Mastering of automotive LED lighting systems and electronics with FloEFD

Martin Isack

28.11.2017

DELVIS PARTNER FÜR INTELLIGENTE LICHTSYSTEME

Outline

- Introduction to myself and my company
- Why are detailed led characteristics important for thermal simulations?
- How to handle LEDs with FloEFD?

Personal introduction

2006–2012 Technische Hochschule Nürnberg

- Masters project: Thermal simulation of led systems
- Experience in general CFD and FEM in the context of leds and electronics
- Usage of OpenFOAM as general purpose simulation tool
- First contact with FloEFD

since 2012 DELVIS GmbH

- Responsible for thermal management of lighting systems and electronics
- Adoption of FloEFD since beginning of 2016

DELVIS history

2002

Company founded, focus on mechanical engineering and prototyping for headlamps and rear combination lamps in the automotive industry

2006

Focus on DESIGN, ELECTRONICS and LIGHTING. System development for automotive lighting applications

2010

Industrialisation of components and systems

Today

170 engineers

DELVIS services and products

Product Groups

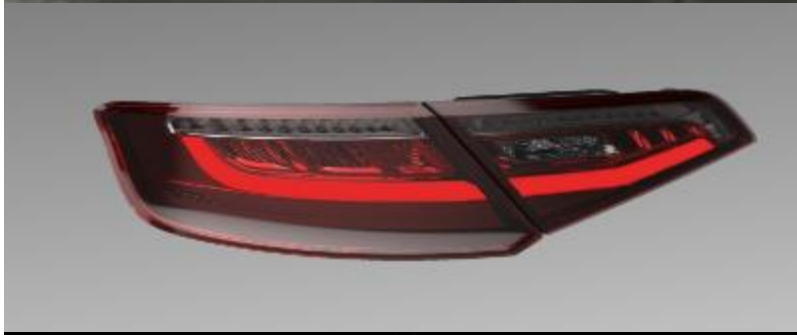
- Interior Lighting
- Exterior Lighting
- Electronics

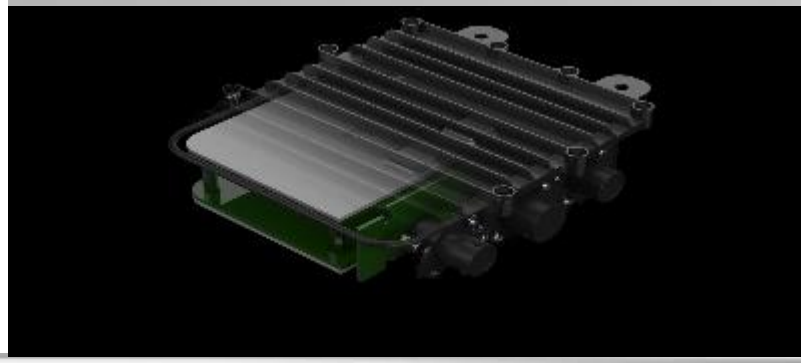
Services

- Predevelopment / Feasibility
- Product Development
- Prototypes / Styling Samples
- Industrialisation

Markets

- OEM
- Accessories
- Aftermarket
- Motorsports

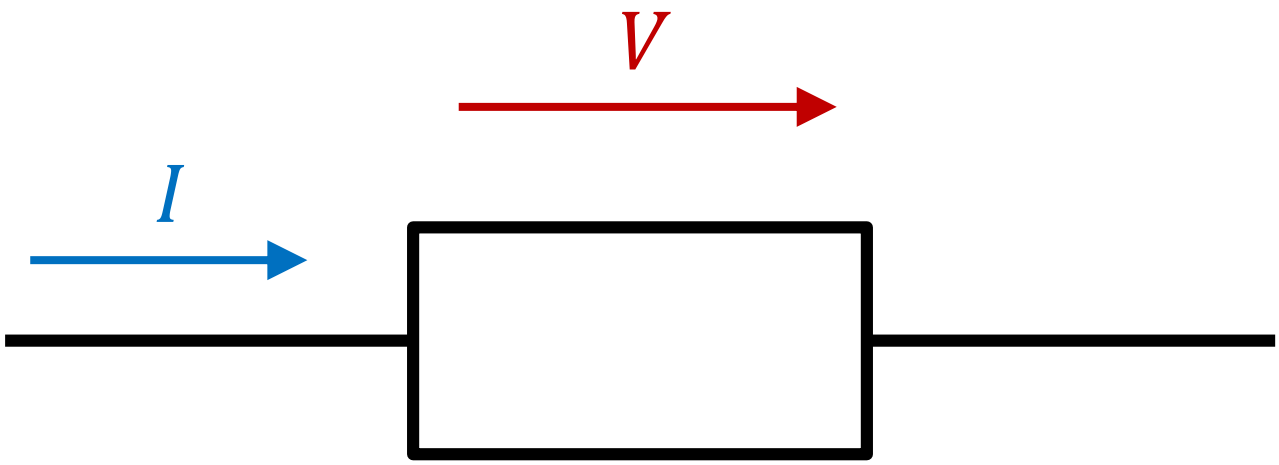




Questions to the audience

- Who of you has already done thermal simulations of LEDs with FloEFD?
- Who is familiar with the FloEFD LED module?
- Who is using T3Ster TeraLED data for the LED module?

