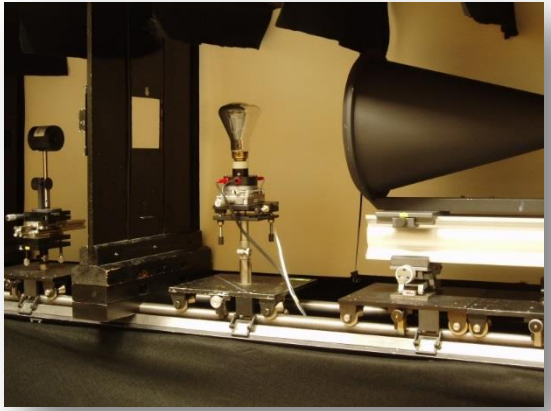
Solid-state lighting measurement activities at NRC

overview

- NRC photometry and spectrophotometry
- Growth of solid-state lighting
- NRC solid-state lighting measurement facility
- Study of different LED sources:
  - LED COBs for luminous intensity
  - LED corn lamps for luminous flux

NRC photometry and spectrophotometry facility



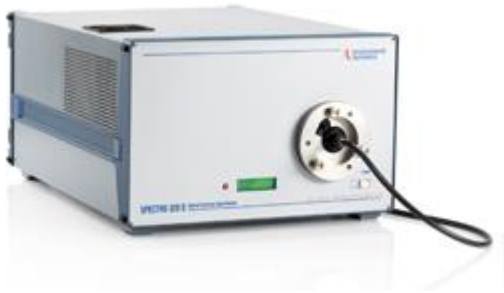
Luminous intensity measurement

Total luminous flux measurement

Incandescent lamps as working standards

NRC photometry and spectrophotometry facility

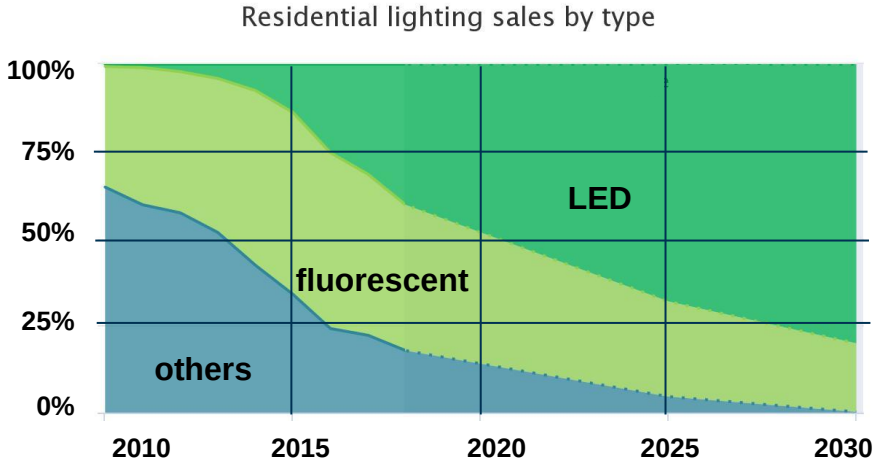
1 metre monochromator

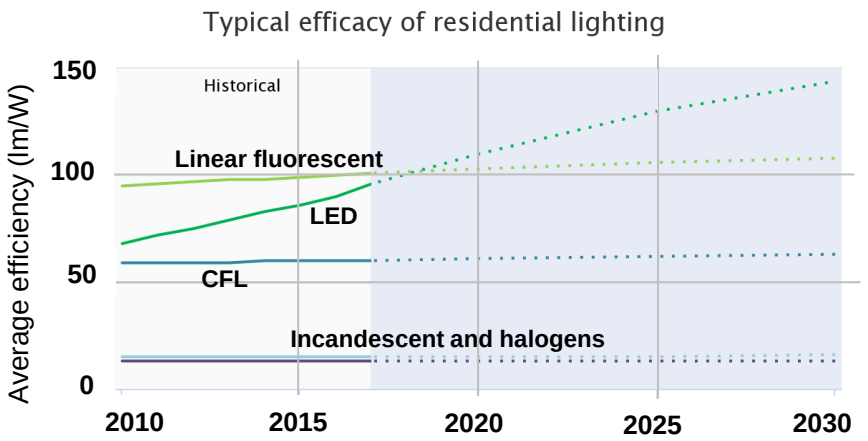


Scanning spectroradiometer

Rise of LEDs

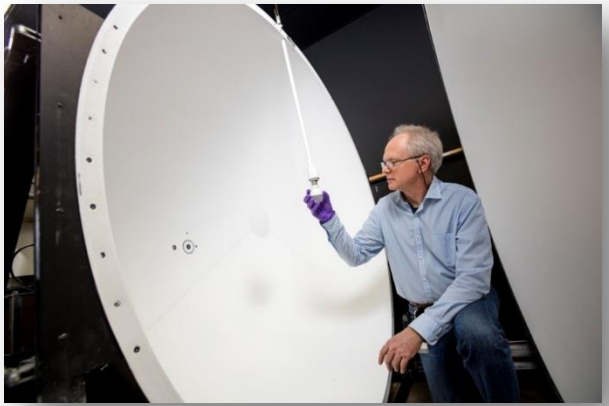
Growth of solid-state lighting



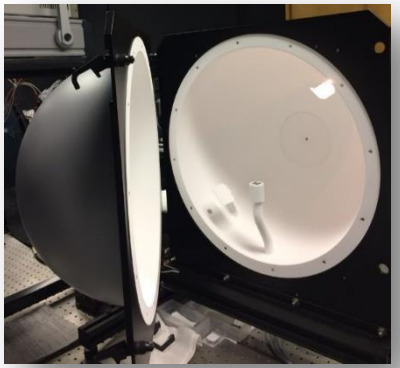


