Linear LED lighting:
Applications and technological challenges

Authors: Vincent Faivre & Dr. Felix Küpper

Agenda

1. Introduction
2. Fulfill requirements on day 1
3. What happens next

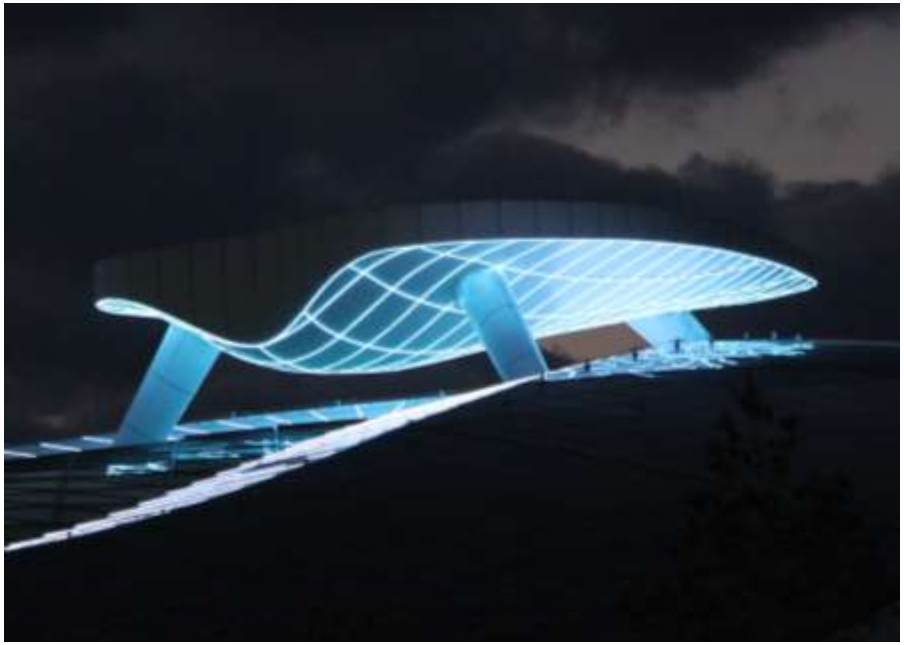
→ Understand the aging factors of mid-power LEDs

→ Thermal management

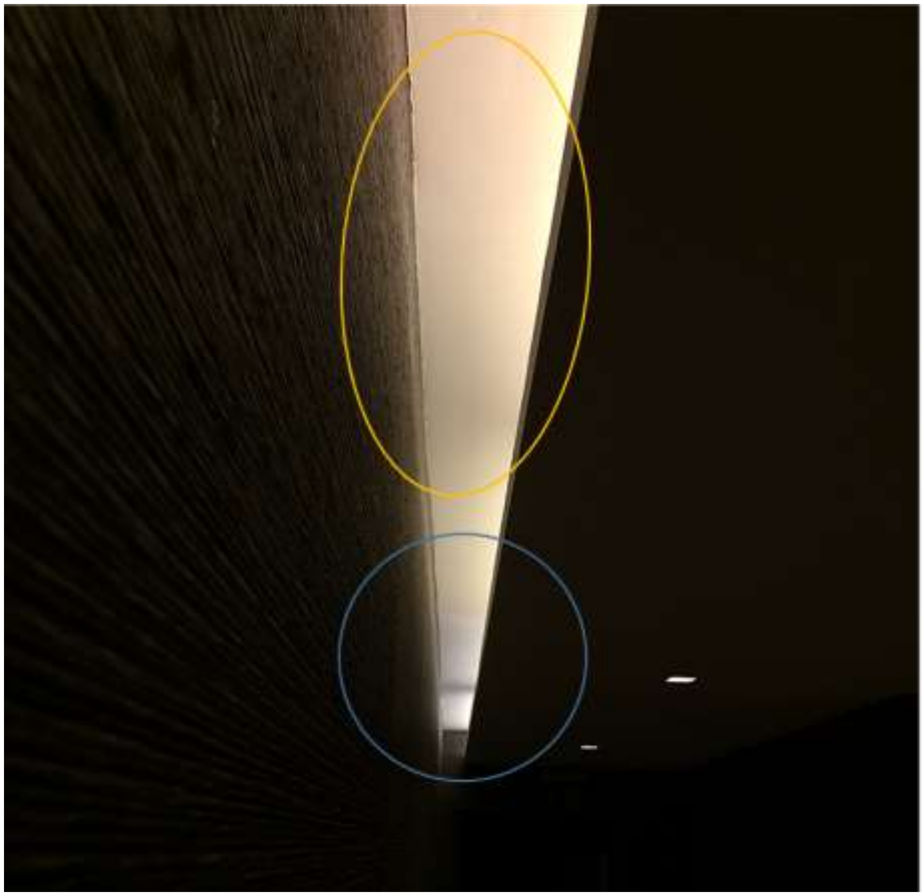
→ Production of linear light source modules