Resistor as heat source

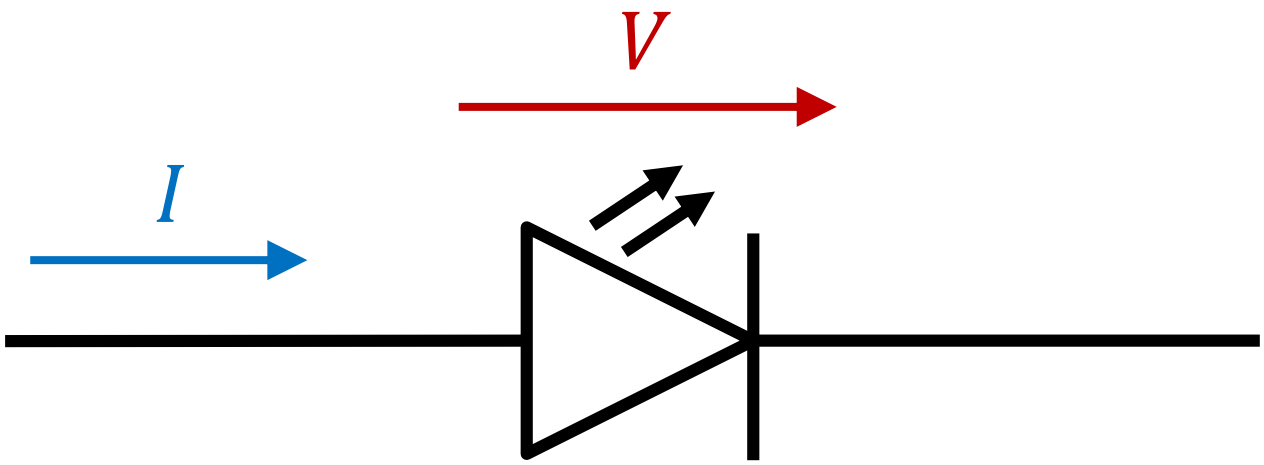


$$R = const.$$

$$V = I \times R$$

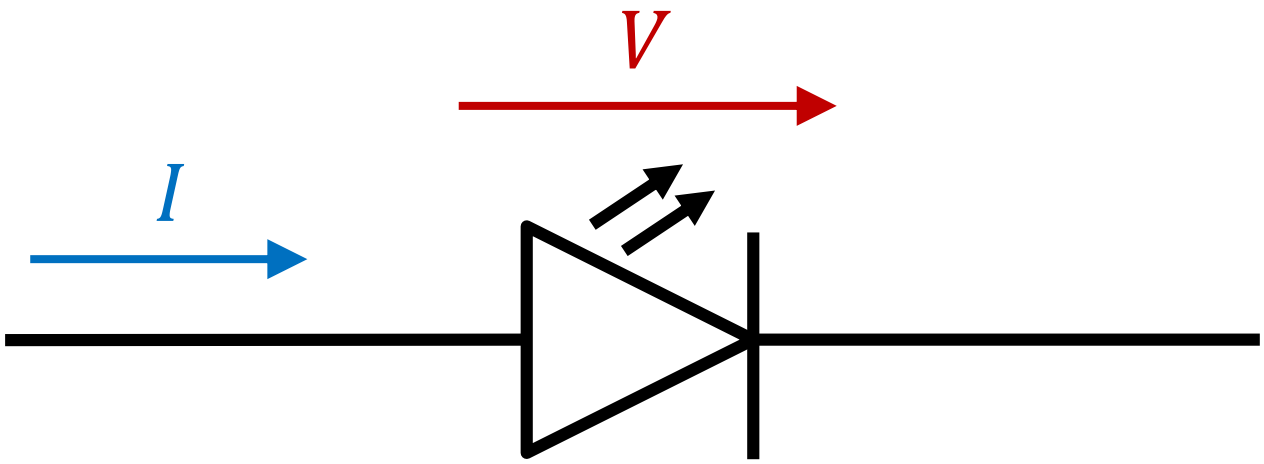
$$P_D = I \times V$$

LED as heat source



$R \neq const.$

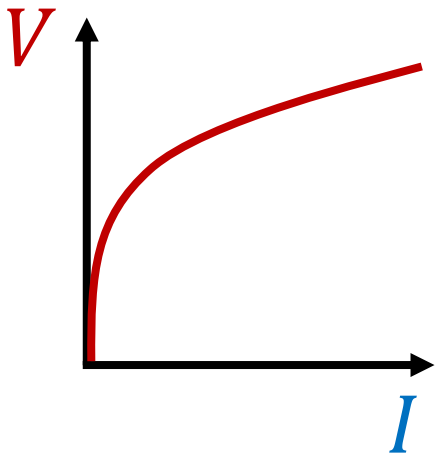
LED as heat source



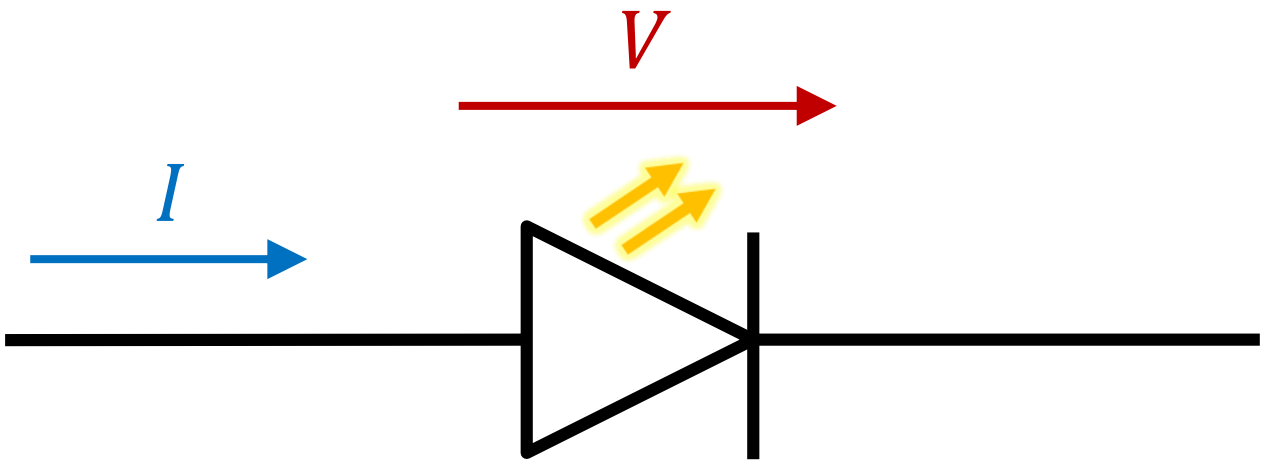
$$R \neq const.$$

$$V = V(I, T)$$

semiconductor