We have to be prepared for increasing number of LED measurement requests

NRC solid-state lighting measurement facility

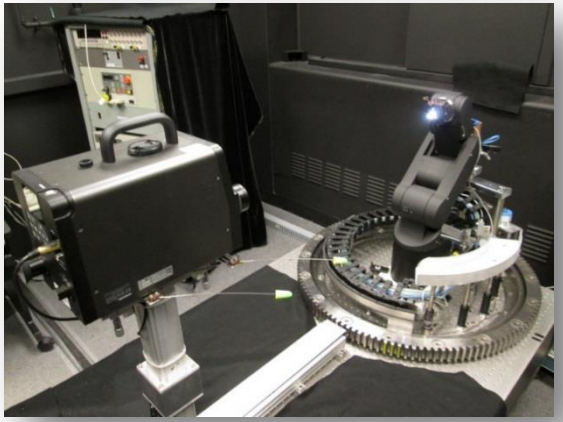


1.6m sphere for 4π and 2π LED total flux measurement

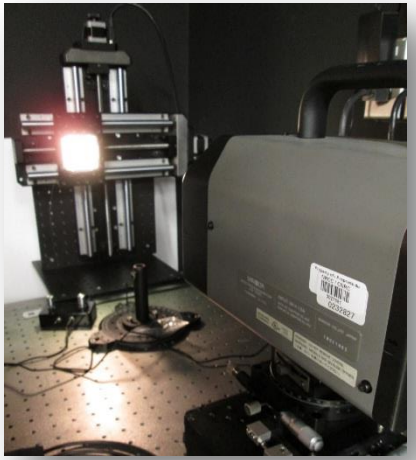


50cm sphere for 4π and 2π LED total flux measurement

NRC solid-state lighting measurement facility



Angular measurement



Spatial uniformity scan

LED COBs for luminous intensity measurement

Image courtesy of GreenAndVibrant..com

Chip on board (COB) LED module

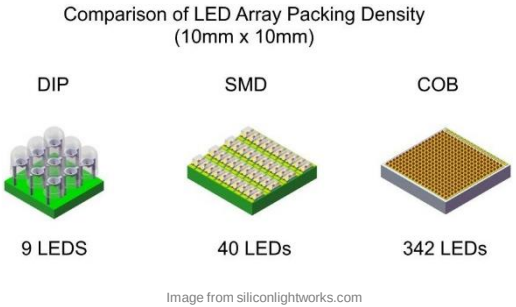
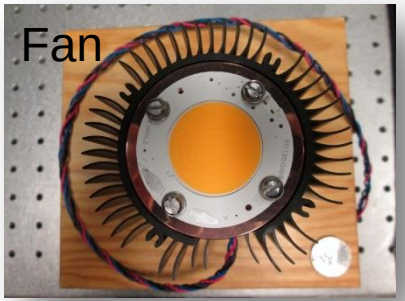


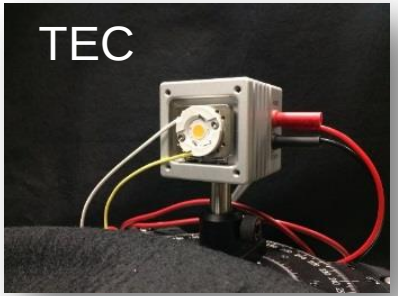
Image from siliconlightworks.com

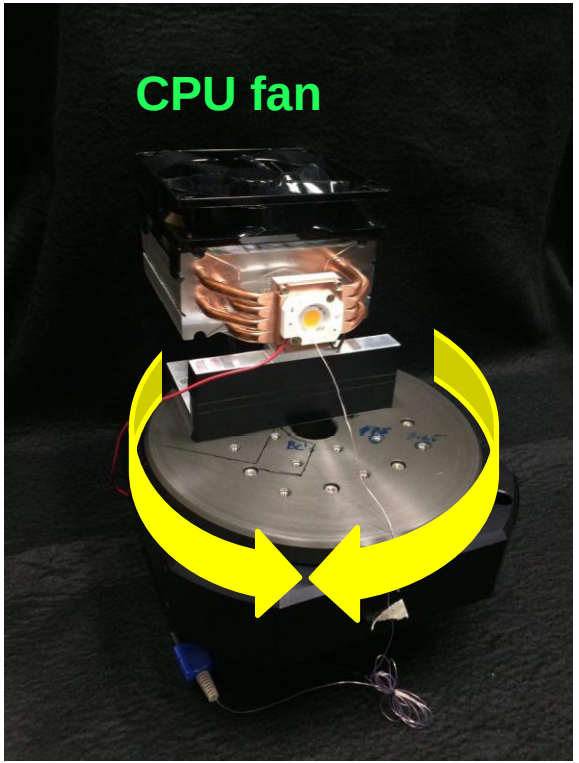
COB advantages

1. **Compactness**
2. **Spatially uniform (?)**
3. **Thermal stability (?)**
4. **High brightness**