Author: Vincent Faivre

LINEAR LED LIGHTING APPLICATIONS



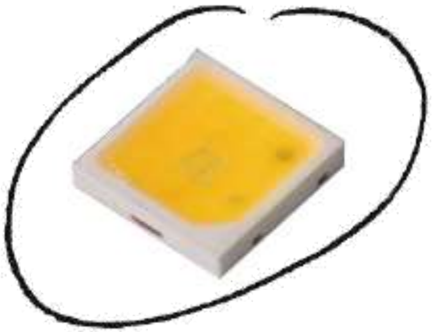
LINEAR LED LIGHTING CHALLENGES



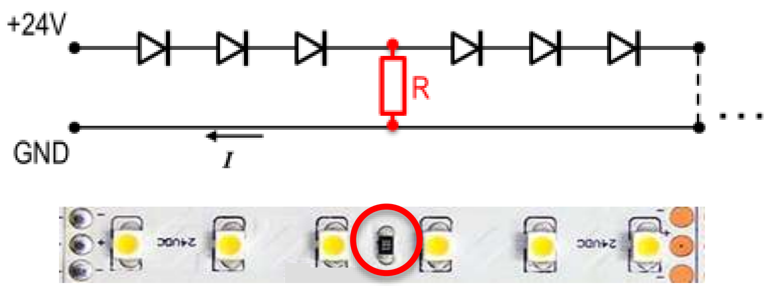
- Homogeneity
- Color consistency
- Reliability
- Lifetime

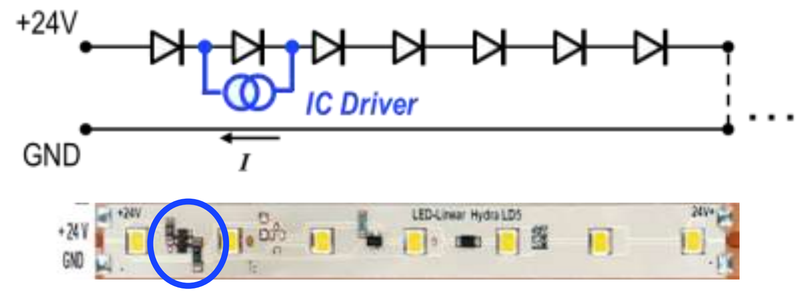
A great luminaire starts with a great light source.

It all starts here



FULFILL REQUIREMENTS FROM DAY 1 ELECTRICAL DESIGN





Resistor controlled DC circuits:

$$I_f = 24V / R$$

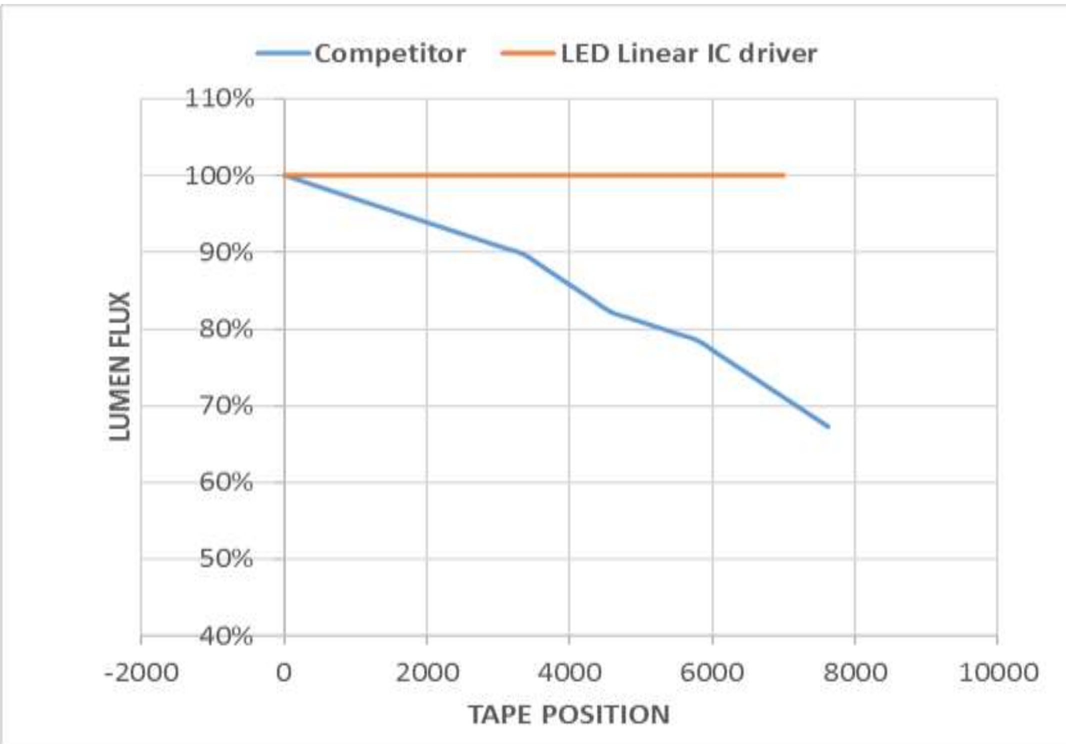
- Voltage drop over length is not balanced
  → Current decreases over length
- High temperature of the Resistor
  *(24 V – 6*3V)*200mA = 1,2W Heat*

IC controlled DC circuits:

- IC driver regulates current on each step
  → Current is stable over whole length
- Example:
  24V – 7 x 2.8V – 1.4V = 3V