LED as heat source



$$R \neq const.$$

$$V = V(I,T)$$

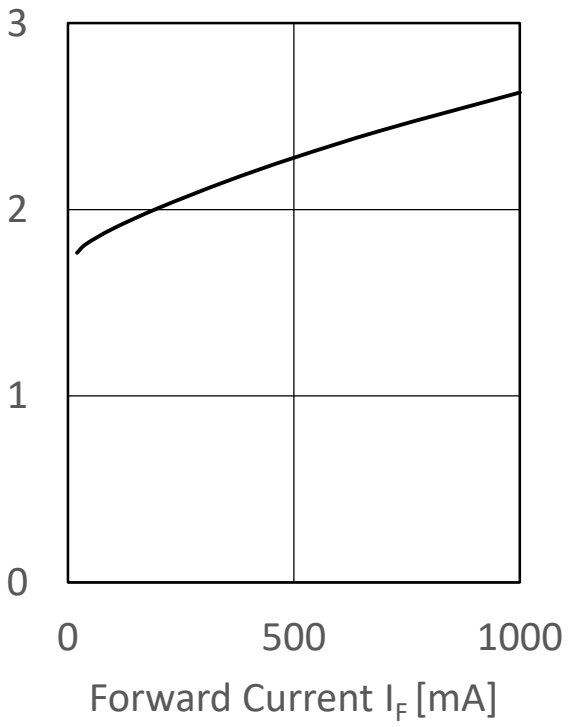
$$P_D = I \times V(I,T) - \Phi_E$$

power dissipation = input power − radiative flux

LED current dependencies

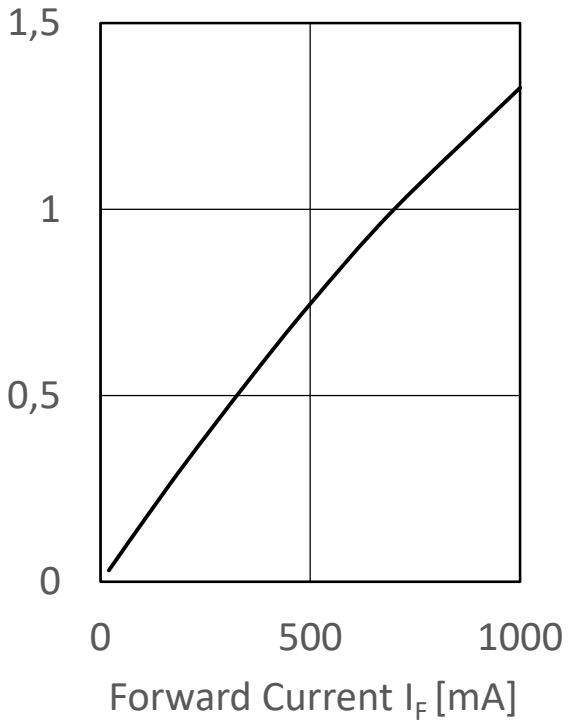
Forward Voltage

V_F [V]



Relative Luminous Flux

Φv/Φv(700mA)

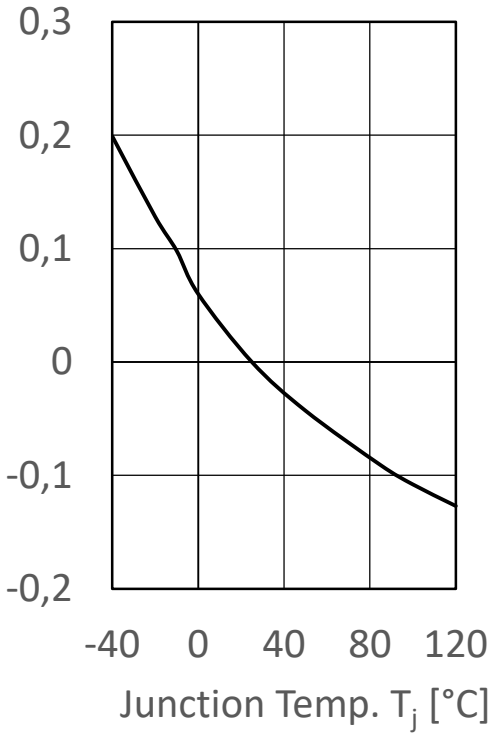