Chip on board (COB) LED module





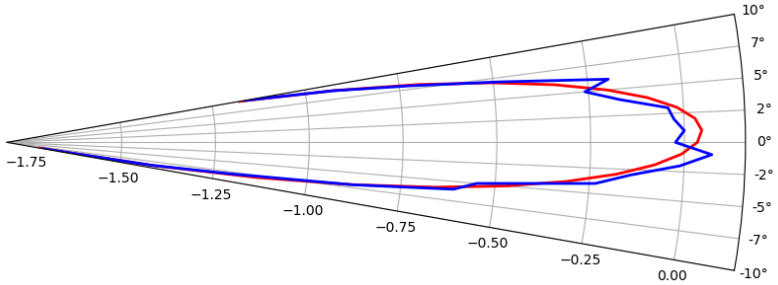


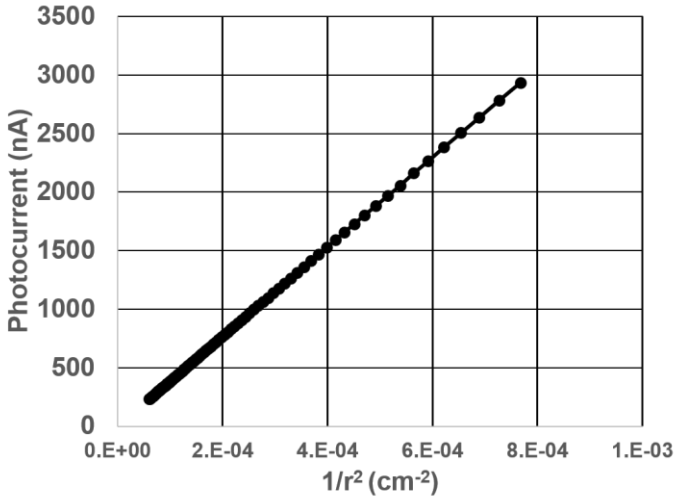
Mounts with cooling modules for the COBs

Test of the COB LEDs

- We verified that the COBs
  - have symmetric angular emission and,
  - the photometer's signal is linearly proportional to 1/distance^2
- Effect of temperature on the COB's performance was studied

Geometry verification





We choose the COBs with symmetric angular profile and linear distance dependence

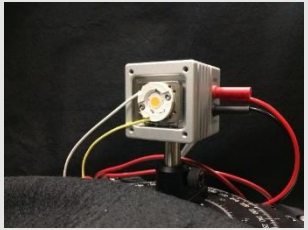
Fractional value

Value of the signal when lamp is switched on

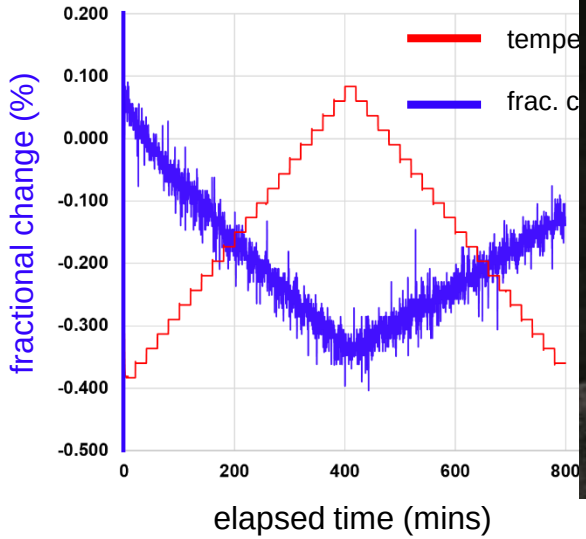
$$\text{fractional value} = \frac{S(t) - S(t_0)}{S(t_0)}$$

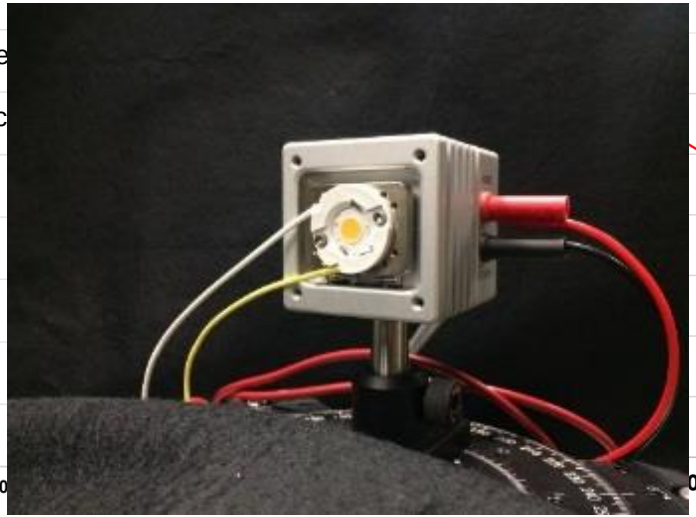
In this presentation S is the signal amplitude from either a photometer or a spectrometer