DC supply | LEDs | IC driver | Overhead for Voltage drop

FULFILL REQUIREMENTS FROM DAY 1
ELECTRICAL DESIGN



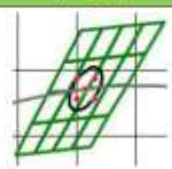
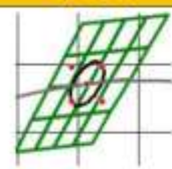
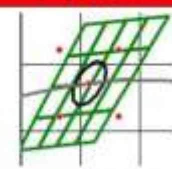
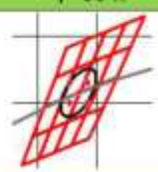
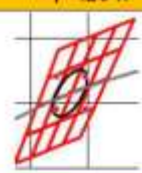
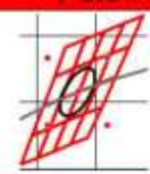
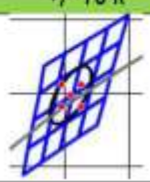
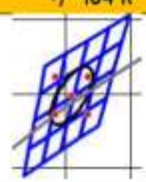
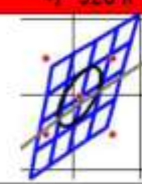
- More than 25% light loss over the maximum specified module length for resistor controlled constant voltage tapes.

Homogeneity

- IC driver on each step guarantee 100% light over the full specified length.

FULFILL REQUIREMENTS FROM DAY 1
SDCM3 IN REALITY

LED LINEAR™ lighting solutions | Member of the Fagerhult Group

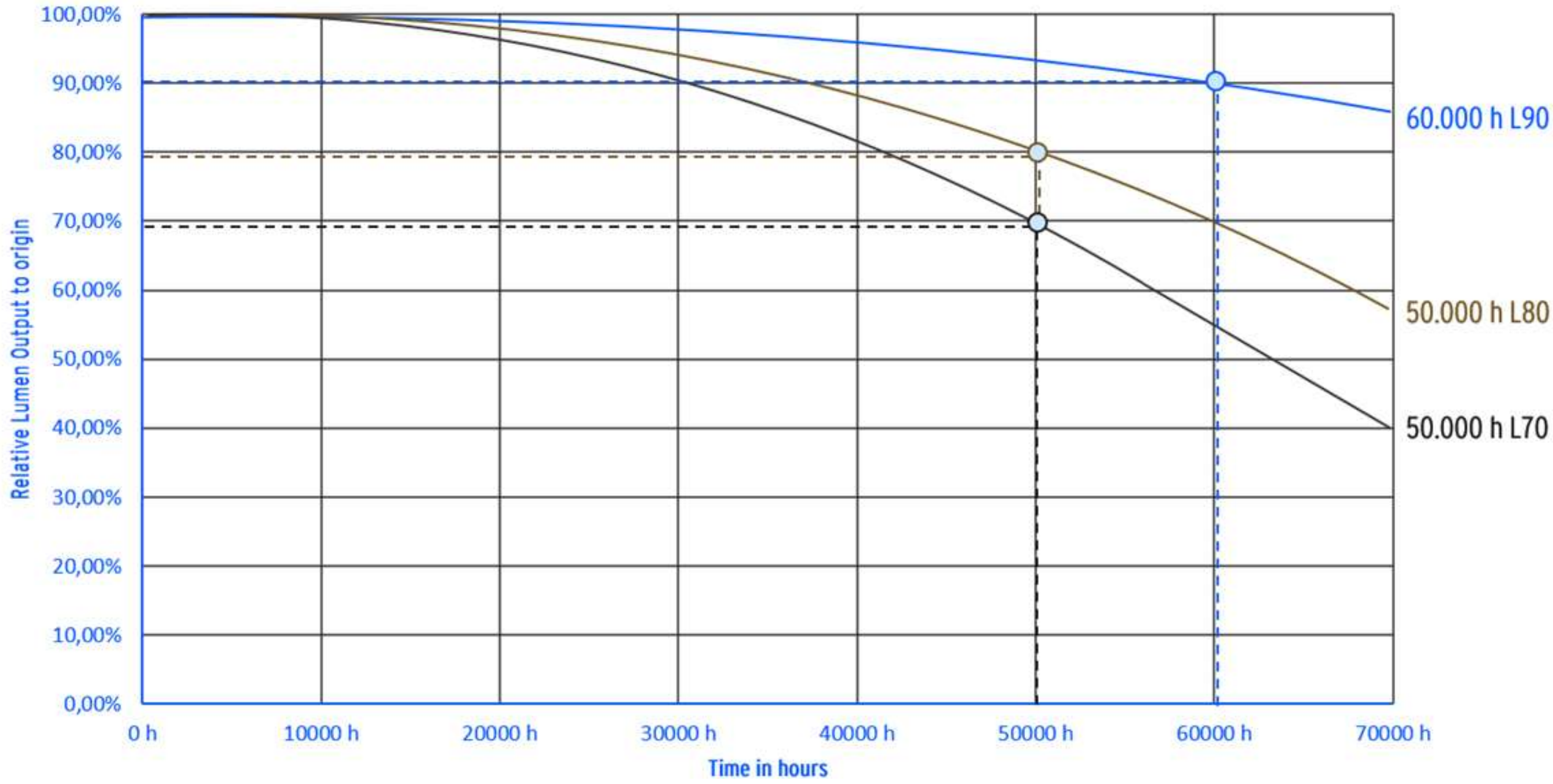
	LED Color Initial Measuring Tolerance		
	CIE (x,y) = +/- 0.003	CIE (x,y) = +/- 0.005	CIE (x,y) = +/- 0.010
	Supplier A	Supplier B	Supplier C
CCT	Reported Delta CCT		
2200K	+/- 39 K	+/- 96 K	+/- 192 K
			
