Aalto University
School of Electrical
Engineering

LNE
Le progrès, une passion à partager

MIKES

Lifetime of LED Light Sources

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EMRP ENG05: Metrology for Solid State Lighting

- **WP1: Traceability for SSL Measurements**
- **WP2: Basic measurement methods for SSL characterisation**
  - Task 2.4: Lifetime estimation of solid state light sources
- **WP3: Human perception of SSL**
- **WP4: Quality metrics for SSL characterisation**
- **WP5: Creating impact**
- **WP6: JRP Management and Coordination**

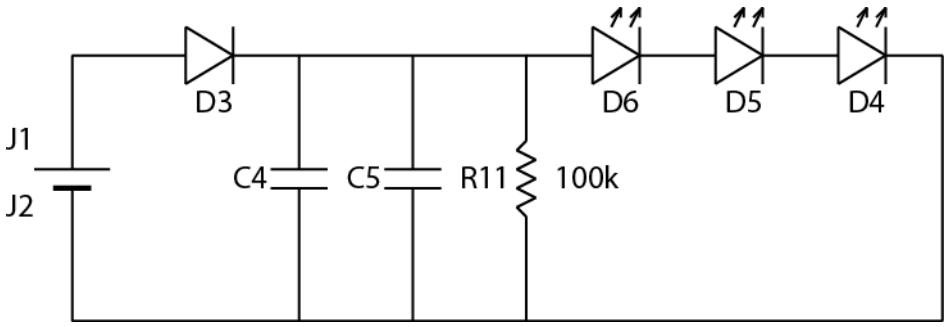
Motivation and research structure

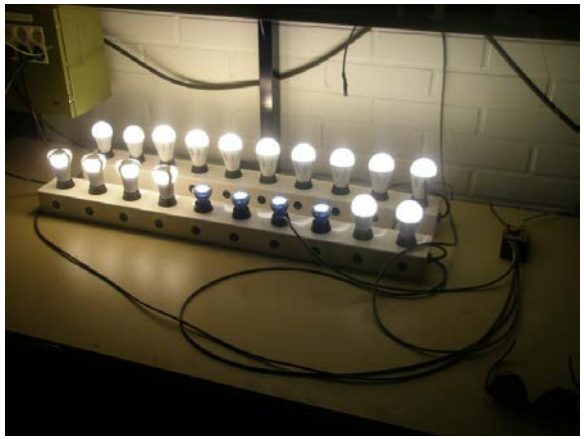
- **Rated lifetimes for LED-lamps are typically 20 000 – 50 000 hours (2-6 years).**
- **Traditional test are too time consuming.**
- **The goal of the research was to study the LED-lamp lifetimes and whether aging could be accelerated by moderate heating.**
- **Aging at room temperature of 25 ºC (Aalto) and at the elevated temperatures of 45 and 60 ºC (LNE).**
- **Periodical measurements for luminous flux, electrical power, luminous efficacy, spectrum, and colorimetric quantities *CCT*, *x*, *y*.**

Studied lamps

- **Five different types of LED lamps from two manufacturers were studied**

Manufacturer	Type	Power [W]	Color temp. [K]	Lifetime [h]
Philips	Master LEDbulb MV	12	2700	25 000
Osram	Parathom PAR16 20	4.5	6500	35 000
Osram	Parathom Classic A 40	8	3000	25 000
Osram	Parathom Classic A 60	12	3000	25 000
Osram	Parathom Classic A 80	12	2700	25 000

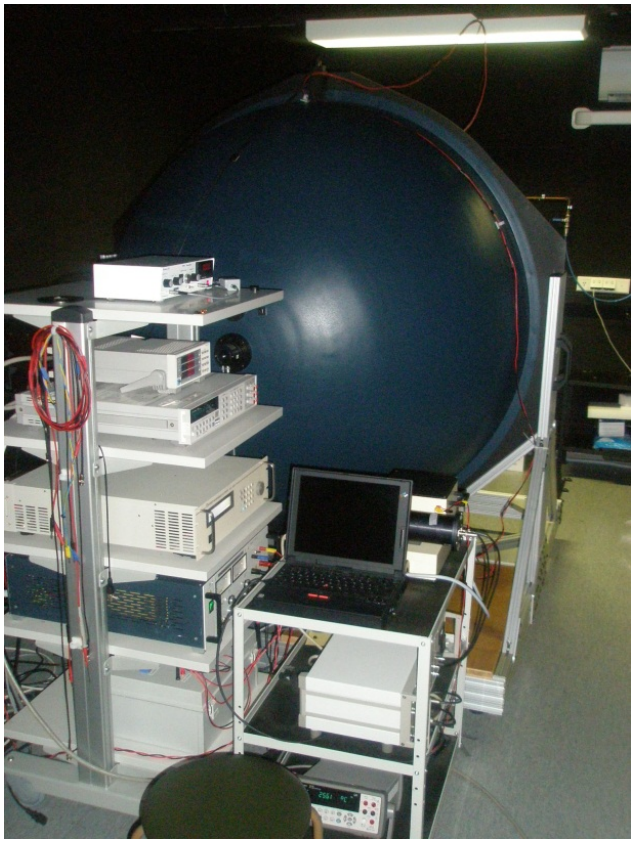


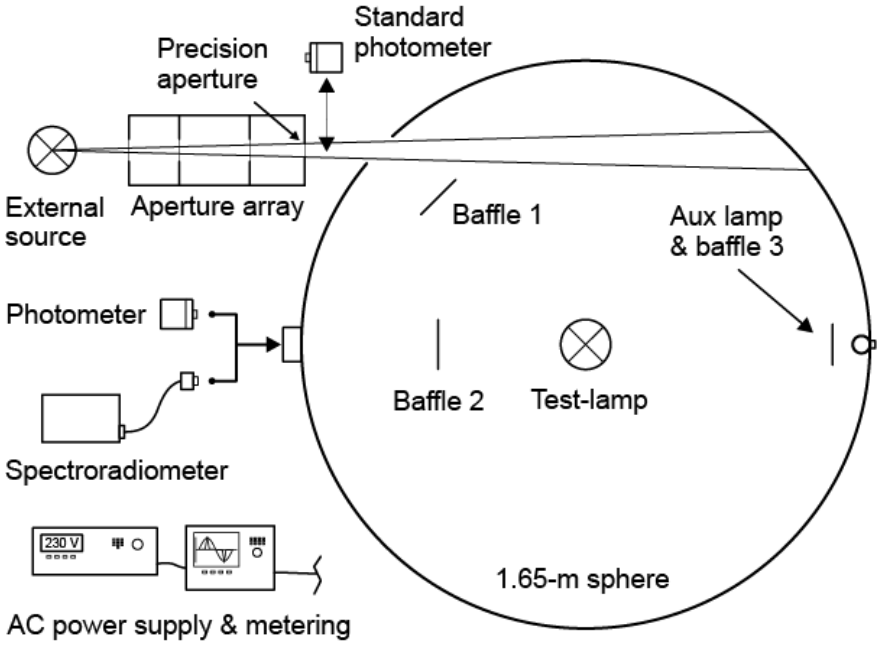


Measurements at Aalto University

- **Four samples of each lamp type.**
- **The room temperature was 25.6±1.4 ºC.**
- **19 months aging period, measurements every 2 months.**
- **Measurement devices:**
  - 1.65-meters integrating sphere
  - HP 3458A, multimeters
  - Yokogawa WT-210, power meter
  - Bentham spectroradiometer