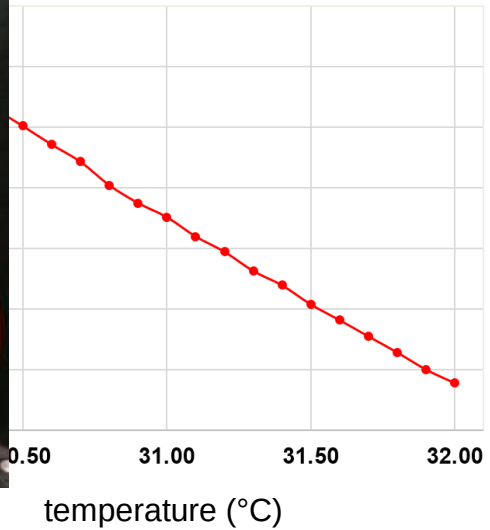
Temperature effect



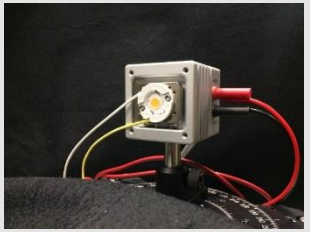
COB's temperature is controlled and measured by a thermoelectric controller



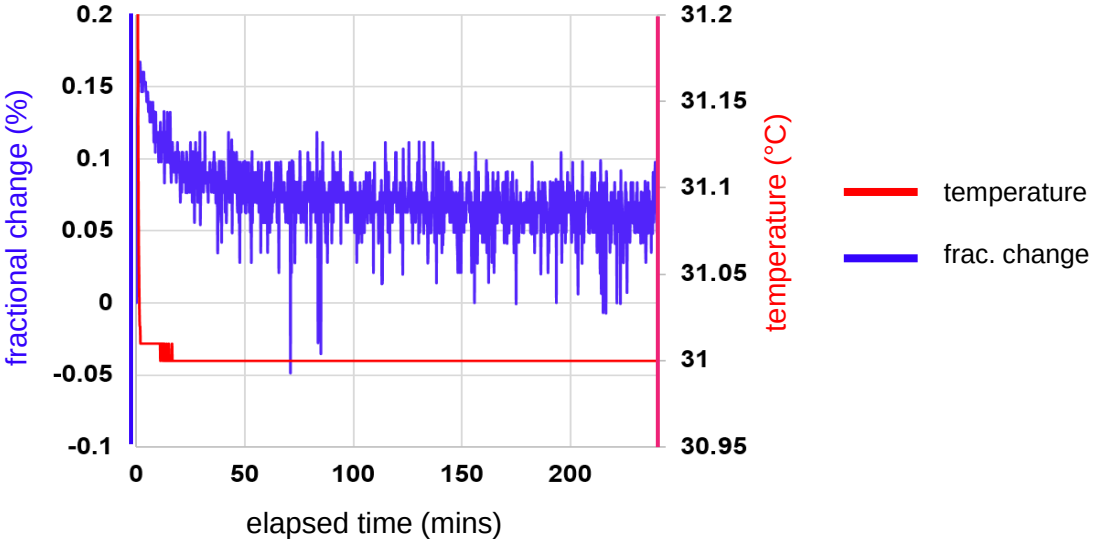




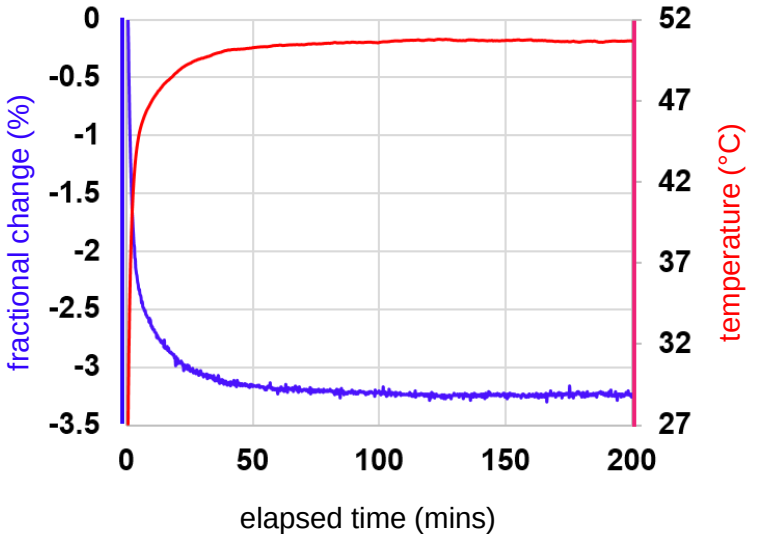
Temperature effect



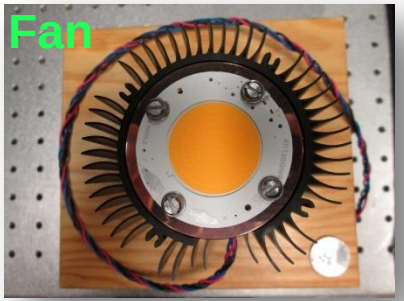
COB's temperature is kept at T = 31°C and measured by the thermoelectric controller