3000K	+/- 56 K	+/- 126 K	+/- 252 K
			
4000K	+/- 78 K	+/- 164 K	+/- 328 K
			

Consistency

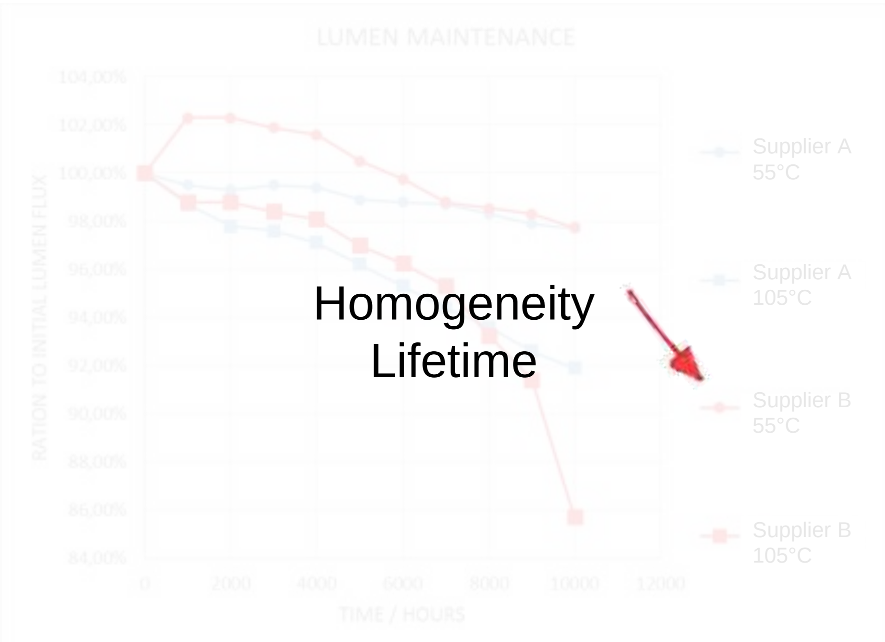
FULFILL REQUIREMENTS FROM DAY 1

WHAT COMES NEXT

AGING OF MID-POWER LEDS
LUMEN MAINTENANCE



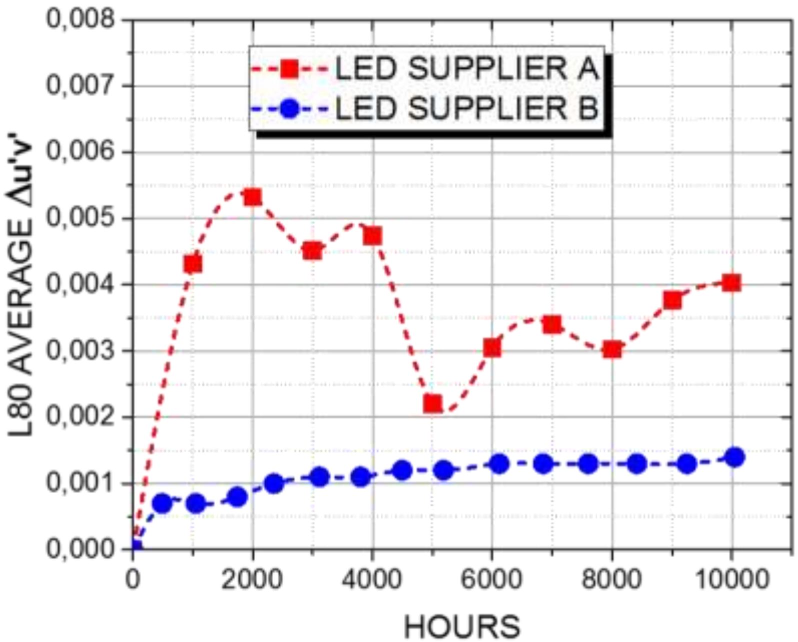
AGING OF MID-POWER LEDS
IMPACT ON LIGHTING QUALITY



Homogeneity
Lifetime

Consistency
Reliability

AGING OF MID POWER LEDS
EXTENDED PHOTOMETRIC CODE HELPS!



6 digit photometric code (IEC/PAS 62717):