Measurements at Aalto University

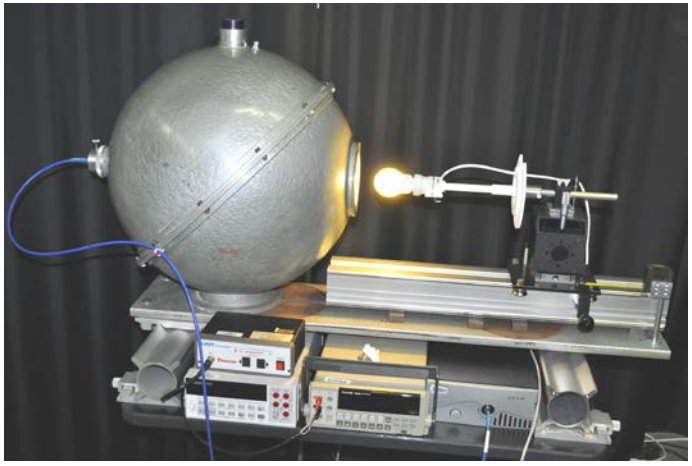




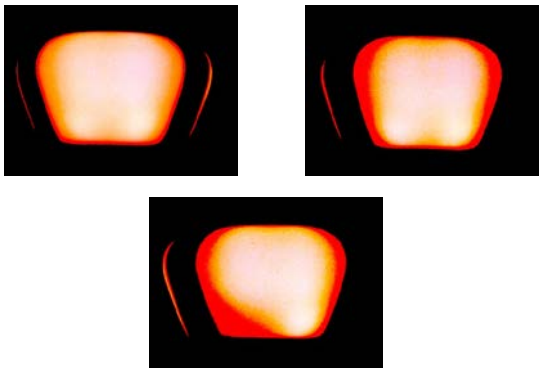
[1] T. Poikonen, T. Pulli, A. Vaskuri, H. Baumgartner, P. Kärhä, and E. Ikonen, "Luminous efficacy measurement of solid-state lamps," *Metrologia* **49** pp. 135–140, 2012.

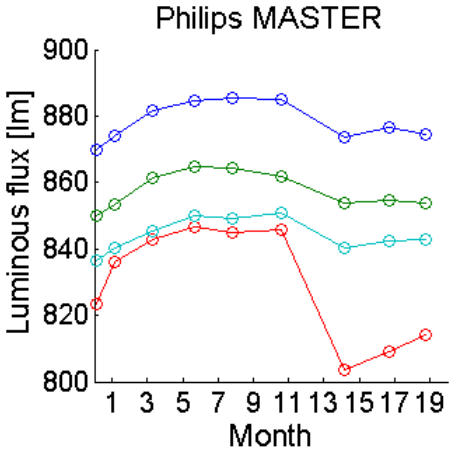
Measurements at LNE

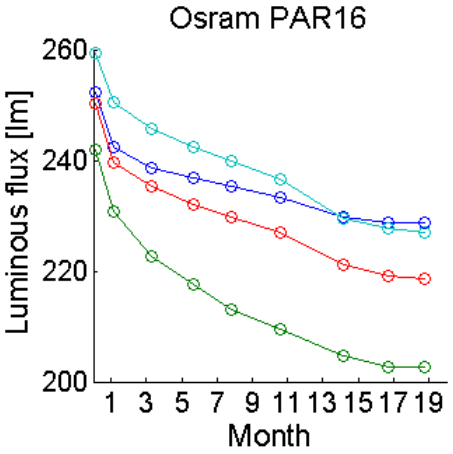
- Lamps were aged in a climatic chamber at elevated temperatures of 45 and 60 ºC.
- 6 months aging period, measurements every 2 months.
- Three samples of each lamp type.
- A moveable measurement system with introduction of warm lamps was designed.

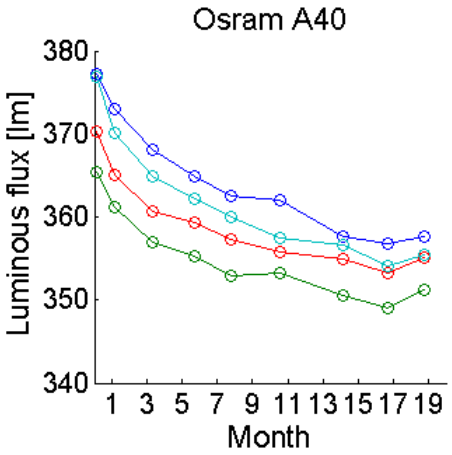


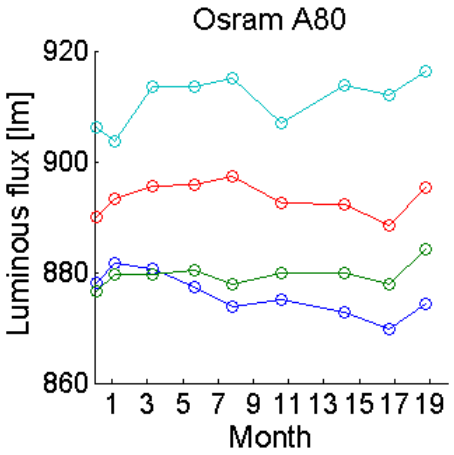
Aging at room temperature, luminous flux