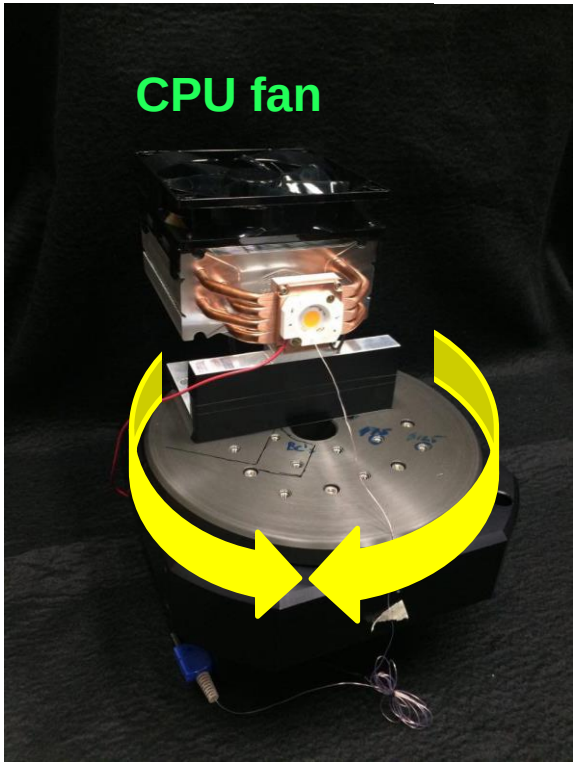


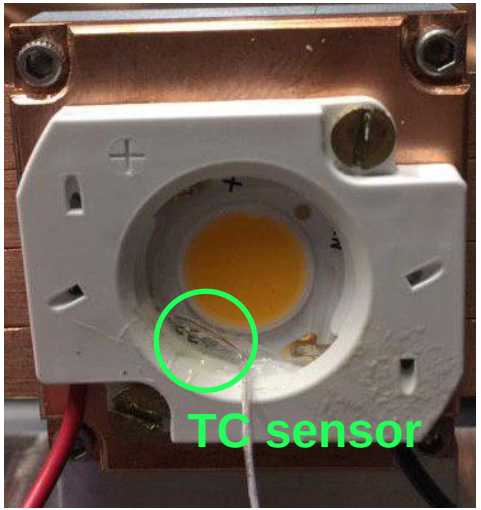
COB's temperature is measured by the thermoelectric controller, however, it is drifting freely



