Thermal Management in elektronischen Schaltkreisen und LED - Systemen

LED Lösungen und ihre thermischen Eigenschaften

Georg Bogner

OS LED E / Materials Valley
18. März 2010

Modern LED Packages and their Applications

Table of Contents:

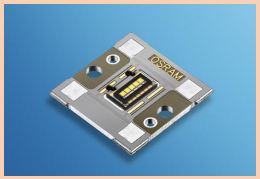
- Overview about OSRAM OS products and technologies
- Importance of chip technology
- Overview about power products and applications fields
- Thermal considerations

OS product solutions for a wide range of applications

Visible LED

Power devices

OSTAR®



Golden DRAGON®

Advanced Power TOPLED®

Micro SIDELED®

SmartLED®

Mini packages

Chipled

PointLED®

MULTILED®

Multi chip packages

Infrared

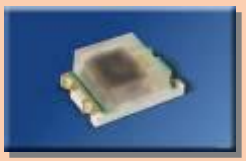
Detectors & Emitters

SMT detector

MIDLED

Sensors

Ambient light sensor



Tilt sensor

Power laser

cw-laser

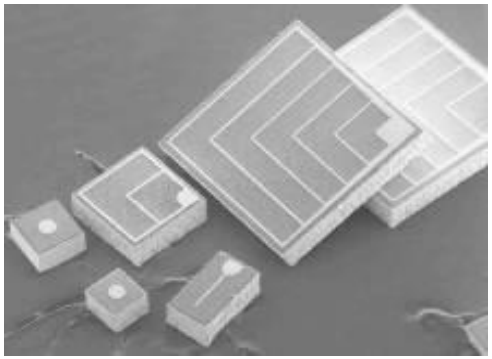
Pulsed laser

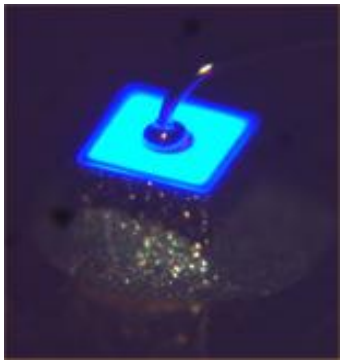
OLED

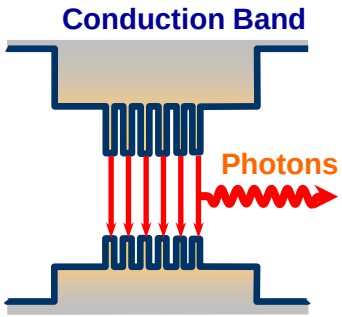
Lighting

Flat light module

Our Technologies







"Bandgap Engineering"

Epitaxy

Substrate

Internal quantum efficiency

Chip Processing

Light extraction
Electrical losses

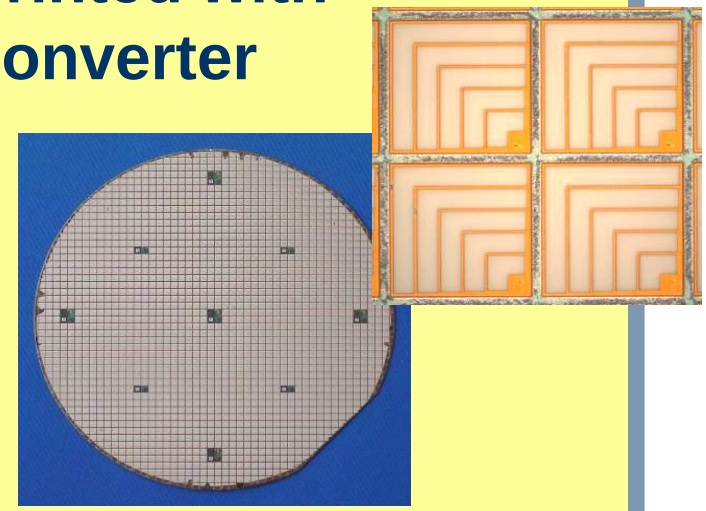
Packaging

Light extraction
Thermal management
λ-conversion

$$\eta_{\text{Wall plug}} = \eta_{\text{int}} \cdot \eta_{\text{electr.}} \cdot \eta_{\text{extr}} \cdot \eta_{\text{package}}$$

Chip Level Conversion - CLC

ThinGaN wafer printed with converter



CLC layer (phosphor + silicone) on surface emitter

⇨ excellent color homogeneity

⇨ die sorted “white” chips

⇨ high luminance

⇨ perfectly suitable for optical systems

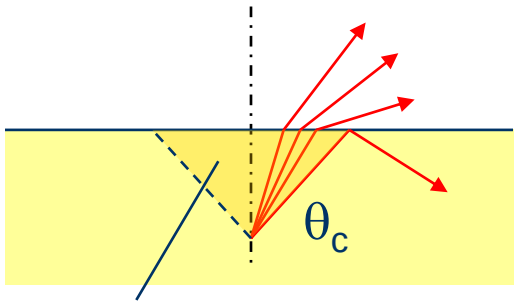
Modern LED Packages and their Applications

Table of Contents:

- Overview about OSRAM OS products and technologies
- Importance of chip technology
- Overview about power products and applications fields
- Thermal considerations