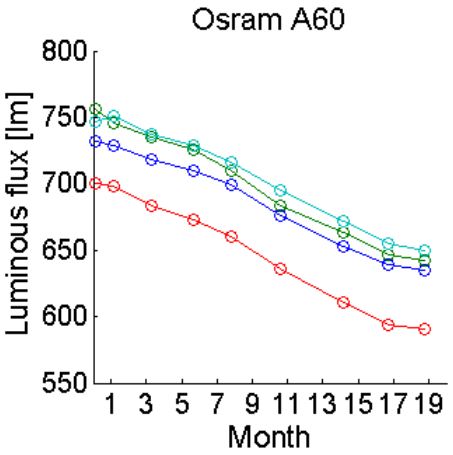




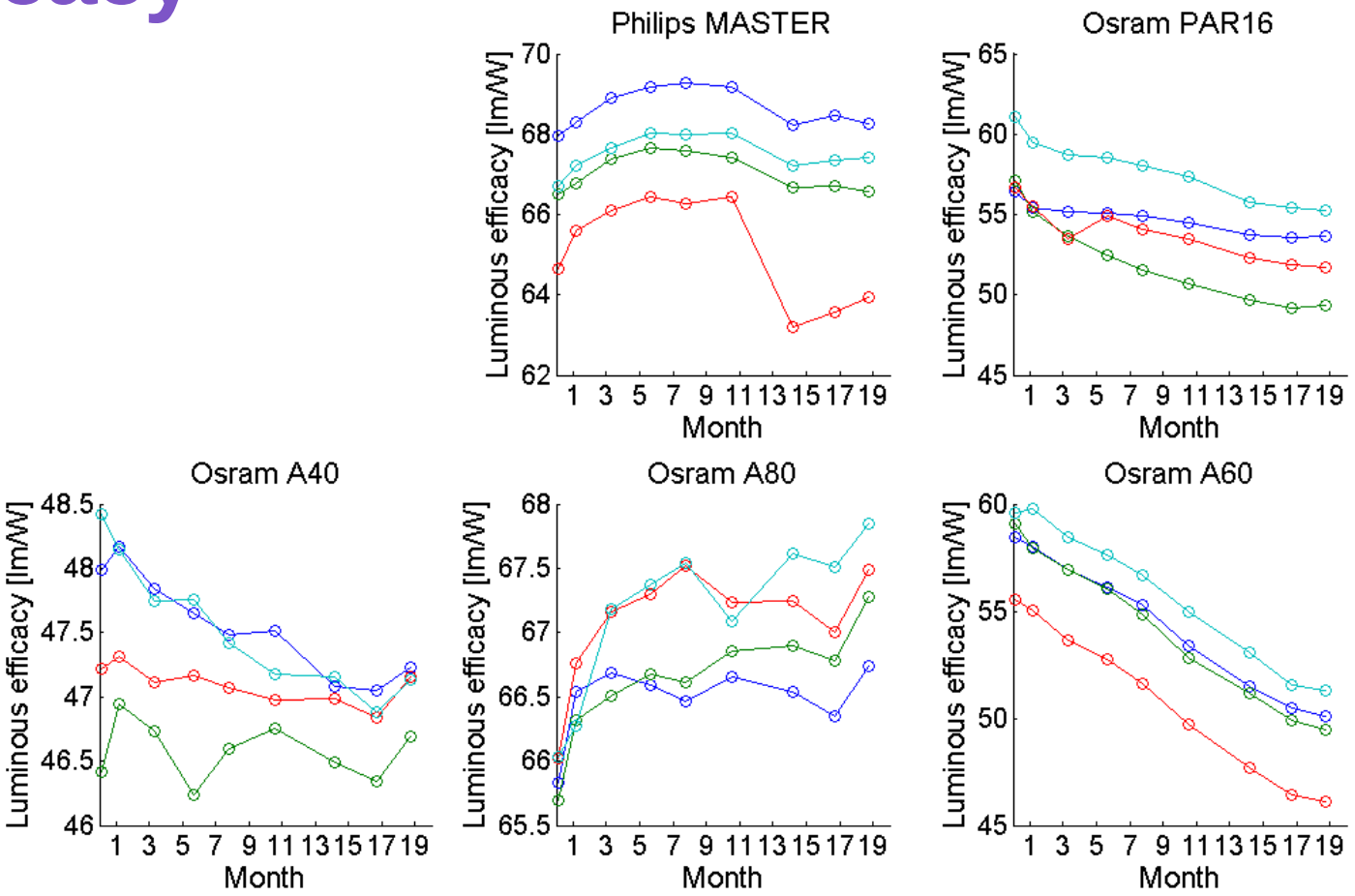




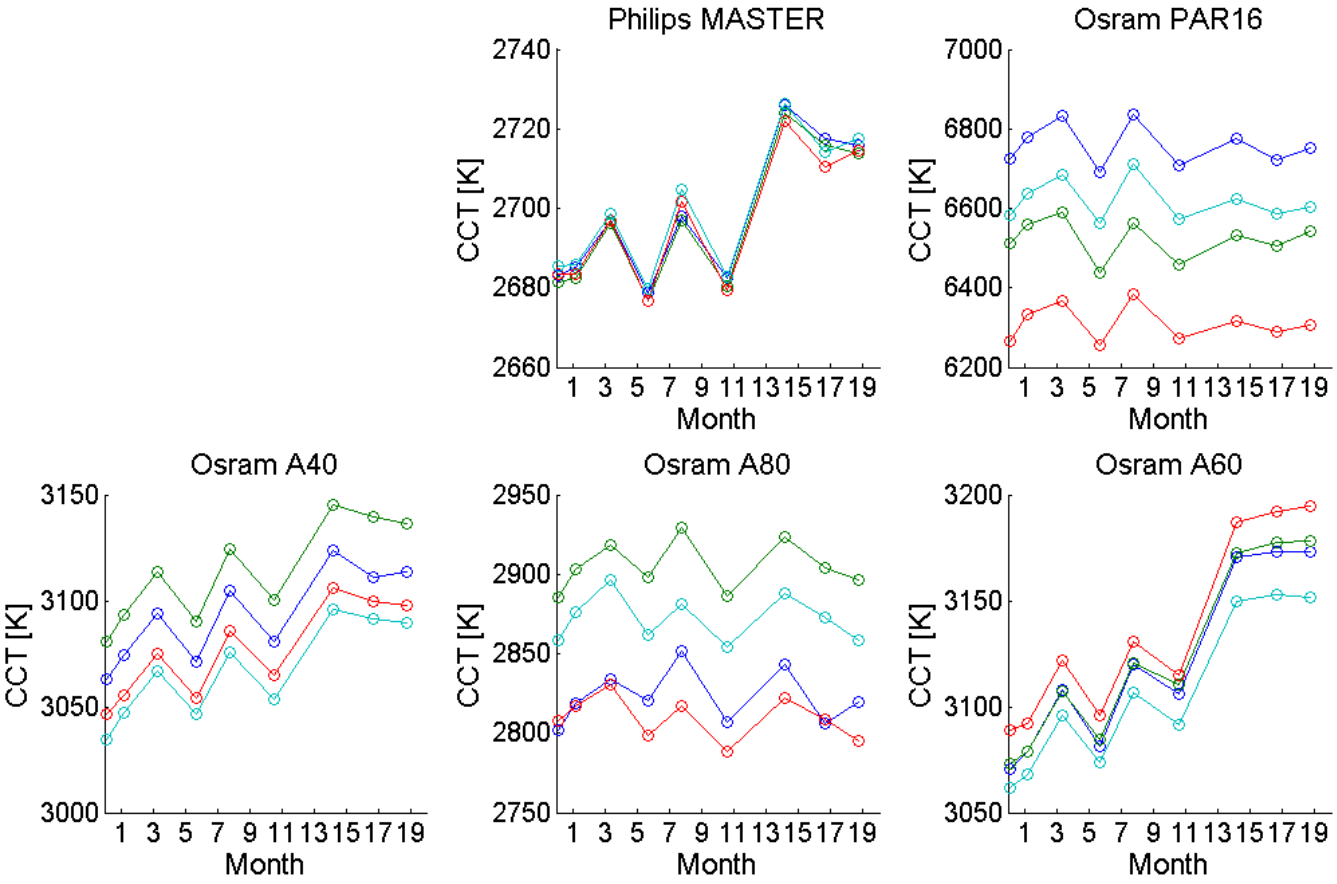




Aging at room temperature, luminous efficacy



Aging at room temperature, correlated colour temperature



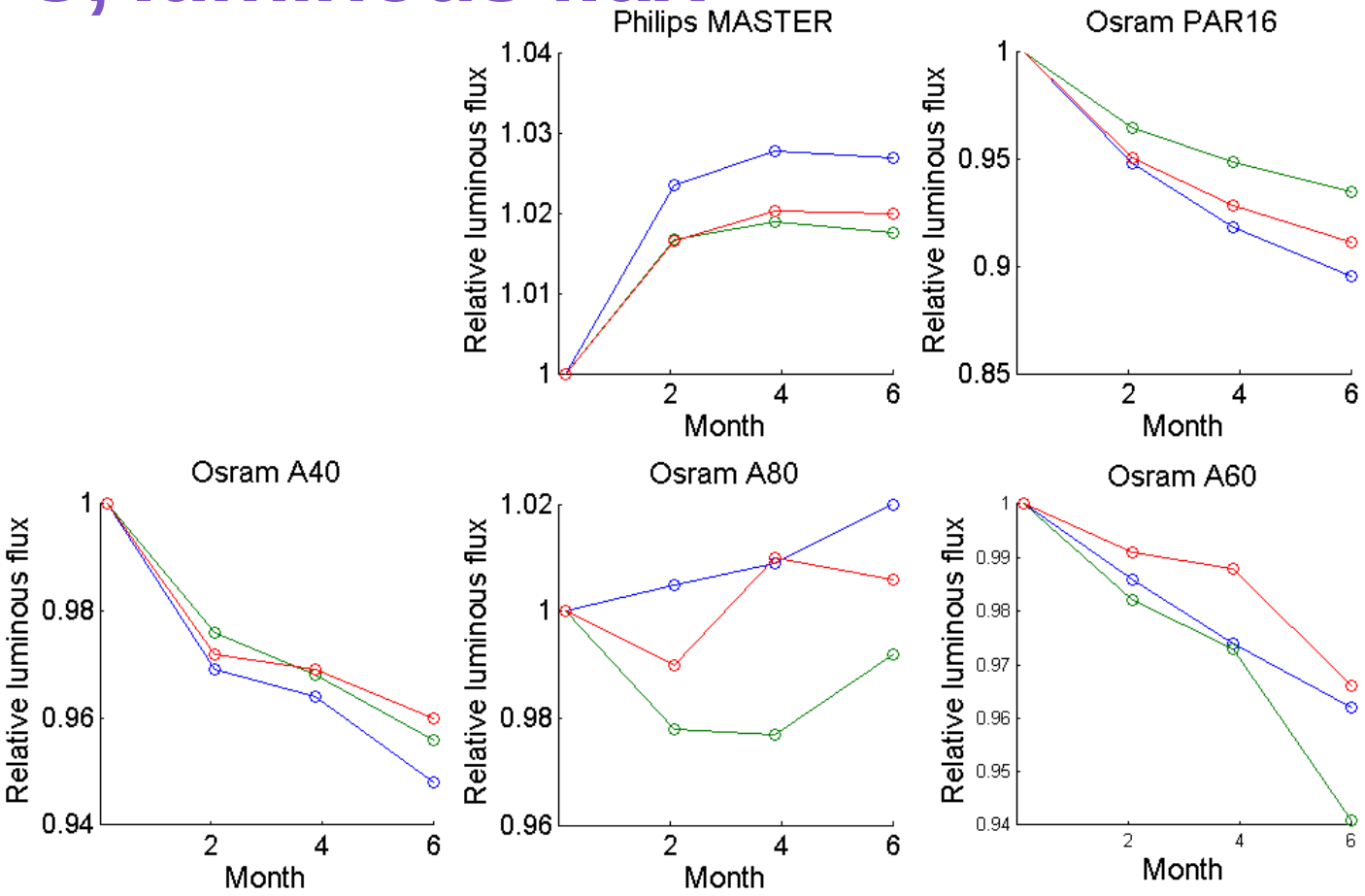
Aging at room temperature, average degradation rates

- **Correlation between luminous flux and luminous efficacy.**
- **Luminous fluxes of Philips Master LEDbulb MV and Osram Parathom Classic A80 did not decrease.**
  - *Remote phosphor (Philips)*
  - *Additional red LEDs (Osram A80)*