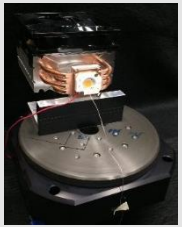
simpler temperature control solution







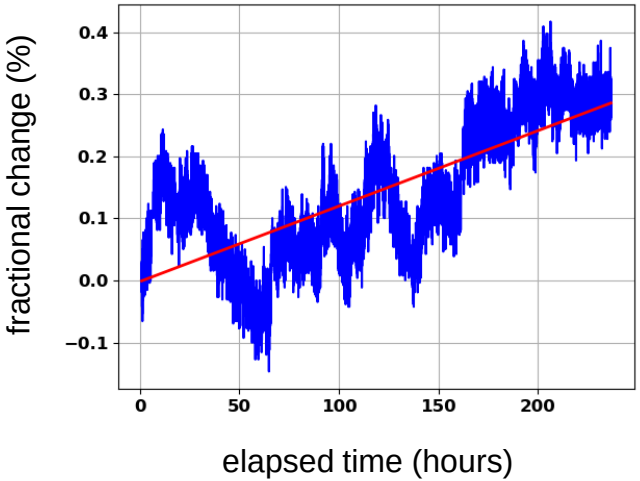
Photometric output



COB 1

Linear fit = a t + b where a = 0.0012 % h^{-1}

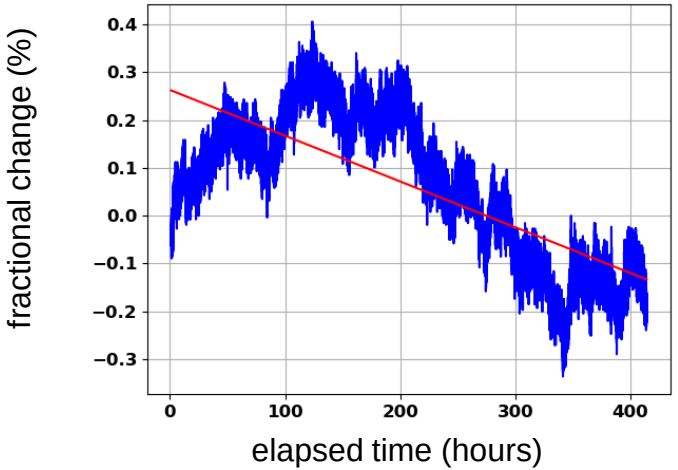
Average temperature = 32.7 (±0.12) °C



COB 2

Linear fit = a t + b where a = -0.0009 % h^{-1}

Average temperature = 33.3 (±0.17) °C



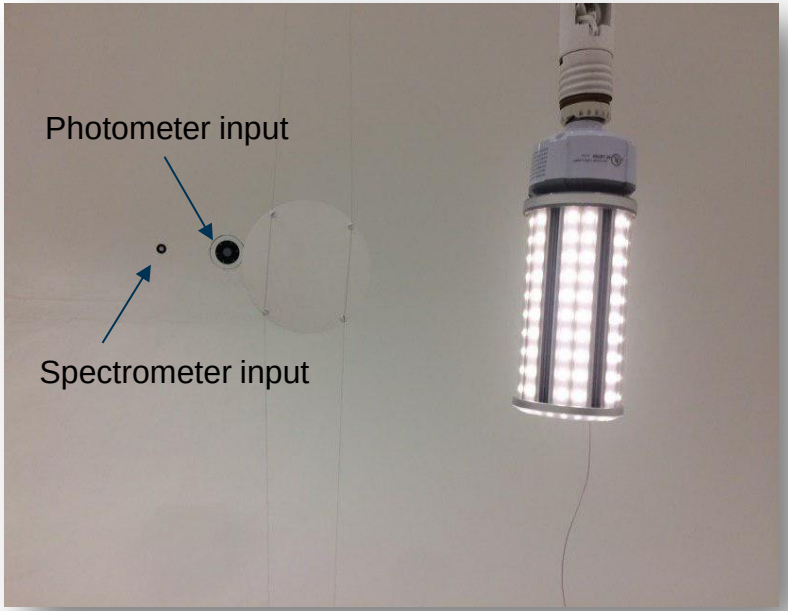
Test of the COB LEDs

- COBs with symmetrical angular emission and linear dependence on the inverse square of the distance are selected,
- Effect of temperature on the performance of the module are tested,
- Aging of the selected module has been in progress.

LED modules for luminous flux

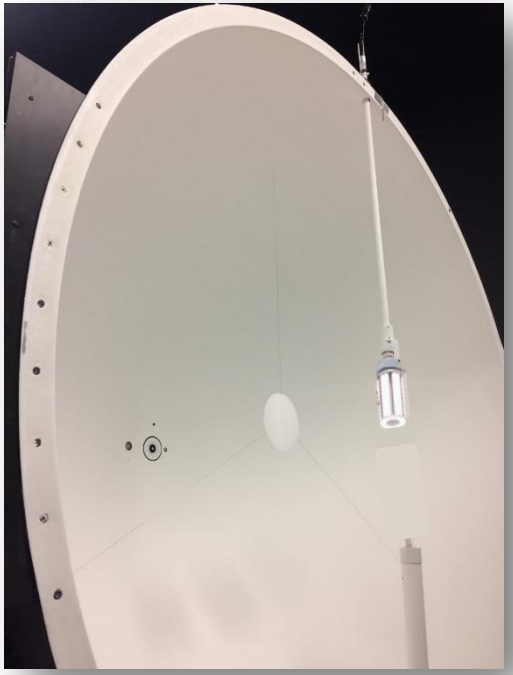
Omnidirectional LED module for luminous flux

Results

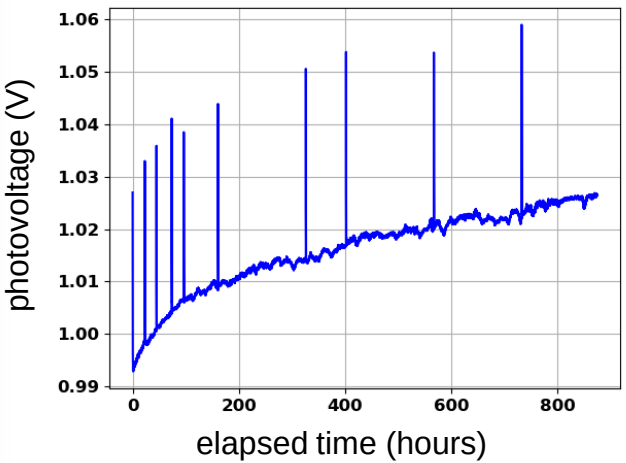


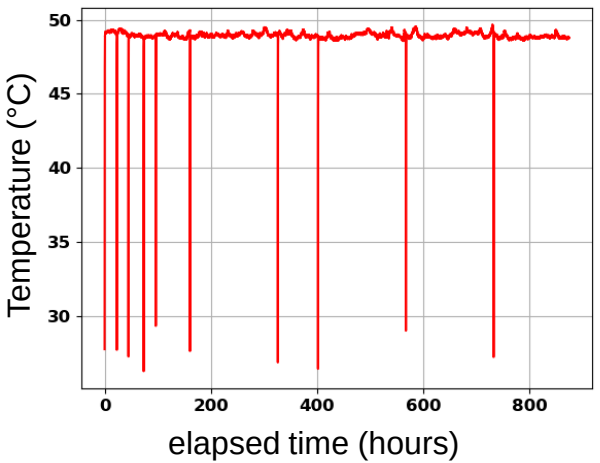
- Photomteric and spectral measurements have been recorded simultaneously.
- Four lamps were aged and monitored for more than 1 month.
- Two lamps are 45 Watt at 3000K and two lamps are 20 Watt at 2700K.
- Only the second set showed a predictable behavior.