Source: OSRAM OS SYNIOS P2720 Datasheet Version 1.2 - KS DMLS31.23

LED temperature dependencies

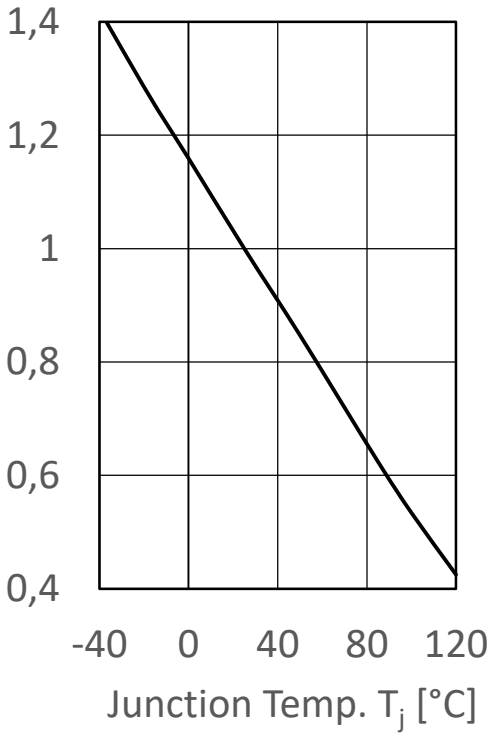
Relative Forward Voltage

$V_F - V_F(25\ °C)$ [V]



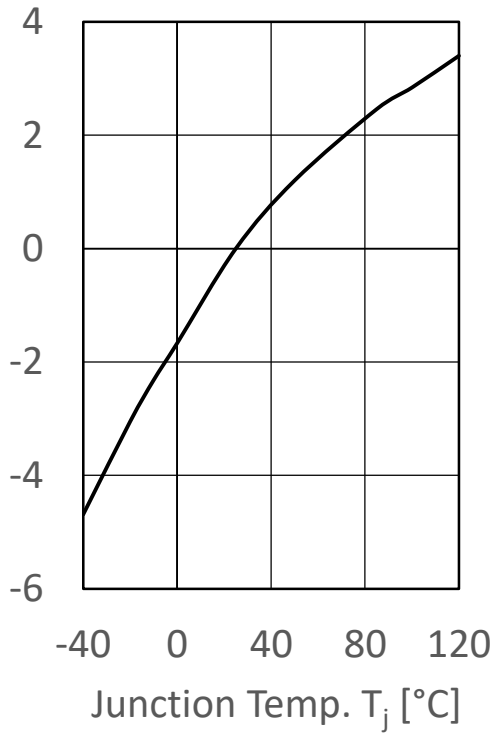
Relative Luminous Flux

$\Phi v/\Phi v(25\ °C)$



Dominant Wavelength

$\lambda_{dom} - \lambda_{dom}(25\ °C)$ [nm]