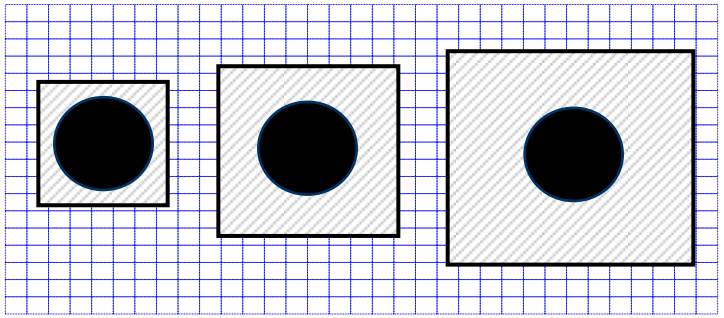
Previous light out coupling problems

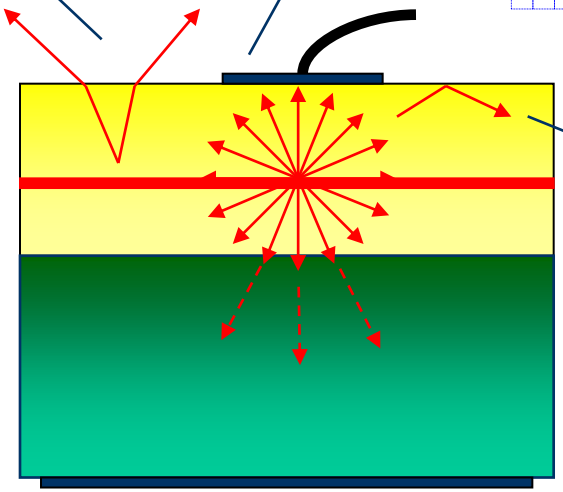
Light out coupling

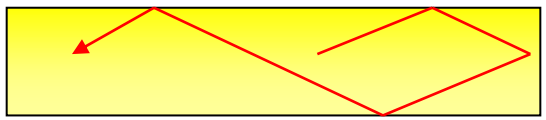


"out coupling cone"

Shadowing by the bond pad







total internal reflection

Absorption in the substrate

$$\Theta_c = \sin^{-1}(n_1 / n_2)$$

$$\Omega_c = 2\pi(1-\cos\Theta_c)$$

$$\eta_{ex} = \Omega_c / 4\pi \approx 1/(4n_2)^2$$

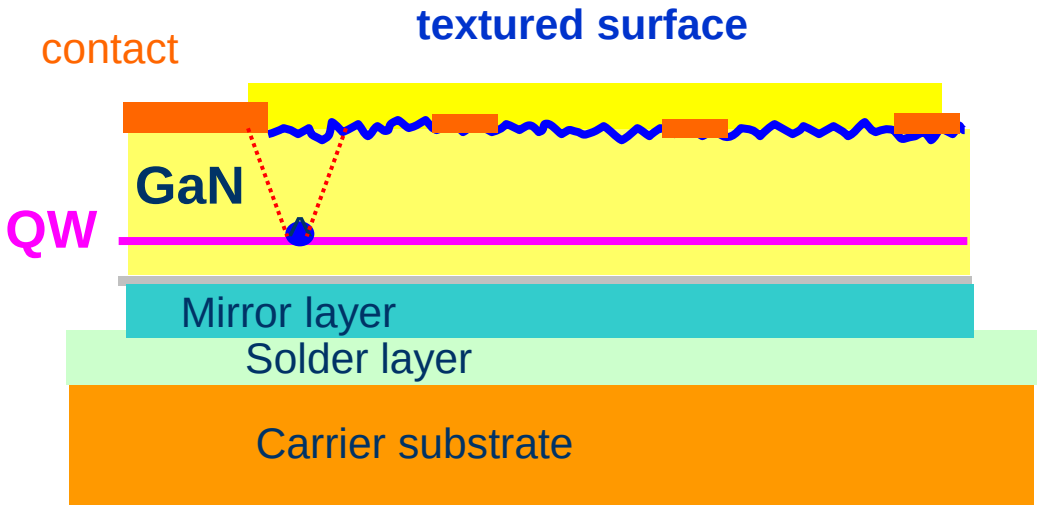
$$\eta_{ex} = 2.2\%$$

ThinGaN: The Way to Improve Light Extraction

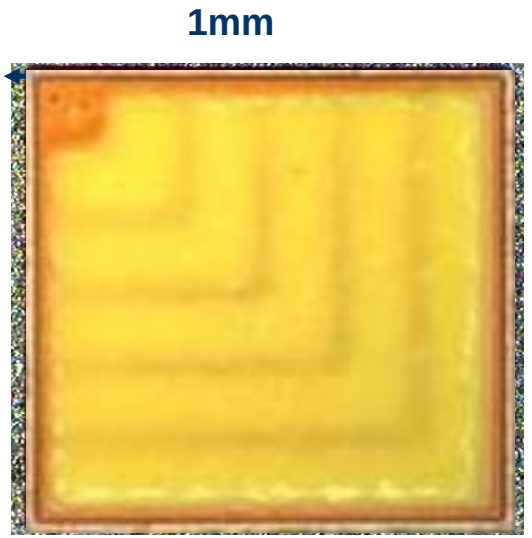
Thinfilm principle:

- prevent absorption in substr. ⇒ highly reflecting mirror
- low internal absorption ⇒ thin epi layers
- prevent waveguiding ⇒ optimize surface roughness

Present actions:



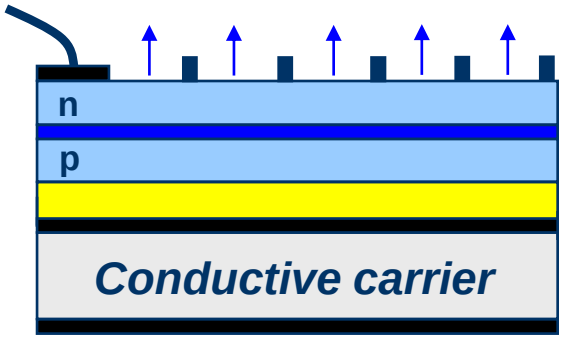
PowerThinGaN; scematic side view



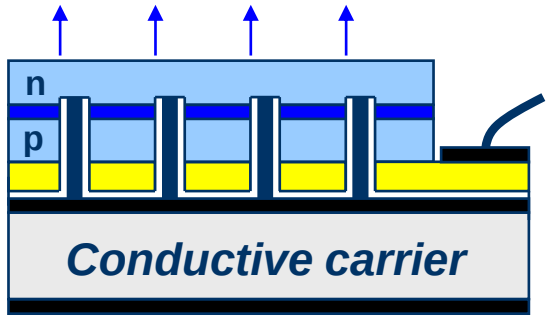
PowerThinGaN top view

Light extraction >80% is reached

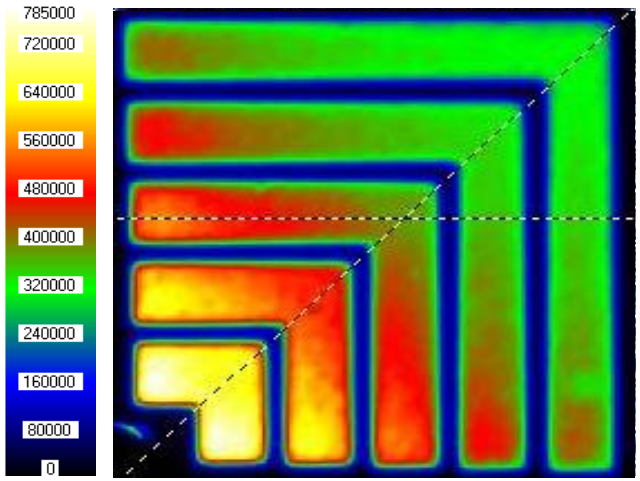
ThinGaN further development: UX3



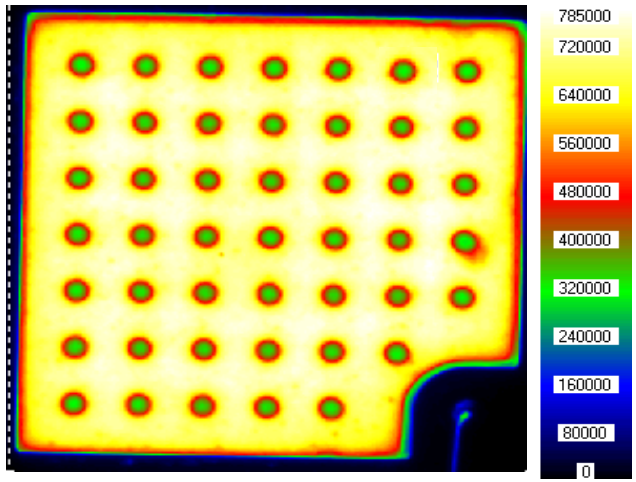
Cross sectional view



Cross sectional view



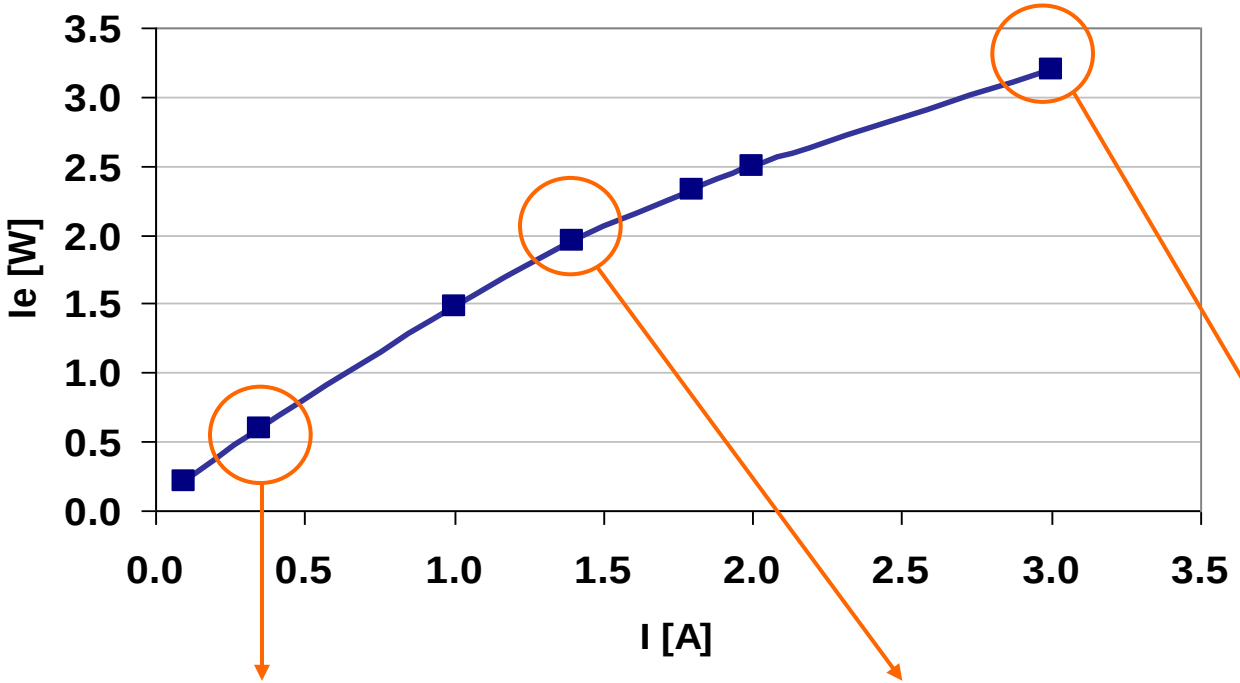
Luminance @ 1,4 A



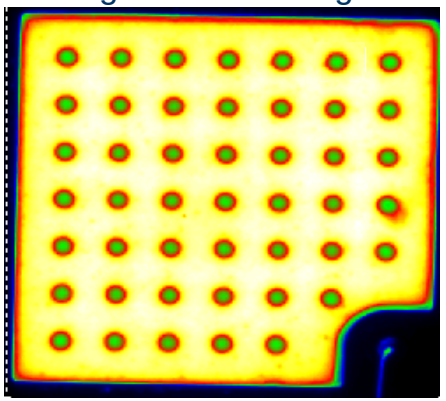
Luminance @ 2,8 A

New Chip Architecture: Top Brightness