Results



Spikes in both graphs coincide



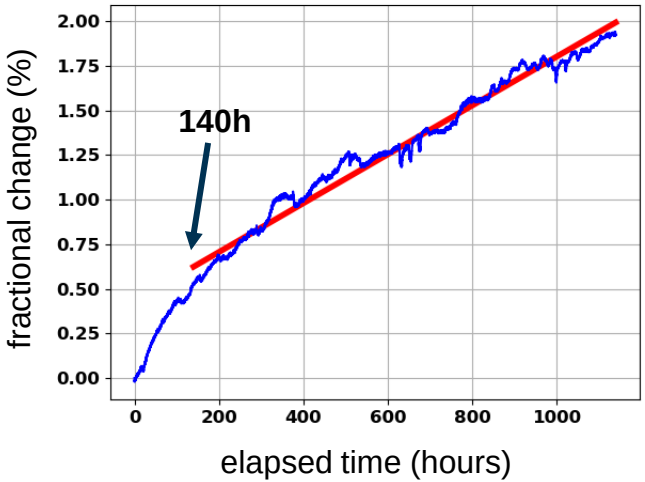


Comparison of two lamps of the same model

Lamp 1

$y = a\,x + b$ where $a = 0.0013\ \%\ h^{-1}$

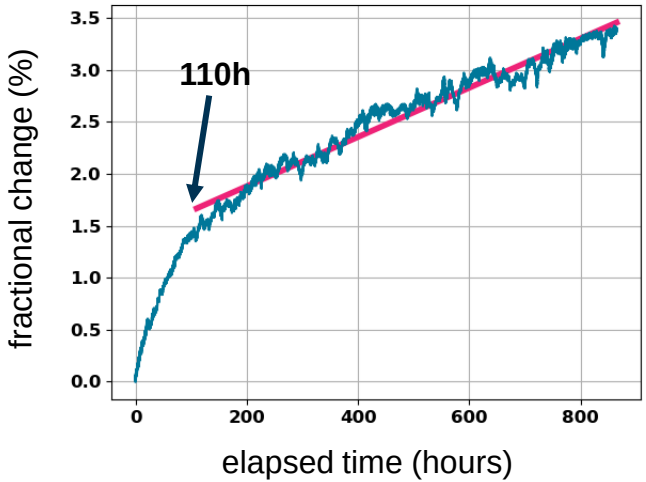
STD of linear section = 0.056



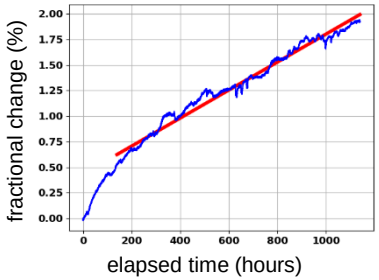
Lamp 2

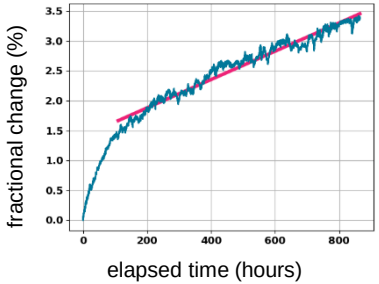
$y = a\,x + b$ where $a = 0.0023\ \%\ h^{-1}$

STD of linear section = 0.095



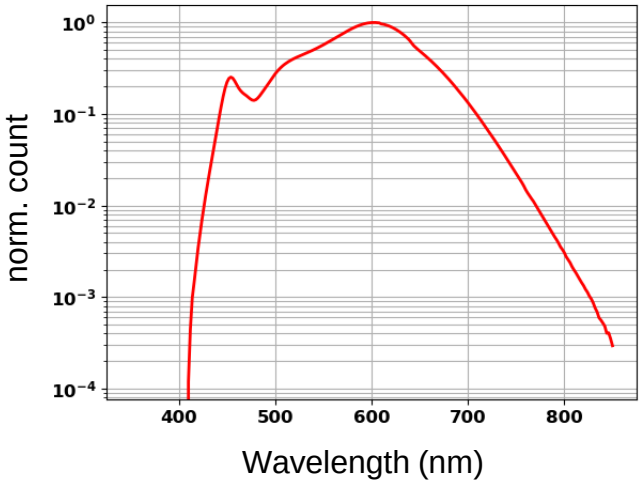
Comparison of two lamps of the same model



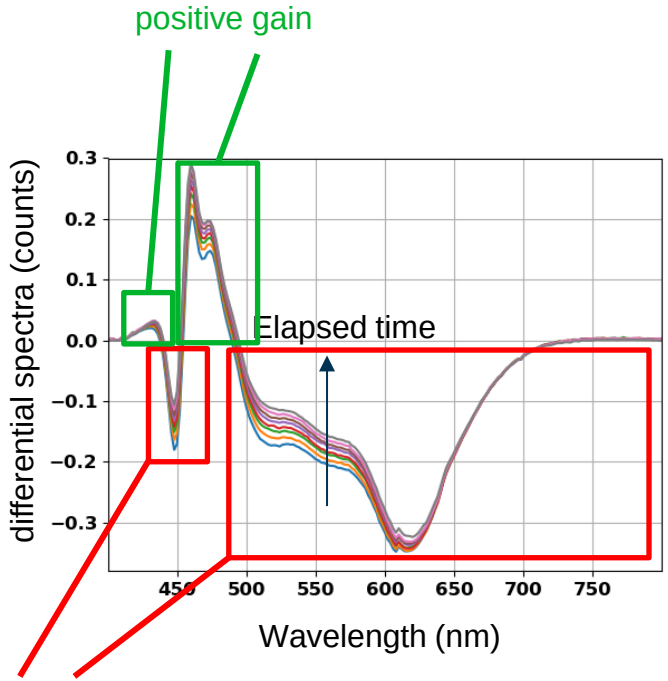


- After certain amount of time the LED output becomes linear and can be estimated for future use.
- Linear fit has different coefficients for the two lamps, however, they are the same order of magnitude.

