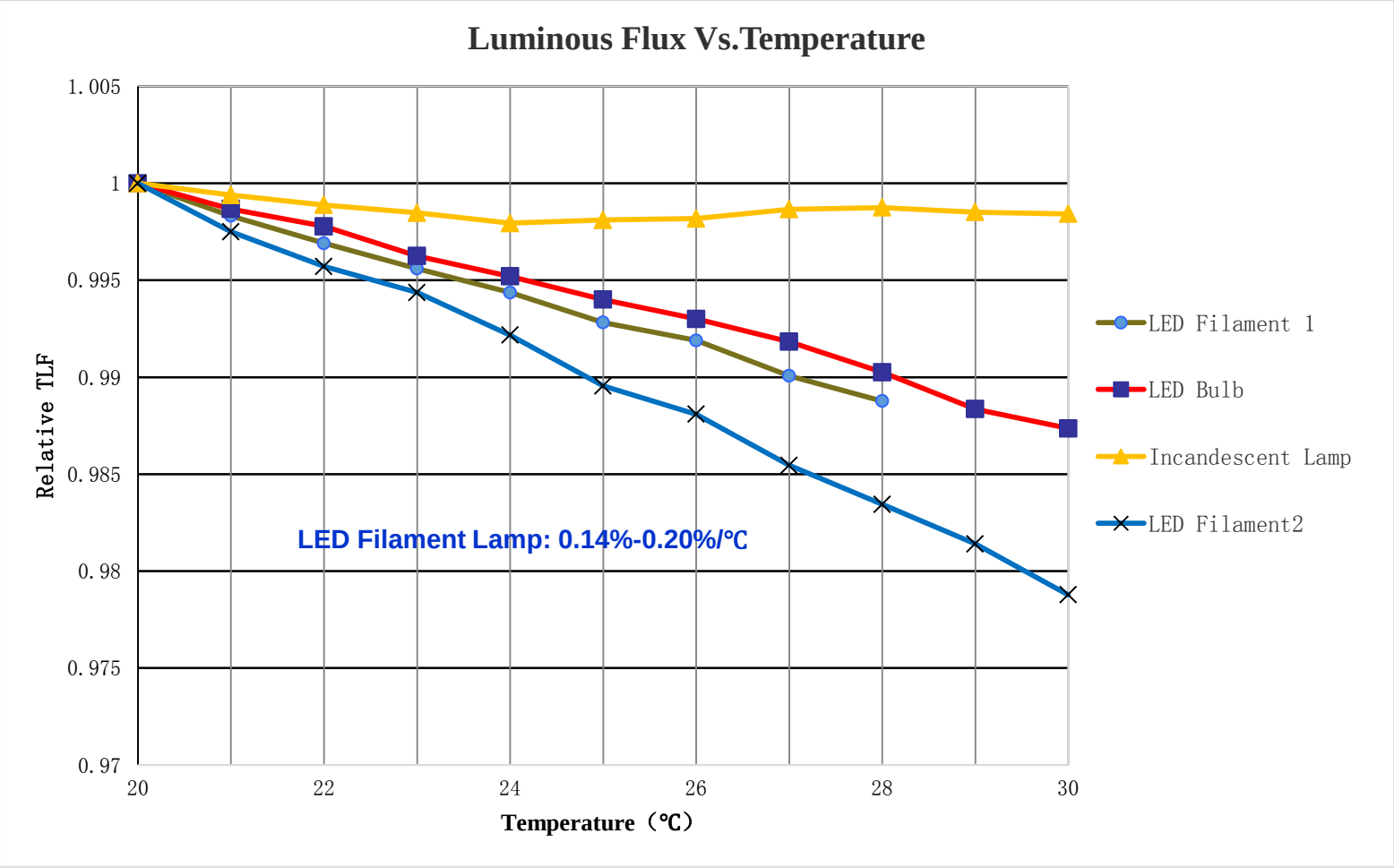
Angle	Photocurrent	Relative Photocurrent
0°	6.8643	1.0004
45°	6.8613	1.0000
90°	6.8613	1.0000
135°	6.8645	1.0005
180°	6.8677	1.0009
225°	6.8698	1.0012
270°	6.8709	1.0014
315°	6.8688	1.0011

8 W LED Filament Lamp

Angle	Photocurrent	Relative Photocurrent
0°	14.991	1.0035
45°	14.958	1.0013
90°	14.939	1.0000
135°	15.016	1.0052
180°	14.986	1.0031
225°	15.038	1.0066
270°	15.037	1.0066
315°	15.013	1.0050

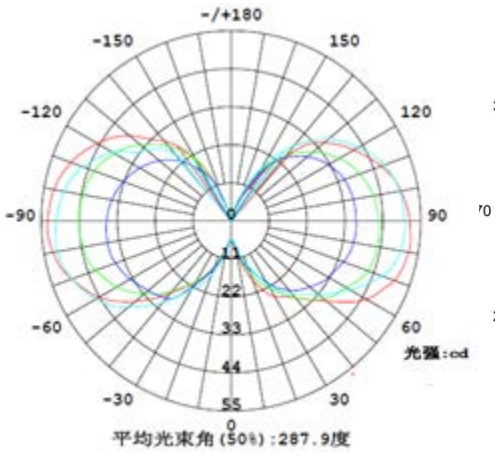
- Results of LED Filament Standard Lamps