Performance of new high current chip design in Dragon +



Epi: Improved MQW
Mirror: Premium Ag design
Package: Golden Dragon +



601,4 mW @ 350 mA

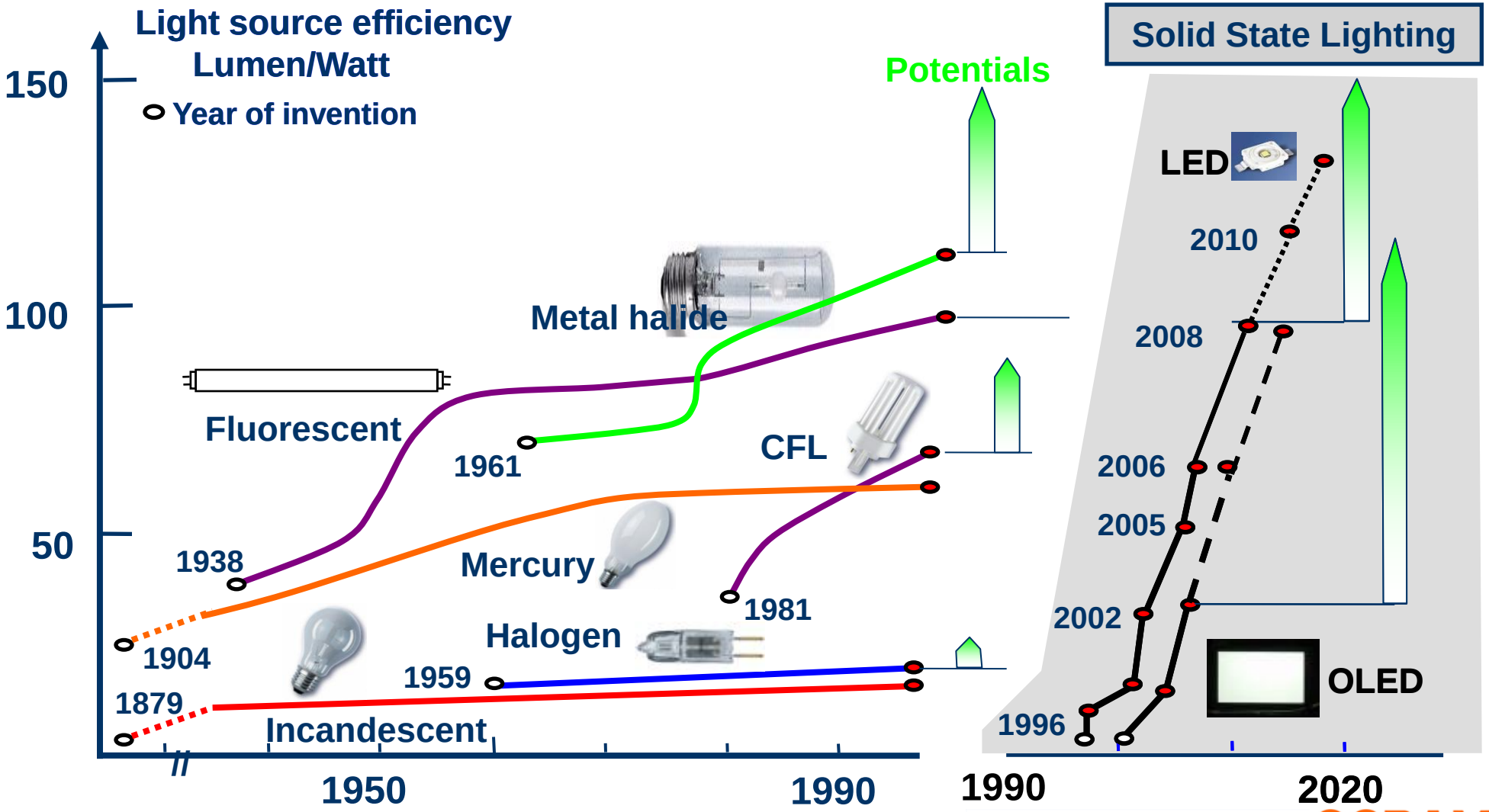
1966 mW @ 1,4 A

3199 mW @ 3 A

White: 155lm; 136lm/W; 3,24V; 5000K; 350mA

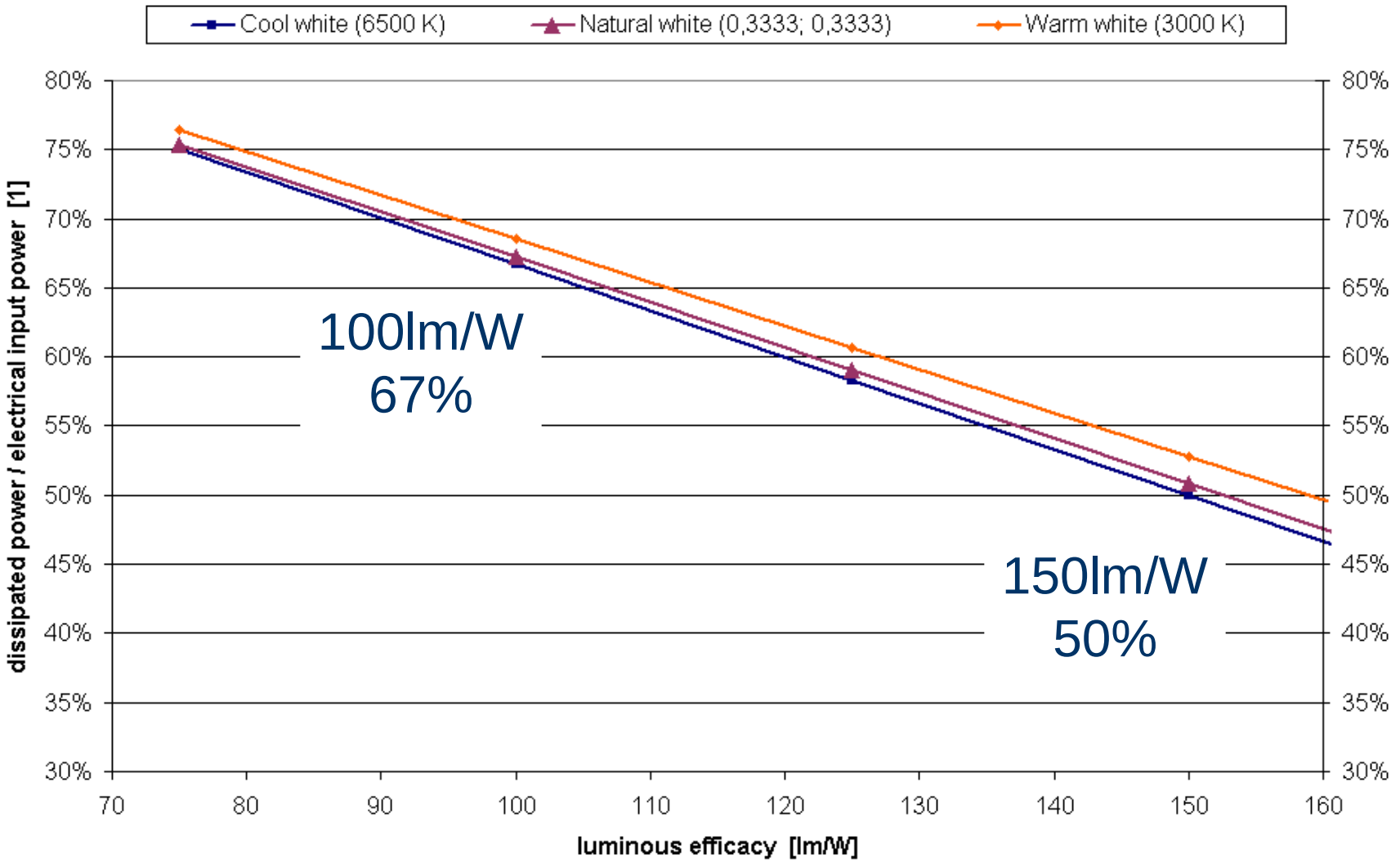
Where is the LED today?

Efficiency of PowerLED beat fluorescent lamps



Opto Semiconductors OSRAM

Dissipated power via luminous efficacy



Modern LED Packages and their Applications

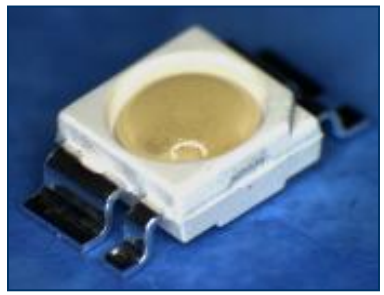
Table of Contents:

- Overview about OSRAM OS products and technologies
- Importance of Chip Technology
- Overview about power products and applications fields
- Thermal considerations

Premolded Power LEDs

GD oval Plus*

Advanced PowerTOPLED



APT+

Golden Dragon®+

Important features:

- Low Rth
- high efficiency
- Long lifetime

OSLON – Product family for a wide field of applications

Optics included:

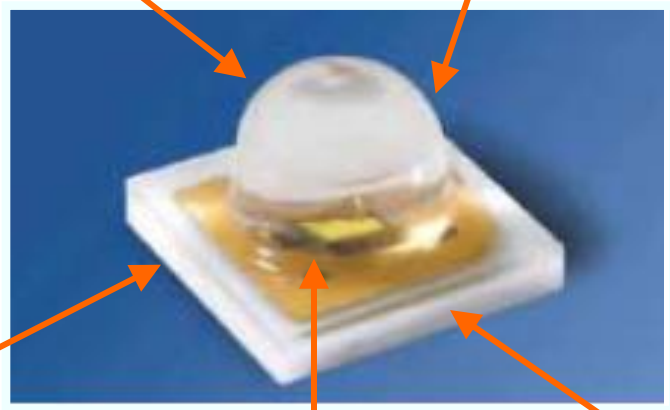
smaller secondary optics

Long lifetime due to materials:

silicone ceramics

Compact size, small footprint:

high packing density, easy for clustering, flexibility for different designs



Different colors and white hues (3000K – 6500K)

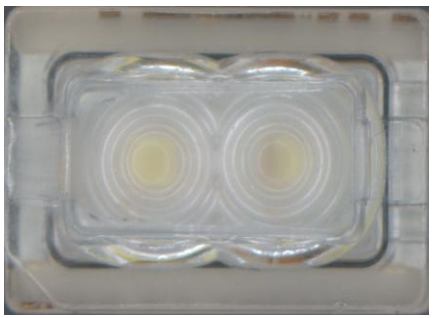
High efficiency

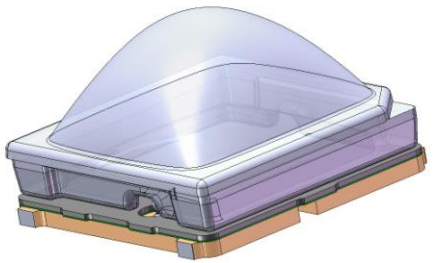
Electrically isolated heat slug

LED products for flash applications

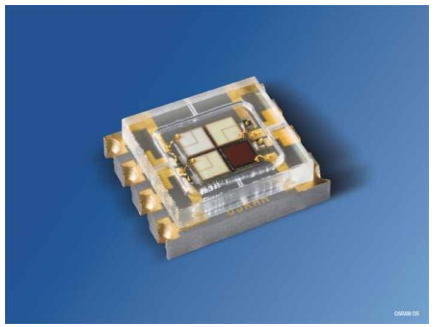
Ceramos Flash
Size: 1.65 x 2.1