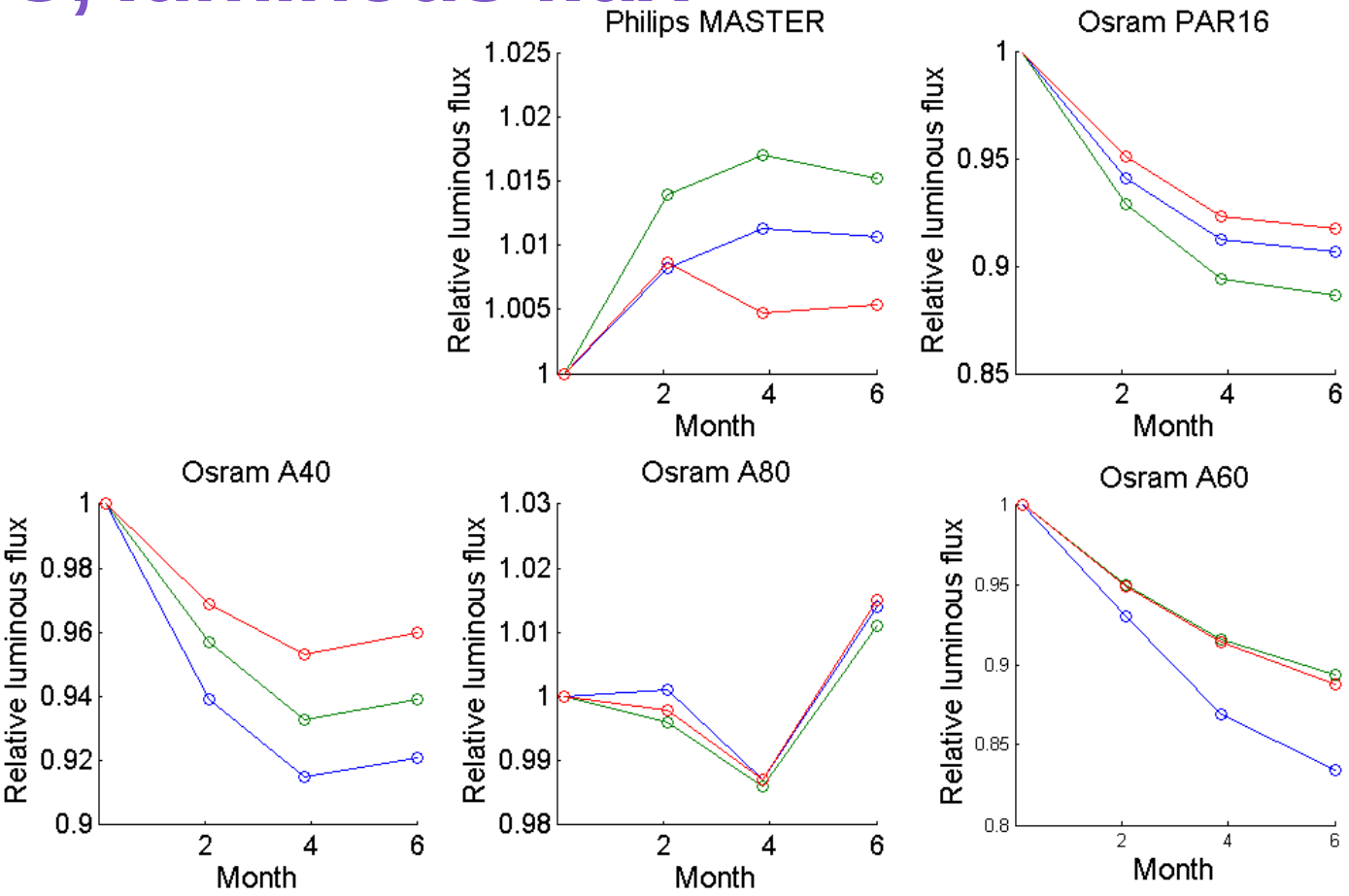
Changes / % (19 mo @ 25 ºC)

Lamp	Flux	Efficacy	CCT
Master LED	0.6	0.5	1.3
PAR16	-12.7	-9.3	0.3
A40	-4.7	-1.0	1.6
A60	- 4.2	-15.3	3.5
A80	0.5	2.2	0.1

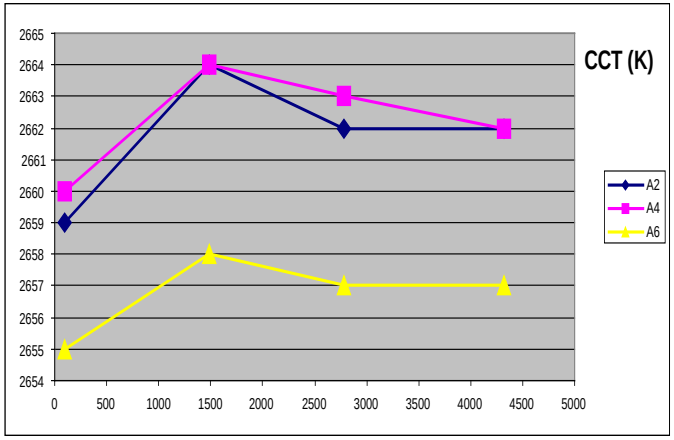
Aging at the elevated temperature of 45 ºC, luminous flux

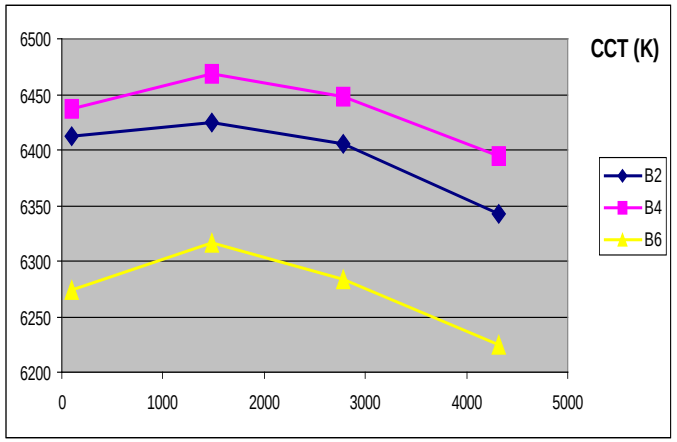


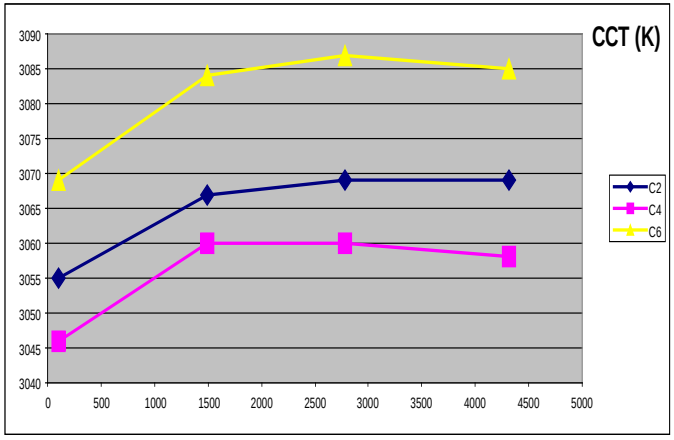
Aging at the elevated temperature of 60 ºC, luminous flux