Spectral measurement

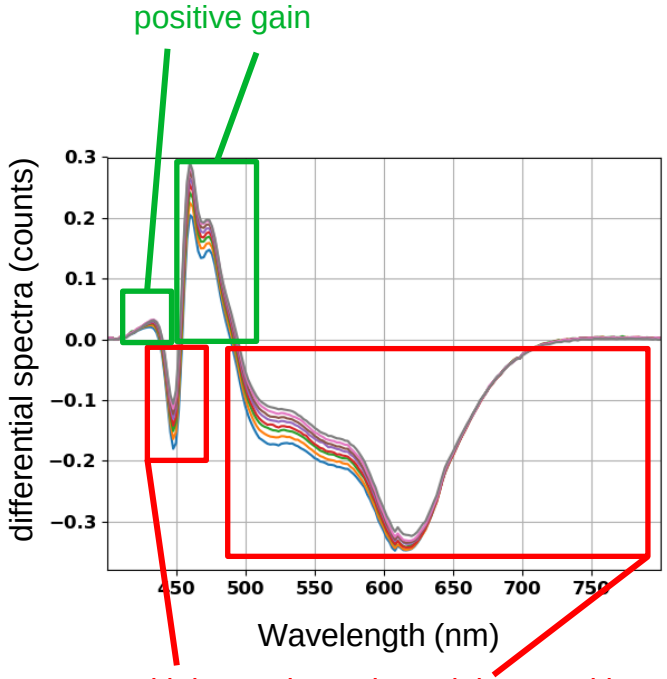


$$\Phi(\lambda, t) - \Phi(\lambda, t_0)$$



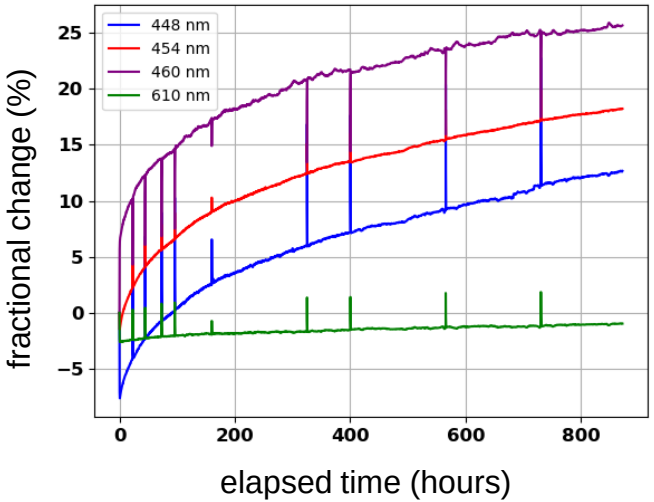
Initial negative gain and then positive gain

Spectral measurement



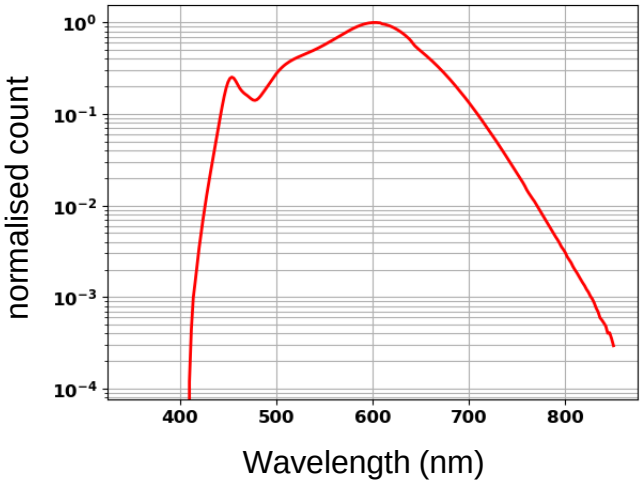
Initial negative gain and then positive gain

Four wavelengths are picked

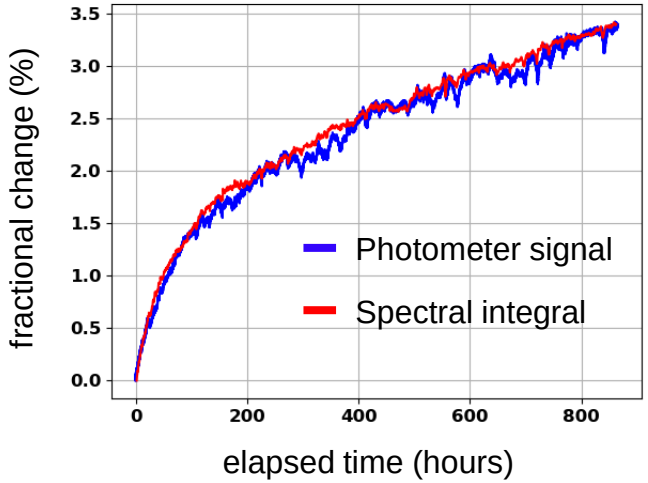


Sign and value of the gain is time dependent for each wavelength

Spectral measurement



$$\int \Phi(\lambda, t) V(\lambda) d\lambda$$



Spectral measurement

- Different wavelengths emitted from the LED module
  - have time dependent gain, however,
  - the luminous integral of all wavelengths increases over time and matches the photometer signal (as it should).

THANK YOU

Amin Rasoulof • William Neil • Eric Côté • Arnold Gaertner

Amin.Rasoulof@nrc-cnrc.gc.ca