OSLUX familiy – power LEDs with lenses



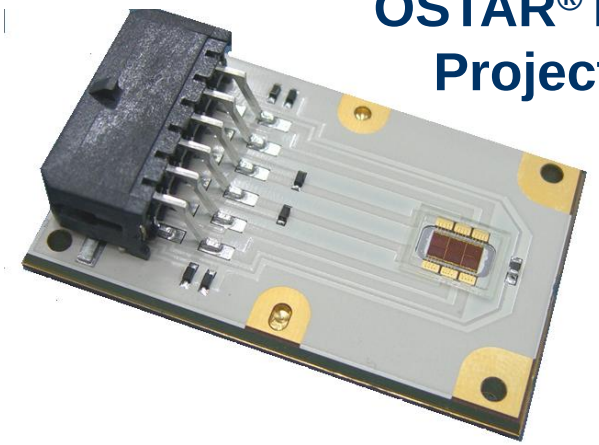


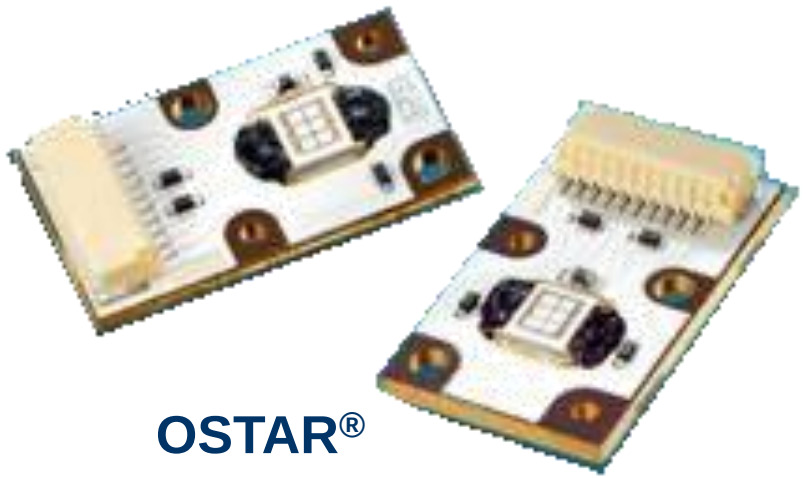
OSTAR - Projection



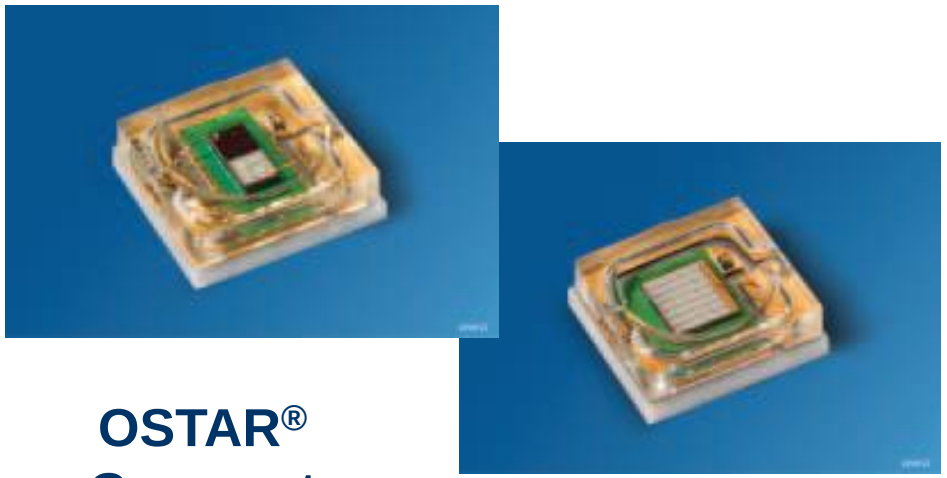
OSTAR® SMT

OSTAR® Power Projection





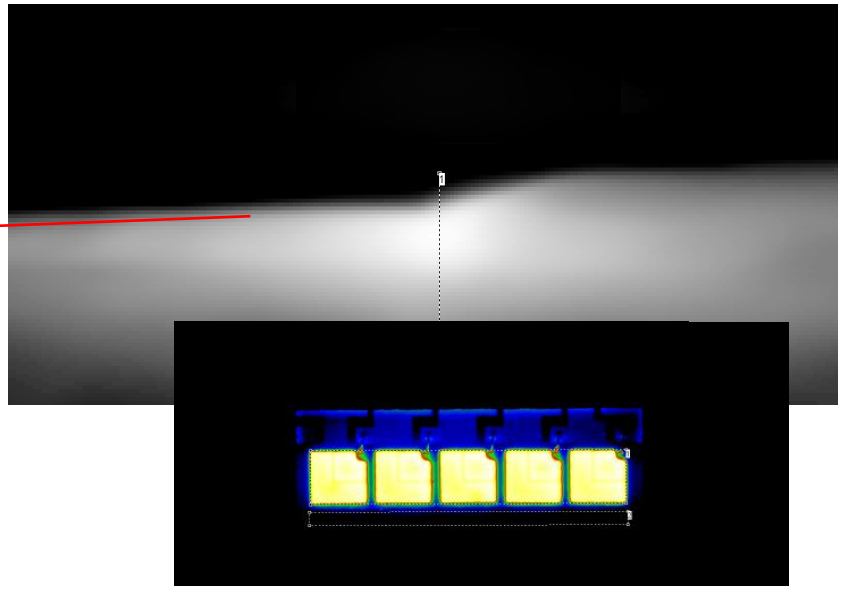
OSTAR® Projection

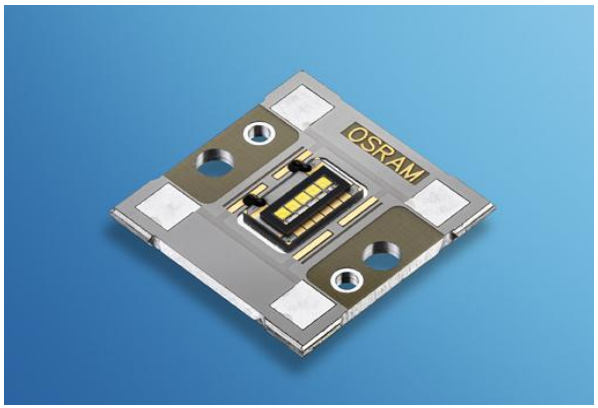


OSTAR® Compact

OSTAR Headlamp

- 1000 lm (1A / 5 Chip)
- 1-5 Chips design scalability
- Shutter feature
- High precision alignment feature
- ECE tailored color binning