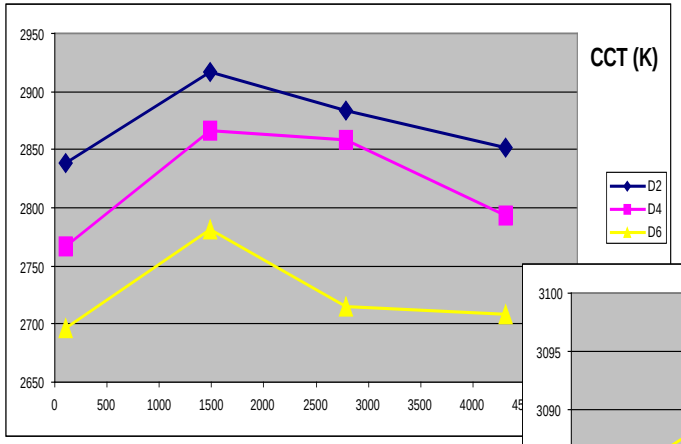


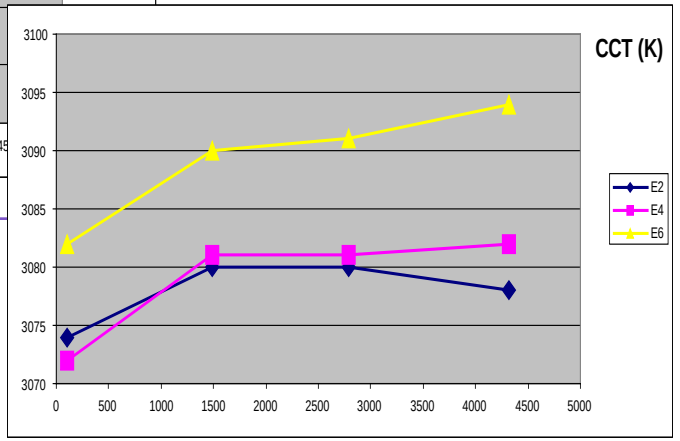
Aging at the elevated temperature of 45 ºC, correlated colour temperature



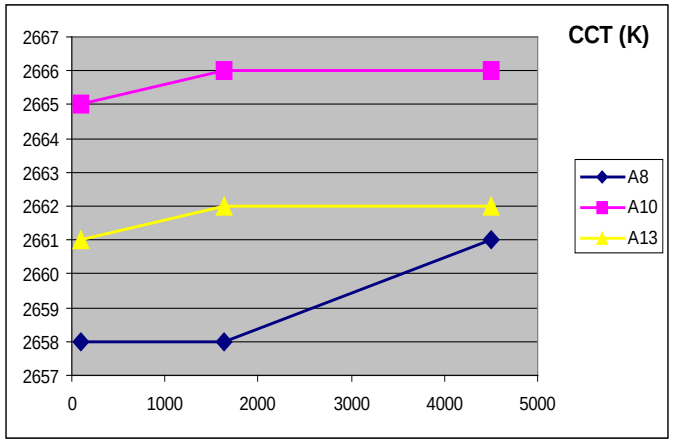


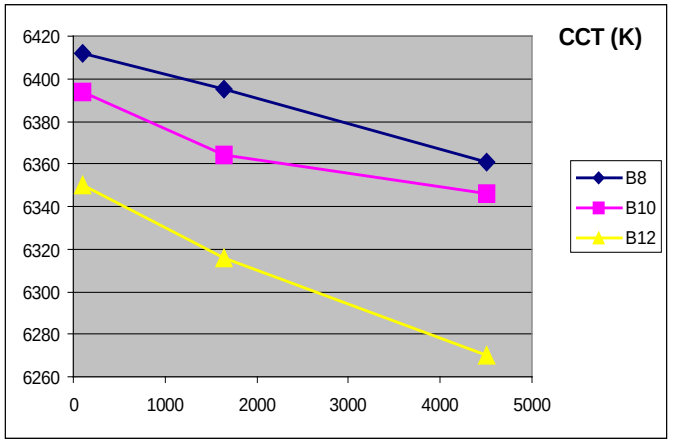


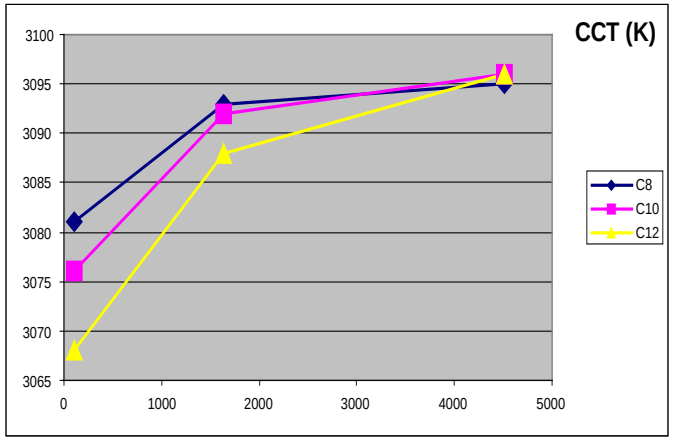


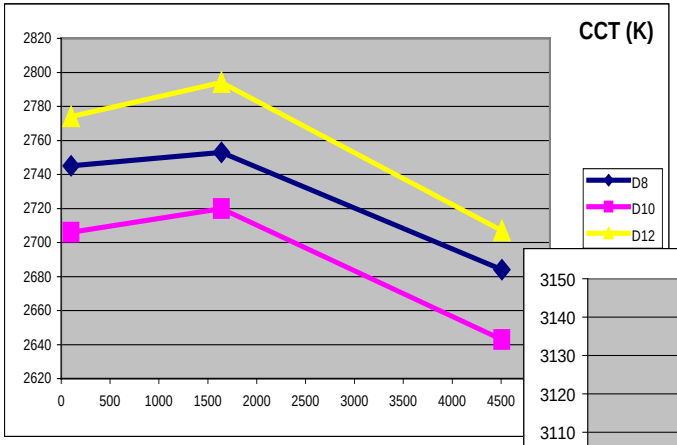


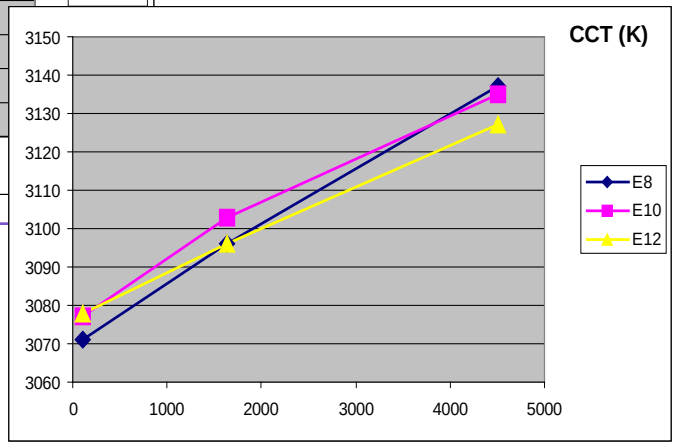
Aging at the elevated temperature of 60 ºC, correlated colour temperature











Aging at the elevated temperatures, average degradation rates

- **Higher temperature accelerates the aging.**
- **Moderate heating did not damage the electronics.**

Changes / % (6 mo @ 45 ºC | 60 ºC)

Lamp	Flux 45 ºC | 60 ºC	CCT 45 ºC | 60 ºC
Master LED	2.1 | 1.0	0.1 | 0.1
PAR16	-8.6 | -9.6	-0.8 | -0.9
A40	-4.53 | -6.0	0.5 | 0.7
A60	-4.4 | -12.8	0.3 | 1.9
A80	0.6 | 1.3	0.6 | -2.3