Initial CRI: 77 – 86: 8
87 – 100: 9

Initial CCT 2700 K: 27

Example: W 9 2 7 / 3 3 9 vs W827/369

Initial chromaticity spread within:
3 step MacAdams: 3
5 step MacAdams: 5
…

Lumen maintenance after 25% of rated lifetime, max. 6 000 hrs

Chromaticity spread after 25% of rated lifetime, max. 6 000 hrs

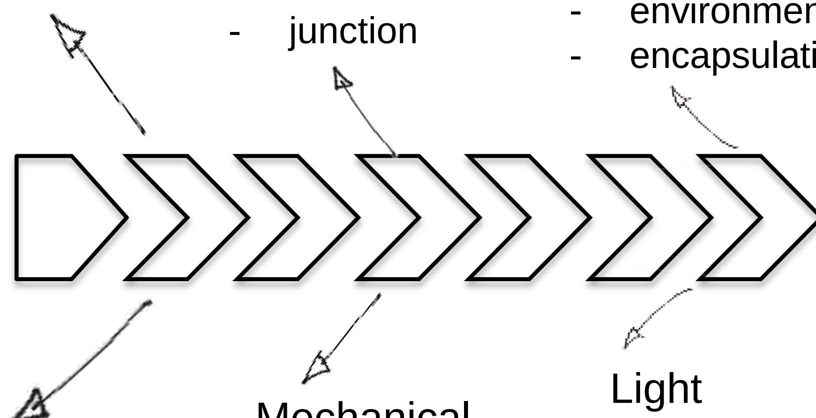
AGING OF MID-POWER LEDS
MAIN INFLUENCE FACTORS

Humidity
- installation
- protection

Temperature
- ambient
- junction

Chemicals
- environment
- encapsulation

LED



Lifetime & reliability

Electrical parameters
- drive current
- forwards voltage

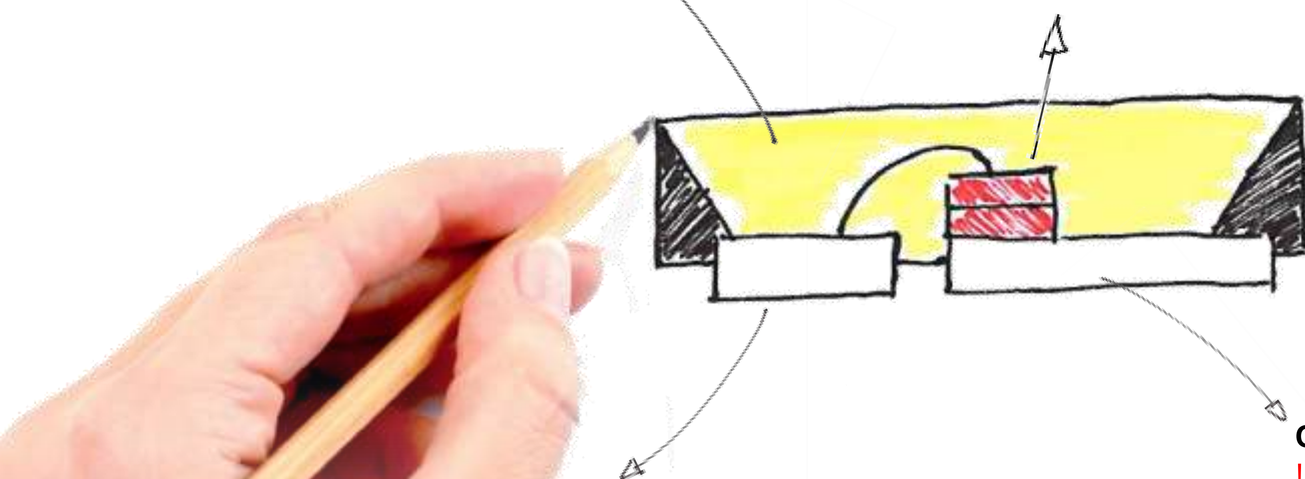
Mechanical Forces
- expansion
- bending

Light
- environment (UV)
- intrinsic (blue LED)

AGING OF MID-POWER LEDS
UNDERSTAND THE INFLUENCING PARAMETERS

Phosphor
- Converts blue light in to white spectrum
- Thermal and chemical stability
- Silicone/Phosphor mixture UV resistance

LED chip (emitting blue light)
- Degradation depends on junction temperature *Tj*
- Stability of the blue emission crucial
- Moisture is forbidden