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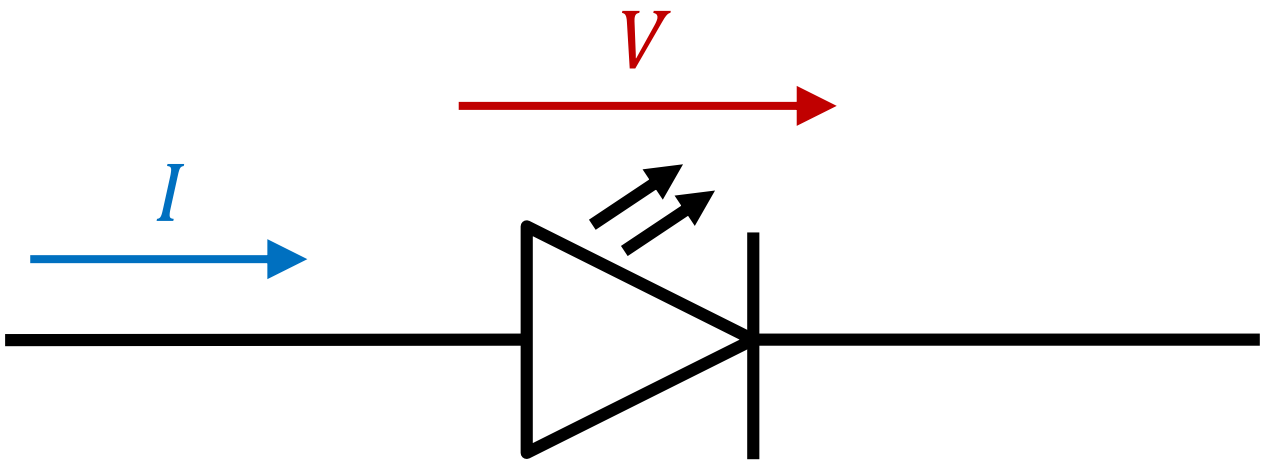
LED as heat source