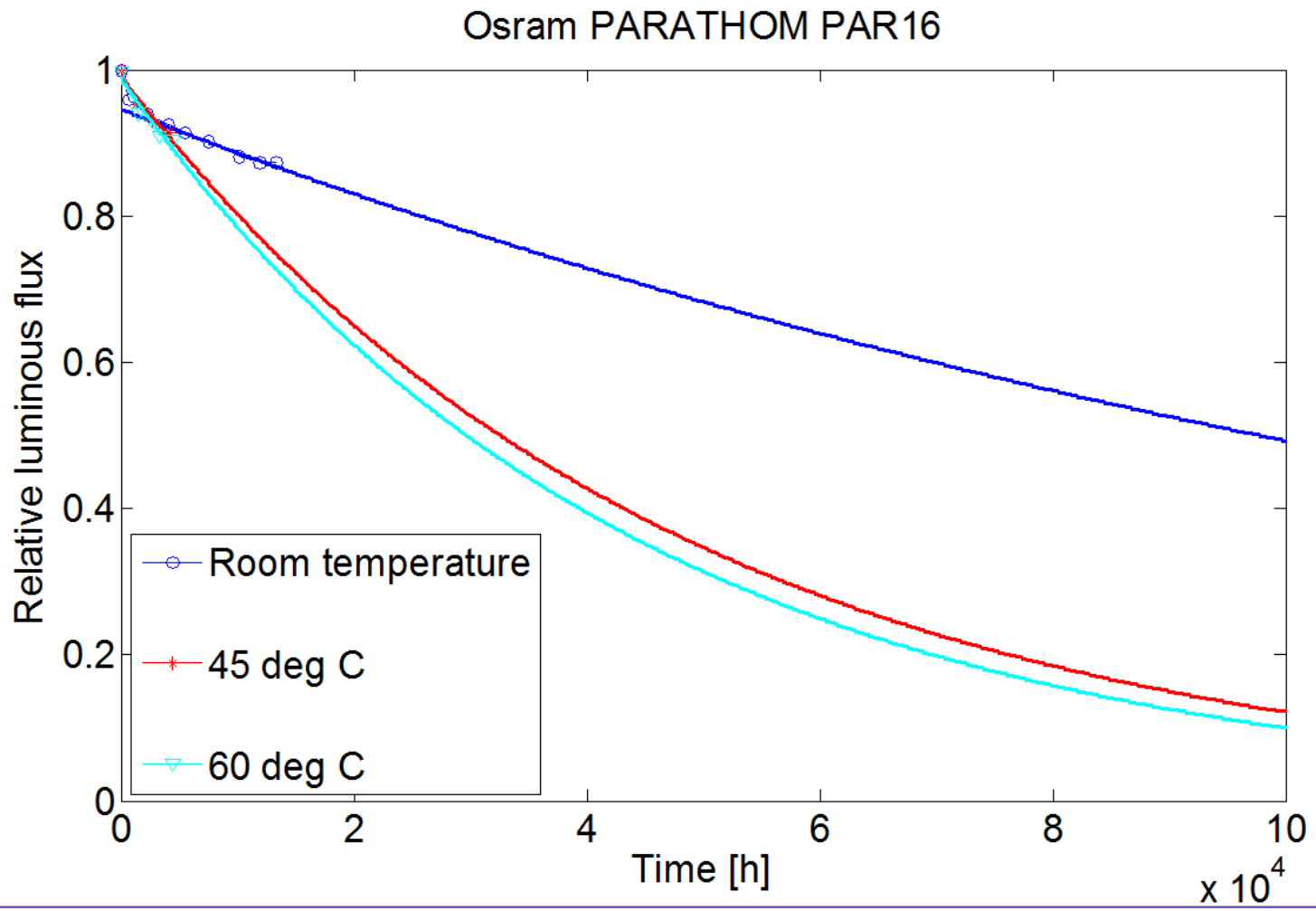
Lifetime prediction

- **Illuminating Engineering Society of North America (IES) has defined the LED lamp lifetime through lumen maintenance in IES TM-21-11.**
- **The lamp is at the end of its lifetime when the luminous flux has decreased to 70 or 50 % of the initial value.**
- **An exponential curve-fit is used to model the decrease of the luminous flux.**