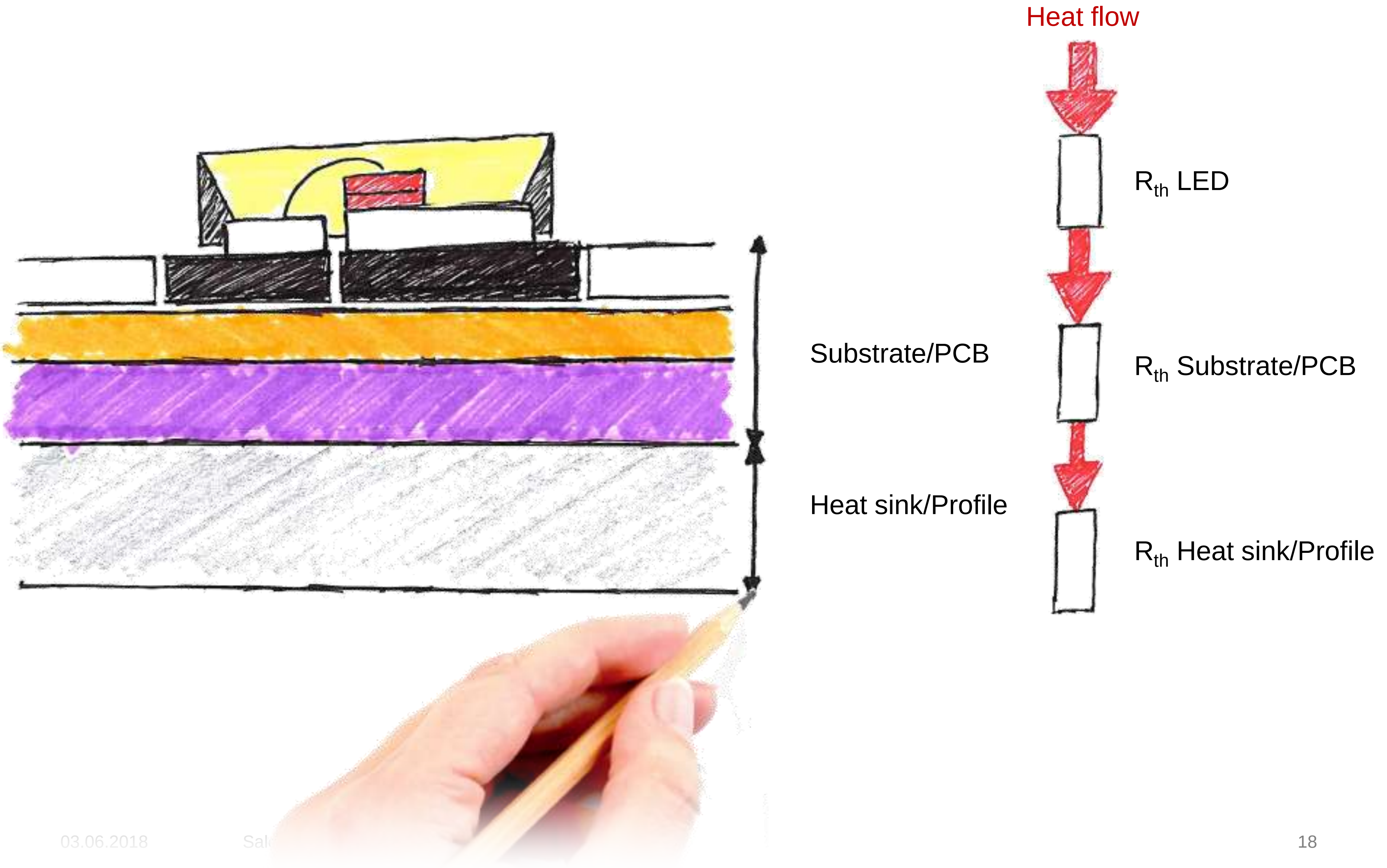
Package housing
- Reflectance of white light
- Resistance to chemicals and UV radiation

Anode
- Bonding wire connects to chip
- Quality of bonding wire essential for mechanical robustness of the package

Cathode
!!! heat transfer !!!
- Thermal resistance *Rth* < 10 K/W
- Heat sink capacity defines junction Temperature *Tj*

Keep T_j as low as possible ?

THERMAL MANAGEMENT
Substrate and heat-sink



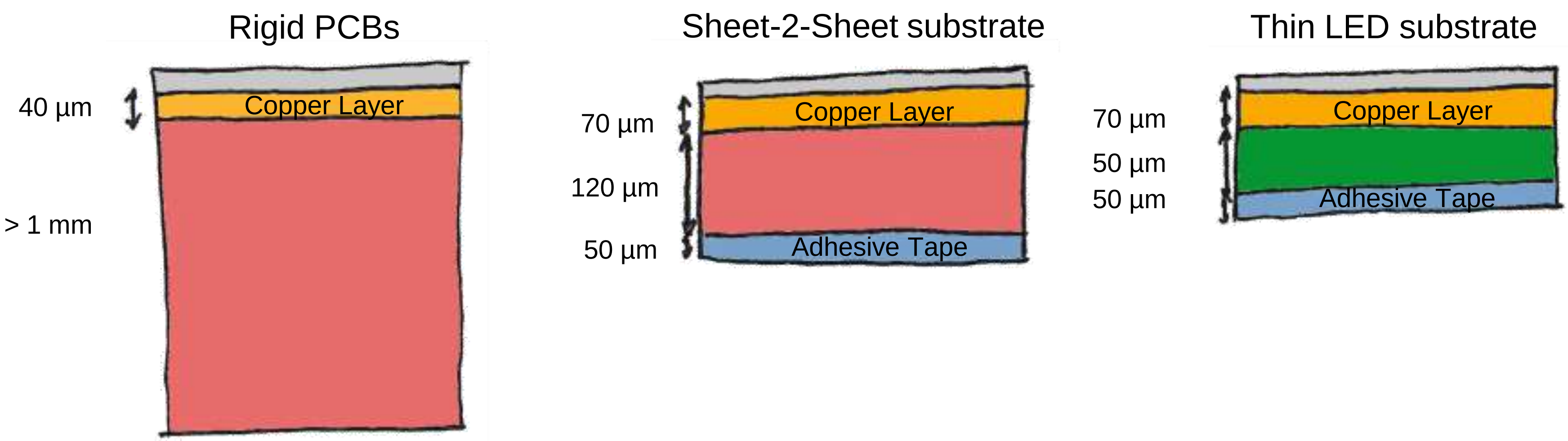
Keep Tj as low as possible → Minimize substrate R_{th} → ?