$$R \neq const.$$

$$V = V(I,T)$$

$$P_D = I \times V(I,T) - \Phi_E$$

radiative flux

$$= f(\Phi_v)$$

luminous flux

Relation between luminous and radiative flux

Light technician world

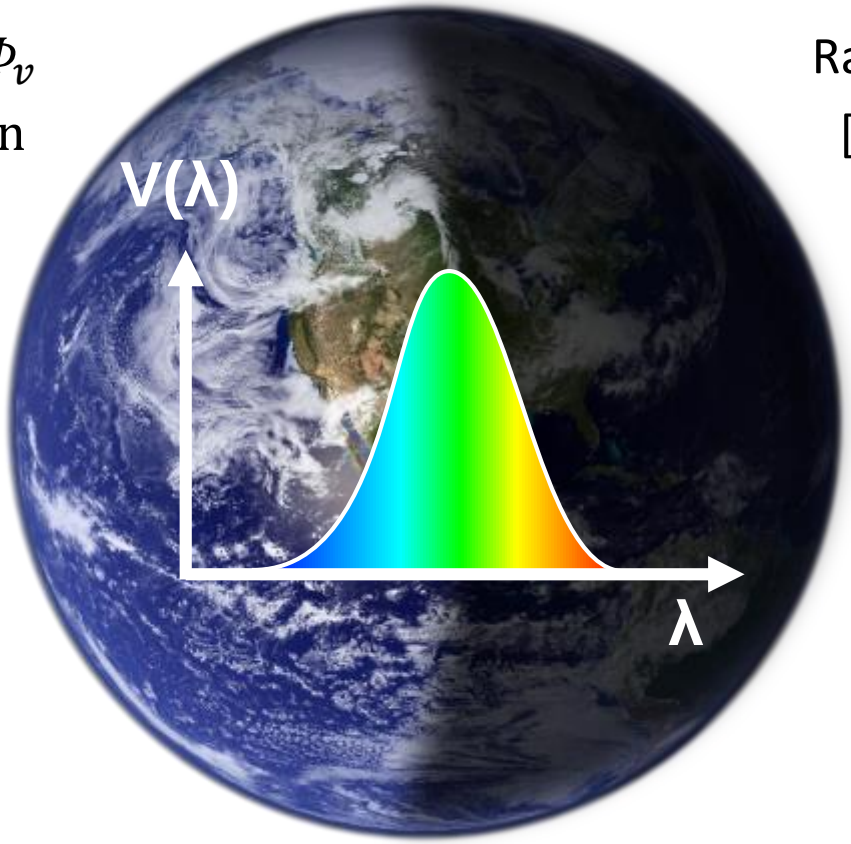
Luminous flux Φ_v

$[\Phi_v] = 1$ lumen

Rest of the world

Radiative flux Φ_e

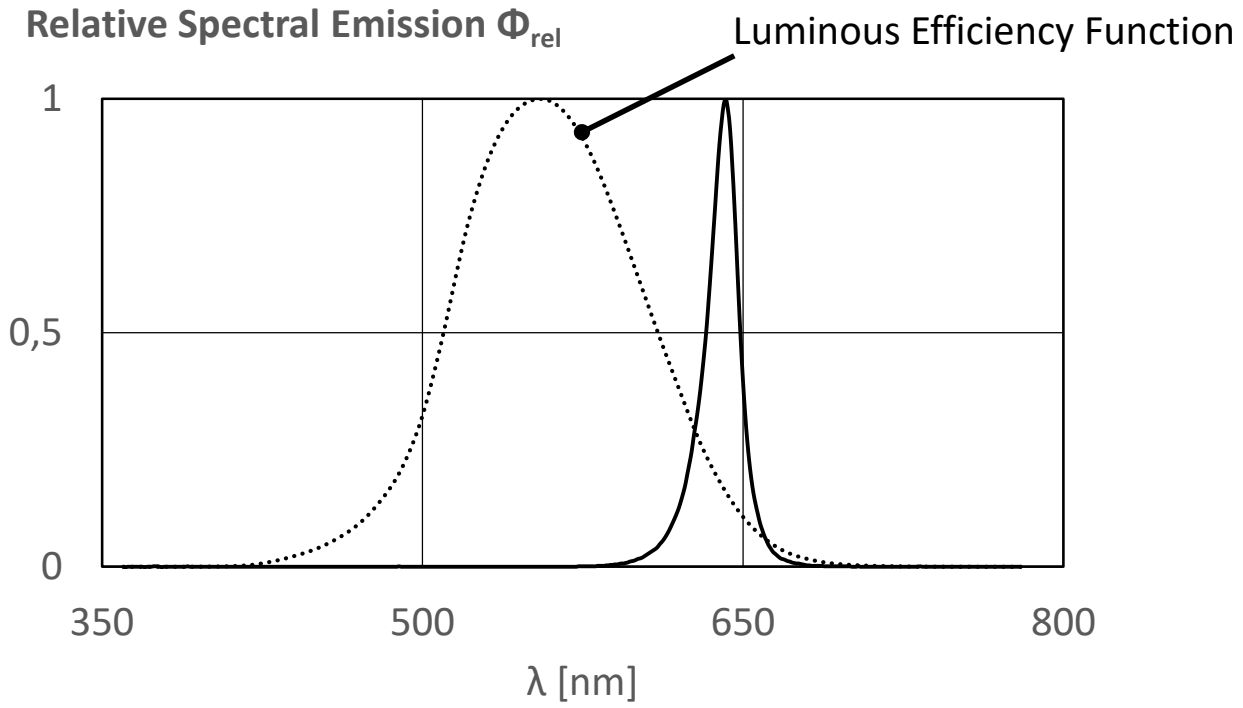
$[\Phi_e] = 1$ watt



Luminous Efficiency Function

Calculation of the radiative flux

$$\Phi_v = K \times \Phi_e \qquad K = K_m \times \frac{1}{\int_0^\infty \Phi_{rel}\, d\lambda} \times \int_0^\infty \Phi_{rel} V(\lambda)\, d\lambda \qquad K_m = 683\ \text{lm/W}$$