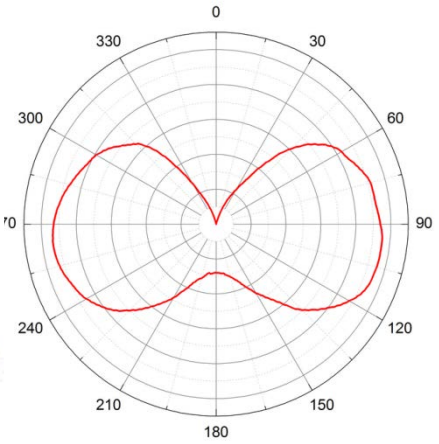
Temperature dependent properties

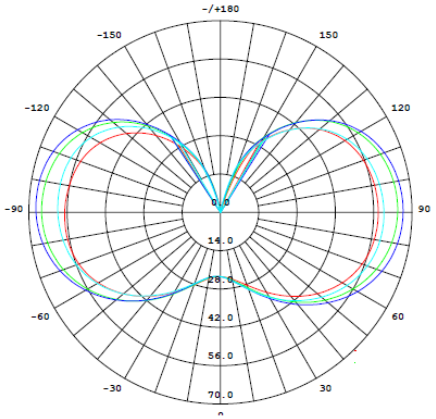


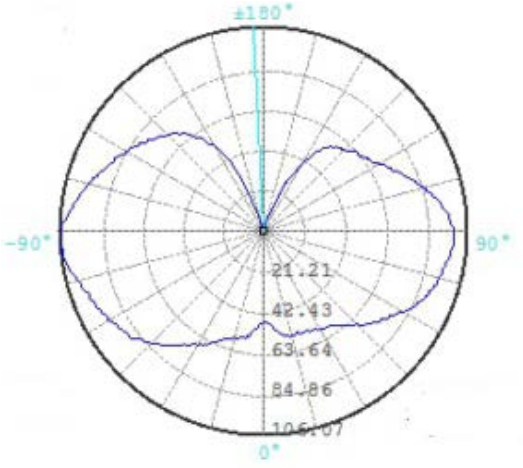
-Results of Standard Filament LED Lamps

Spatial luminous intensity distribution of different type of LED filament lamp (TFL)









-Results of Standard Filament LED Lamps

LED filament lamp for luminous intensity

Distance d/m	Photo Current i_p	i_p*d^2	Deviation (normalized at 6999.1mm)
0. 4774	377. 49	86. 0340	−0. 02%
0. 9802	89. 547	86. 0360	−0. 02%
1. 4918	38. 683	86. 0877	0. 04%
1. 9613	22. 374	86. 0660	0. 01%
2. 8637	10. 491	86. 0327	−0. 02%
4. 2080	4. 8568	86. 0006	−0. 06%
5. 8526	2. 5098	85. 9680	−0. 10%
6. 9991	1. 7567	86. 0537	0. 00%

Luminous Intensity :
587 cd

CCT: 2747 K

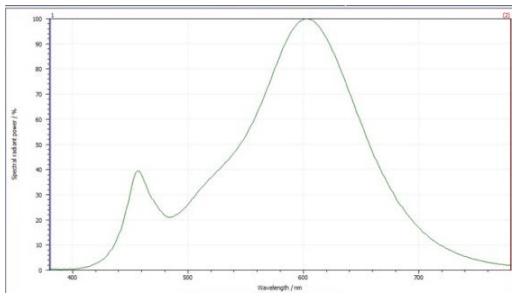
Standard LED filament lamp Vs. Incandescent standard lamp

	Incandescent lamp	LED filament lamp
Drift rate	0.02%	**About 1/10 of Incandescent lamp**
Life time	<2000 h	**>5000 h**
Warm up time	5-10 min	**6-12 min**
Short time stability	0.02%-0.05%	**0.02%-0.05%**
Reproducibility	0.1%	0.1%
Shelf life	good	Under investigation
Transportation	Fragile	**Robust**
Temperature dependency	None	~ 0.2% /℃
Spatial distribution	Good	Under improvement

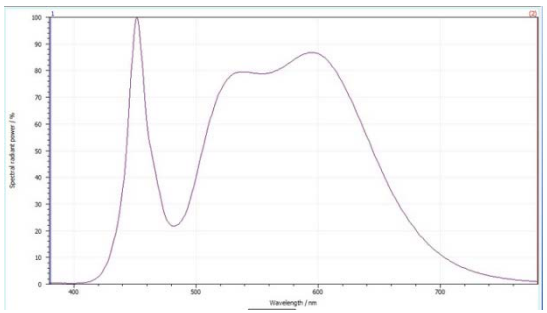
- Results of LED Filament Standard Lamps

The clan of standard LED filament lamp

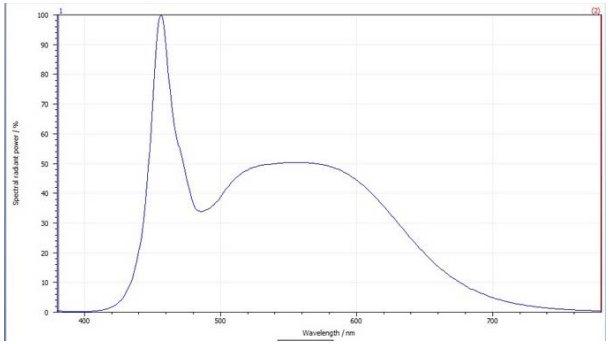
Driver	Power	CCT	Bulb
AC	4W	2700K	Clear
DC	6W	4000K	Frosted
	7W	6500K	



Warm White ~2700K



Cool White ~4000K



Day White ~6500K

Thanks !