THERMAL MANAGEMENT
Substrate architecture

Rigid PCBs

Sheet-2-Sheet substrate

THERMAL MANAGEMENT
Substrate architecture

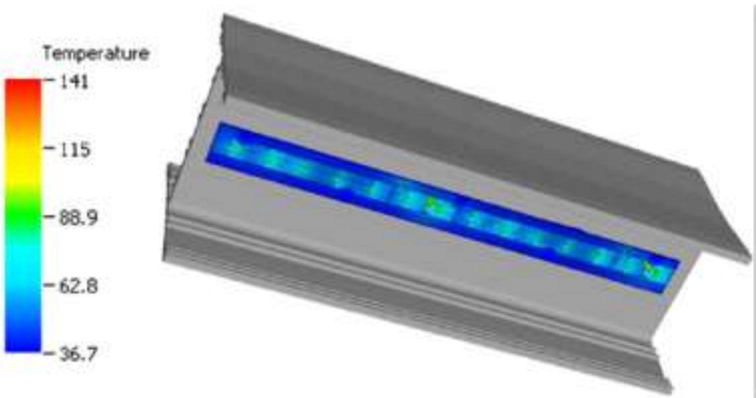


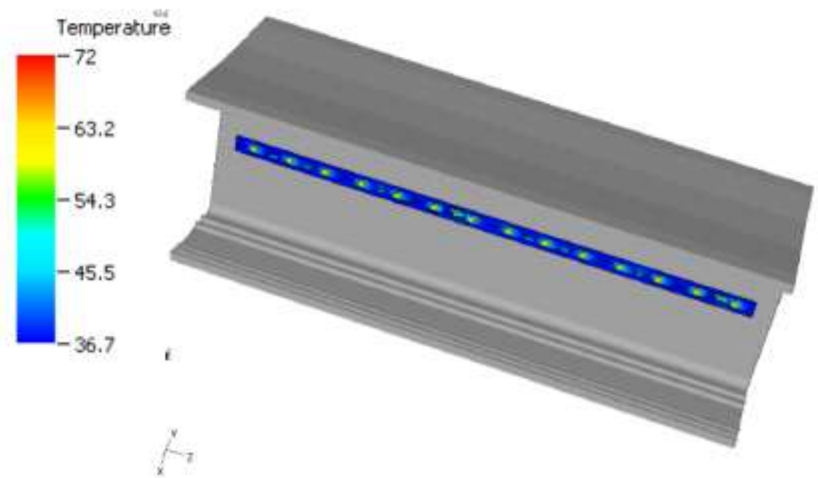
Plastic or FR4 → Heat insulator

Heat conductive materials

THERMAL MANAGEMENT
Comparative simulation

Thermal Management: PCB vs. flexible PCB @ 7250 lm/m





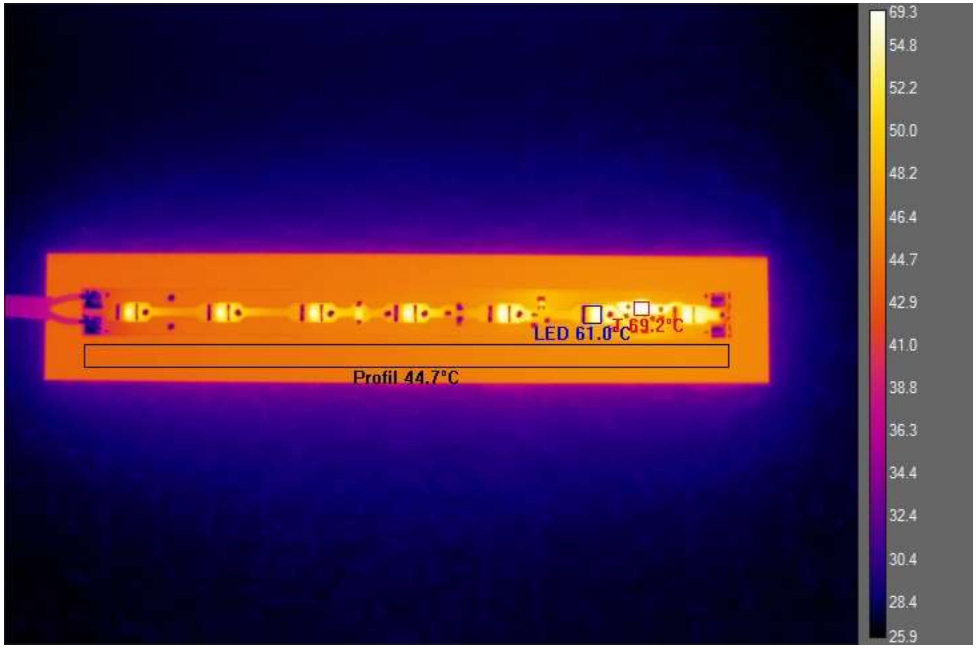
Rigid PCB (Zhaga)

→ Tj > 95°C

Thin flexible PCB (Reel-to-Reel)

→ Tj < 65°C

THERMAL MANAGEMENT
Measurement



Experimental setup: 40 W/m (12 W/ft) LED tape with thin flexible PCB mounted on flat aluminum plate

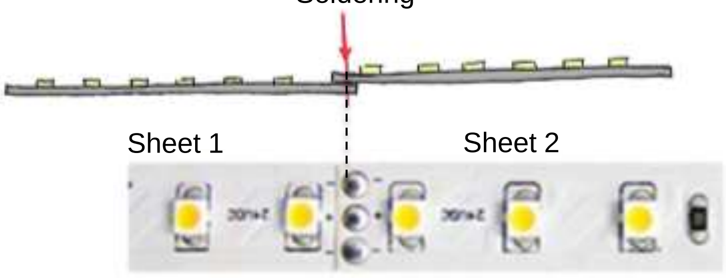
→ LED temperature does not exceed 60°C!