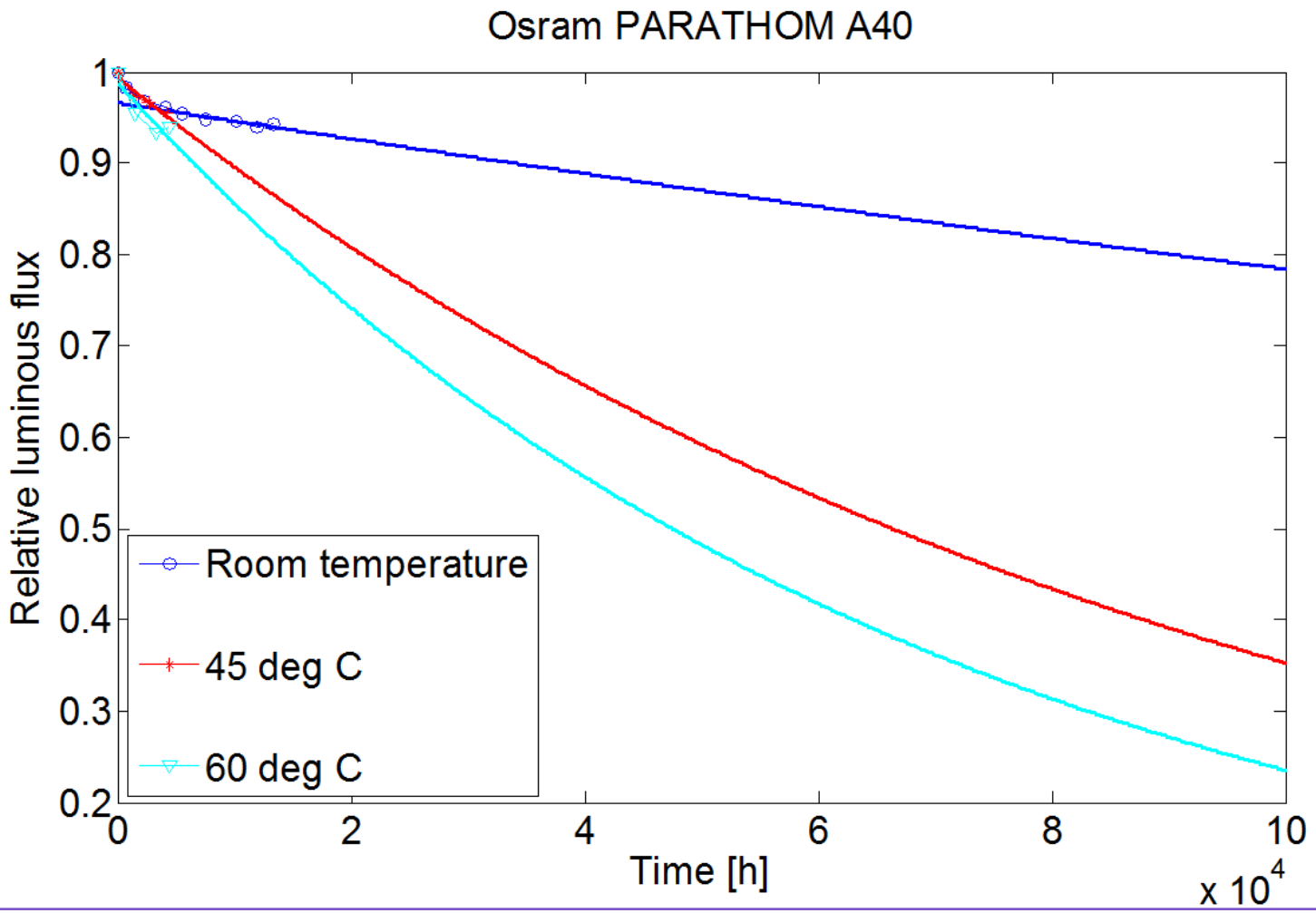
$$\Phi(t) = Be^{-\alpha t}$$

- **Fitting is made for the last 50 per cent of the measurement data.**
- **If the measurement period is less than 5000 hours, the fitting is made for all the data.**

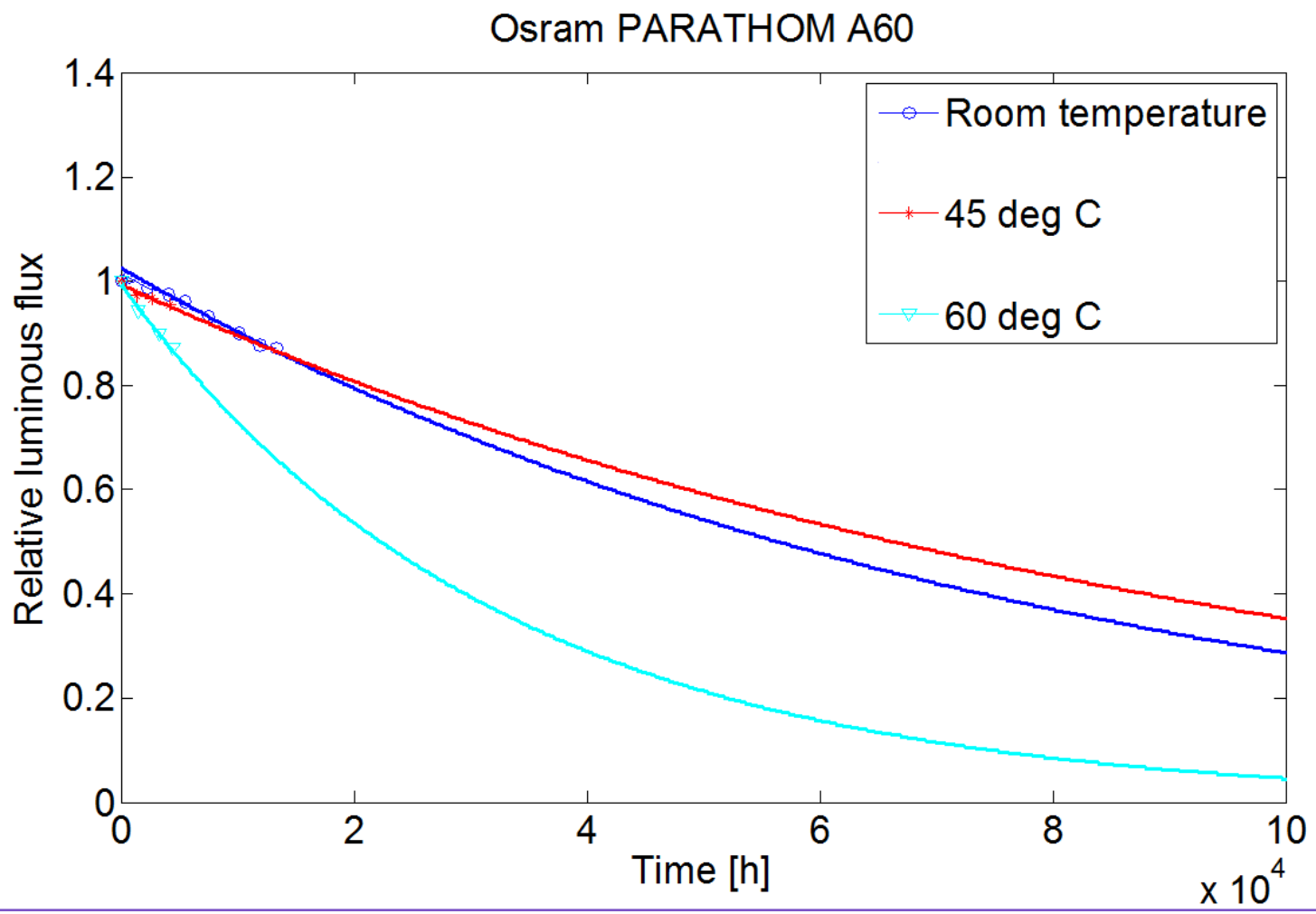
Osram Parathom PAR16 20



Osram Parathom Classic A40



Osram Parathom Classic A60



Lifetime acceleration factor

- **The acceleration factor can be found by dividing the lamp lifetime at room temperature with the lifetime at the elevated temperature.**
- **Lifetimes are calculated in the same way for natural and accelerated data (average of L_{70} and L_{50}).**
- **An average acceleration factor for all lamp types is achieved:**
  - Aging at 45 ºC accelerates the aging by a factor of 1.3.
  - Aging at 60 ºC accelerates the aging by a factor of 3.

Conclusions

- **Moderate heating does not break the electronics of the lamp.**
- **An exponential curve fit can be used to predict the lamp lifetime.**
- **Generally aging increases the CCT.**
- **For the lamps studied, the expectable lifetimes exceed the manufacturer specifications.**

Lamp	L_{70} | L_{50} @ 25 °C	L_{70} | L_{50} @ 45 °C	L_{70} | L_{50} @ 60 °C
Master LED	-	-	-
PAR16	46 300 | 97 900	16 600 | 32 700	15 100 | 29 800
A40	154 000 | 315 500	34 000 | 66 400	24 100 | 47 600
A60	30 000 | 56 500	33 900 | 66 400	11 400 | 22 400
A80	-	-	-