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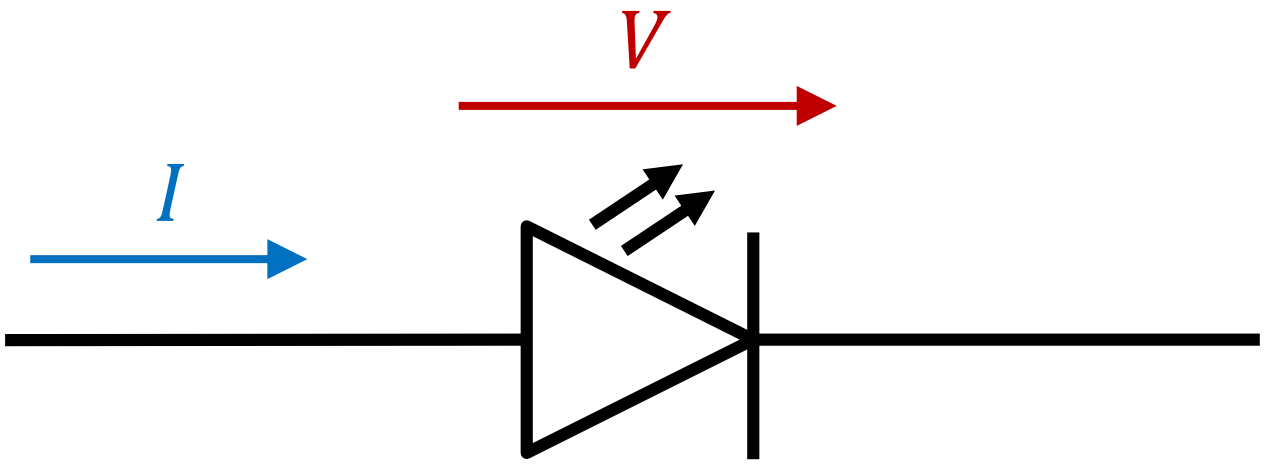
LED as heat source



$$R \neq const.$$

$$V = V(I,T)$$

$$P_D = I \times V(I,T) - \Phi_E$$

power dissipation = input power − radiative flux

LED binnings

- Tolerances in LED production
- Different properties for one LED type
  (voltage, luminous flux, spectrum)
- LEDs with similar properties grouped together by manufacturer

LED binnings

Brightness Groups	min. Luminous Flux [lm]	max. Luminous Flux [lm]
6J	50	56
⋮	⋮	⋮
8J	100	112

Voltage Groups	min. Forward Voltage [V]	max. Forward Voltage [V]
M3	2.15	2.30
⋮	⋮	⋮
W3	2.60	2.75

Source: OSRAM OS SYNIOS P2720 Datasheet Version 1.2 - KS DMLS31.23

Different binning – different power

SYNIOS KS DMLS31.23 @ 700 mA, 2.45 V, 100 °C

binning flux	thermal power	
50 lm	1.44 W	
112 lm	1.20 W	17 % less

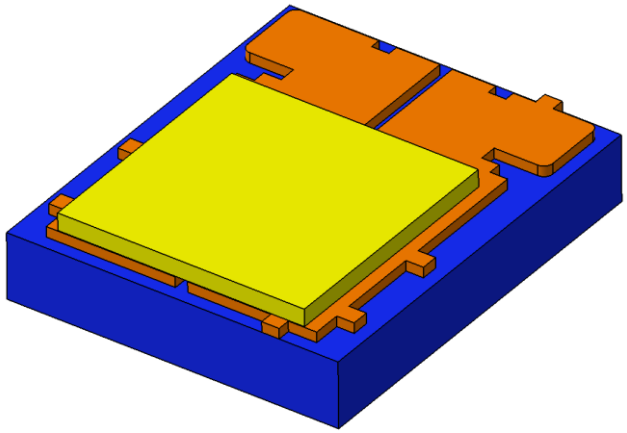
SYNIOS KS DMLS31.23 @ 700 mA, 75 lm, 100 °C