Keep Tj as low as possible → Minimize substrate R_{th} → Substrate optimization → ?

Keep Tj as low as possible → Minimize substrate R_{th} → Substrate optimization → Production process

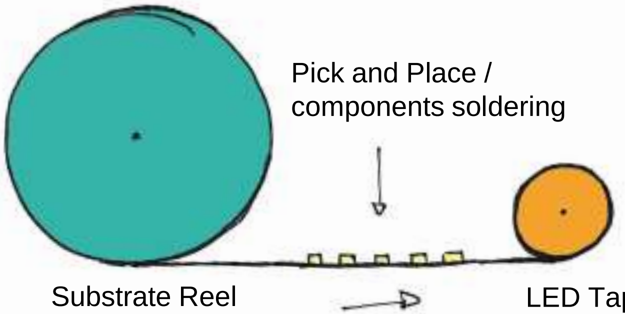
REEL-TO-REEL TECHNOLOGY
DIFFERENCE TO SHEETS

Sheet-to-sheet



- Solder point between sheets acts like a rated break point
- Overlap between sheets have bad thermal contact to heat sink
- Sheet material is thicker and less flexible than R2R material
- Mostly soldered and cut by hand

Reel-to-Reel (R2R) technology



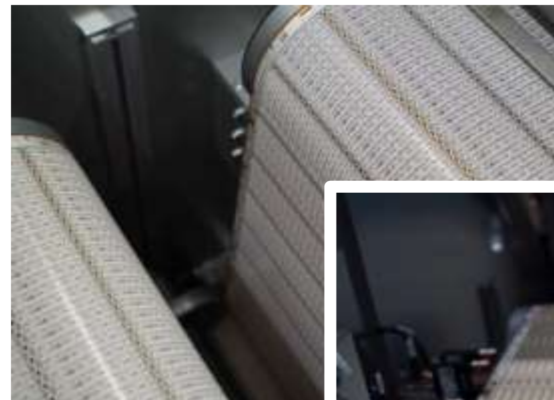
- No stairway-effect between cut-lengths
- Improved mechanical stability due to homogeneous flexible material
- State-of-the-art precision in pick and place process
- Fully automated process with in-line inspection

REEL-TO-REEL TECHNOLOGY
DIFFERENCE TO SHEETS

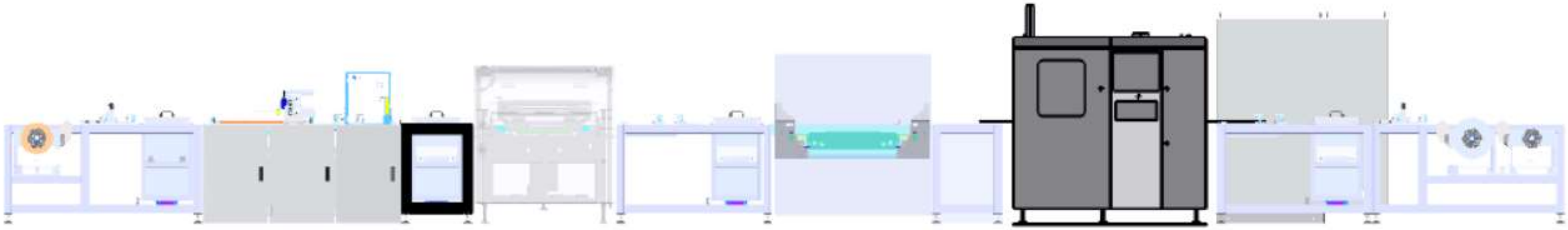
Sheet-to-sheet



Reel-to-Reel (R2R) technology




REEL-TO-REEL TECHNOLOGY
PRODUCTION LINE TOPOLOGY



Keep Tj as low as possible → Minimize substrate R_{th} → Substrate optimization → Production process

✓ ✓ ✓ ✓

TO SUM UP

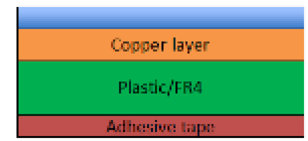
How to recognize a high quality LED tape?

Reel-to-Reel (R2R) VS. Sheet-to-Sheet

No breake points or air gaps

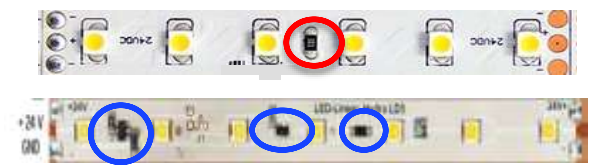
Tape substrate avoiding FR4 or plastic layers

Avoid heat barriers in LED tape, those tend to be thicker and less flexible



IC-Driver regulated VS. Only Resistor controlled

Avoid heat bombs on tape, voltage drops = lumen drops over run length



Ask for availability of a 6digit photometric code to evaluate long term performance

Instead of just looking at the inital Binning

Ask for the actual lifetime of a product via the full Lp/Bp value

Such as LED Linear´s L90/B10

THANK YOU