binning voltage	thermal power	
2.15 V	1.13 W	
2.75 V	1.55 W	37 % more

Modelling of LEDs

Detailed thermal model

Information from manufacturer is required about geometry and materials



Black box

Single Material

- no information about junction temperature

2-resistor model

- includes thermal resistances
- information in datasheet

Structure function

- includes thermal capacity
- measurement required

Heat sources for LEDs

Surface/volume heat source

or

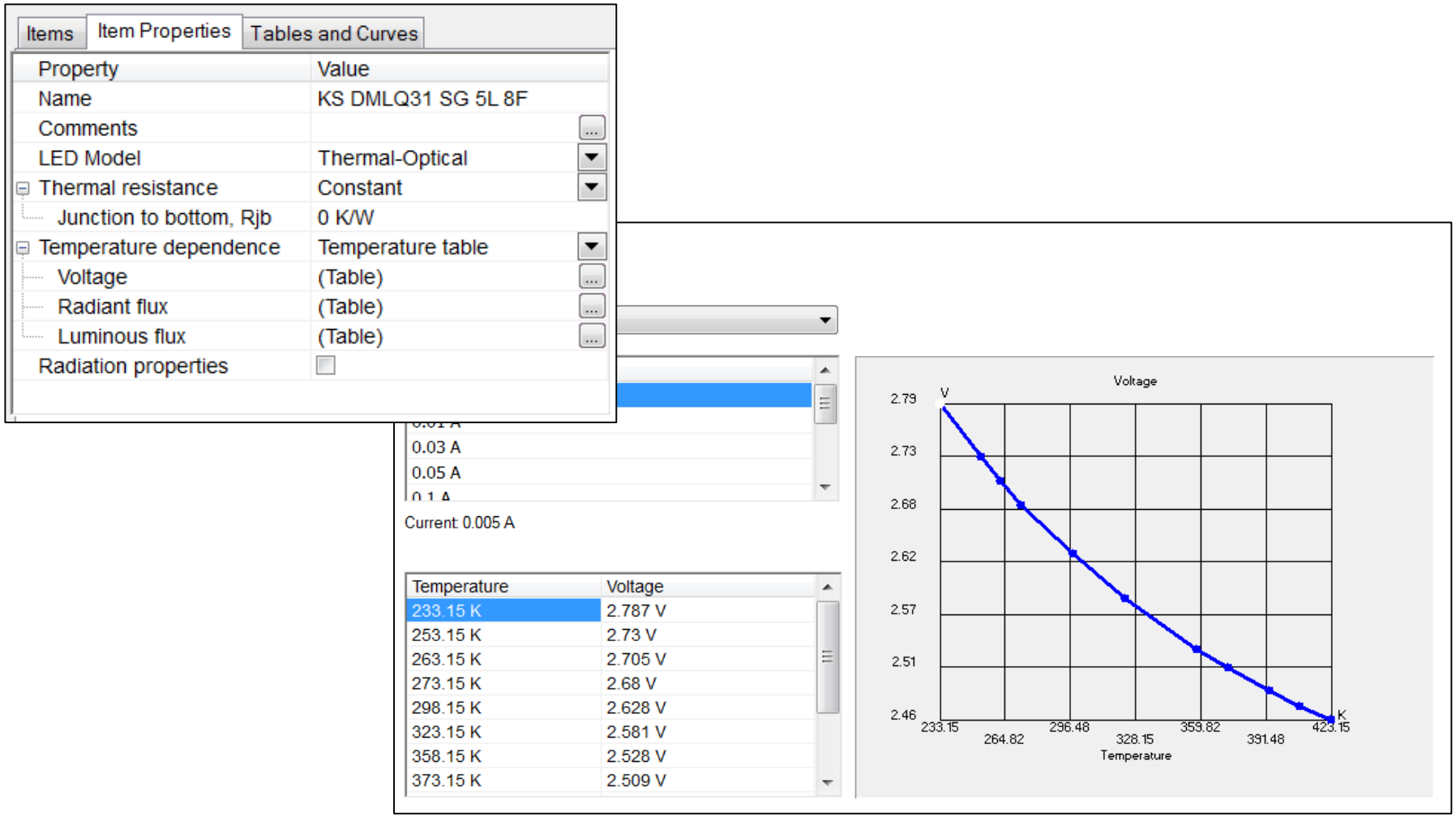
FloEFD 2-Resistor model

- calculate the power for a fixed current and temperature
- calculate a temperature dependent power for a fixed current

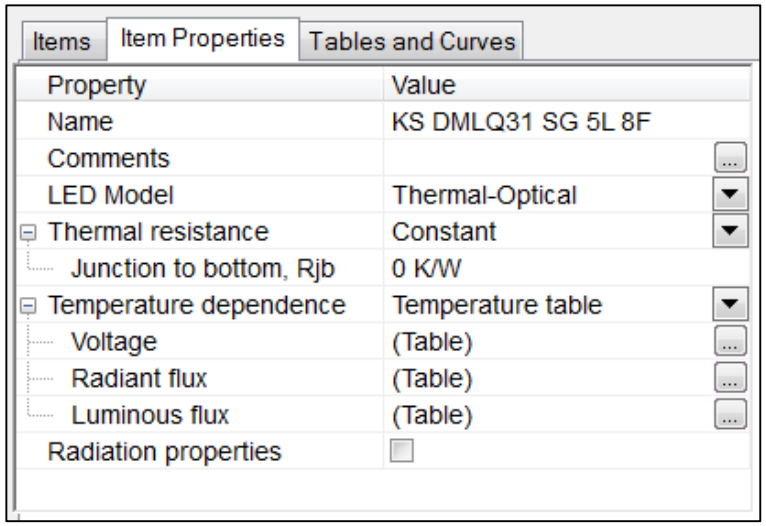
FloEFD LED model

- detailed thermal LED model
  with temperature
  and current dependencies

FloEFD LED module



Create FloEFD LED models



Thermal resistance
structure function **or**
constant thermal resistance

Voltage
function of temperature and current

Luminous flux
function of temperature and current

Radiant flux
function of temperature and current
(can be calculated by the luminous flux using the LEDs spectrum)

Mentor Graphics T3Ster TeraLED

Measures

- forward voltage
- luminous flux
- radiative flux

as a function of

- current
- temperature

Source: Mentor Graphics

- detailed structure function
- data can be imported into FloEFD as LED model

How do you handle LEDs with FloEFD?

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