Semiconductor Light for Automotive

Headlamp

Ambient lighting

HUD

Day time running light

2008

Interior

RCL & CHMSL

2003

Semiconductor Light for Visualization

Outdoor display

Personal projection
LED/Laser

traffic light

Photo camera
Flashlight

Visualization

LCD + Keypad
back light

Indoor video wall

Large area LCD backlights

Projection Solutions with LEDs

Professional projection

Business projection

embedded projection

Companion projection

Semiconductor Light for Illumination

Decorative Lighting

LED Street Lighting

General Lighting

Marker Lights

Corporate Lighting

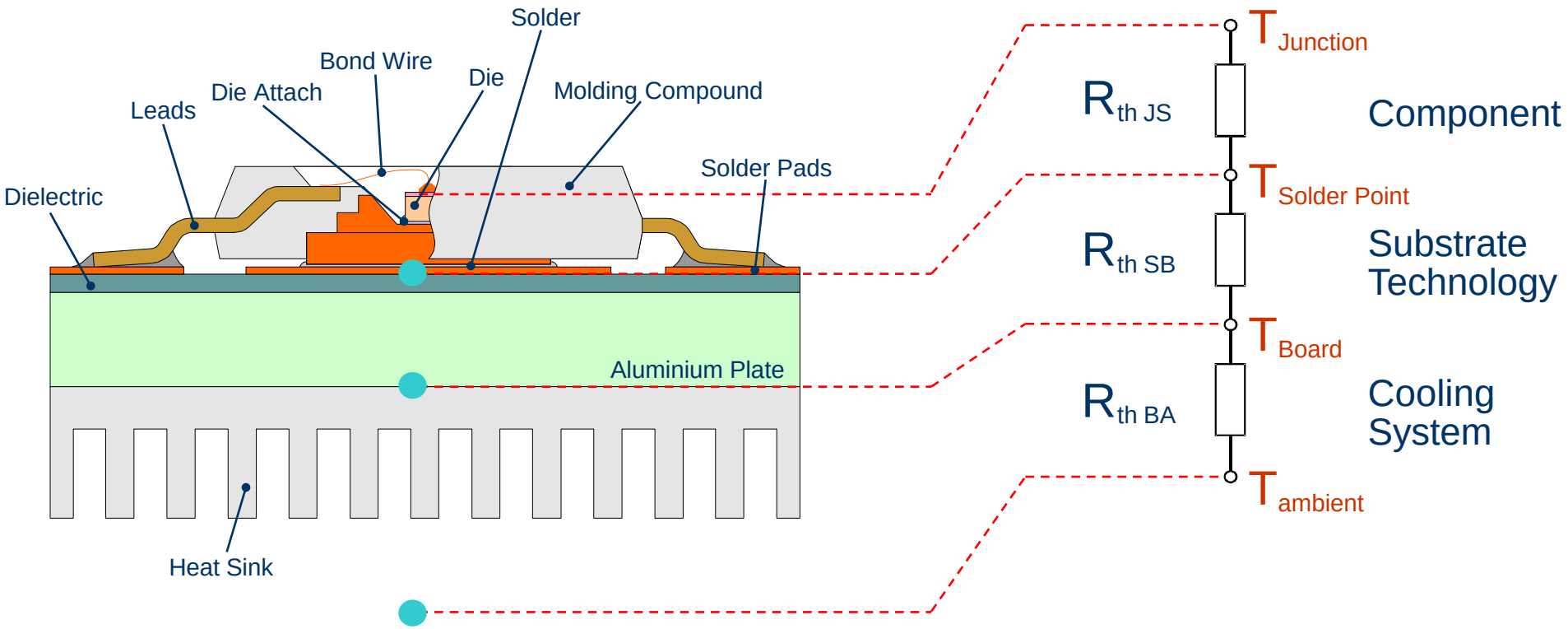
Architectural Lighting

Modern LED Packages and their Applications

Table of Contents:

- Overview about OSRAM OS products and technologies
- Importance of Chip Technology
- Overview about power products and applications fields
- Thermal considerations

LED Thermal System Configuration

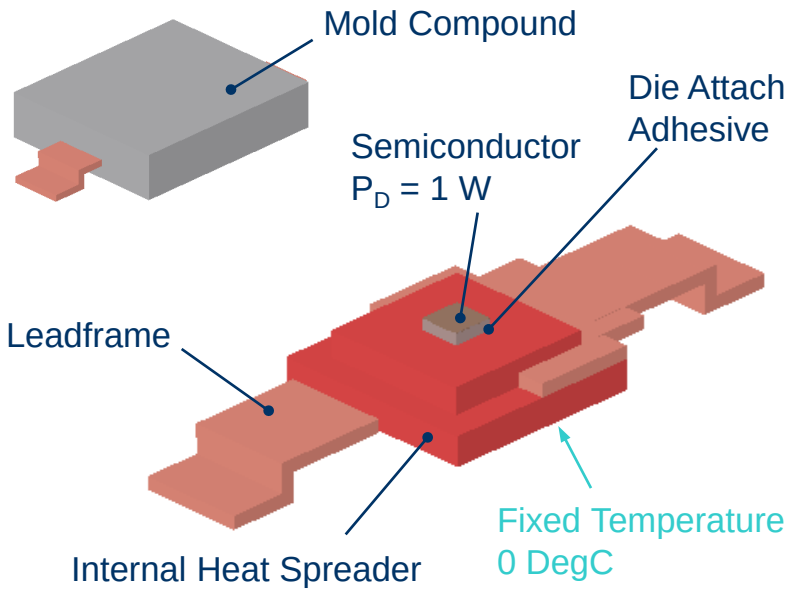


Thermal System Configuration

Thermal Resistor Network

Internal Thermal Resistance Rth $_{JS}$

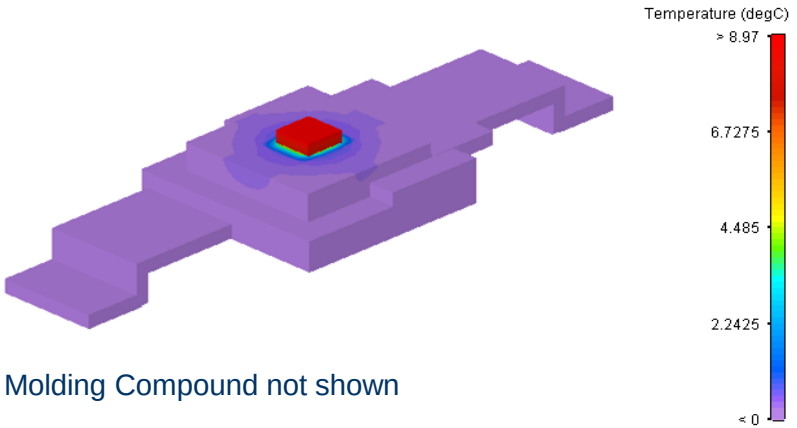
Thermal Model



- Fixed Temperature on all leads
- Power Dissipation P_D = 1 W
- Only heat conduction

Analysis Results

Temperature Distribution



Molding Compound not shown

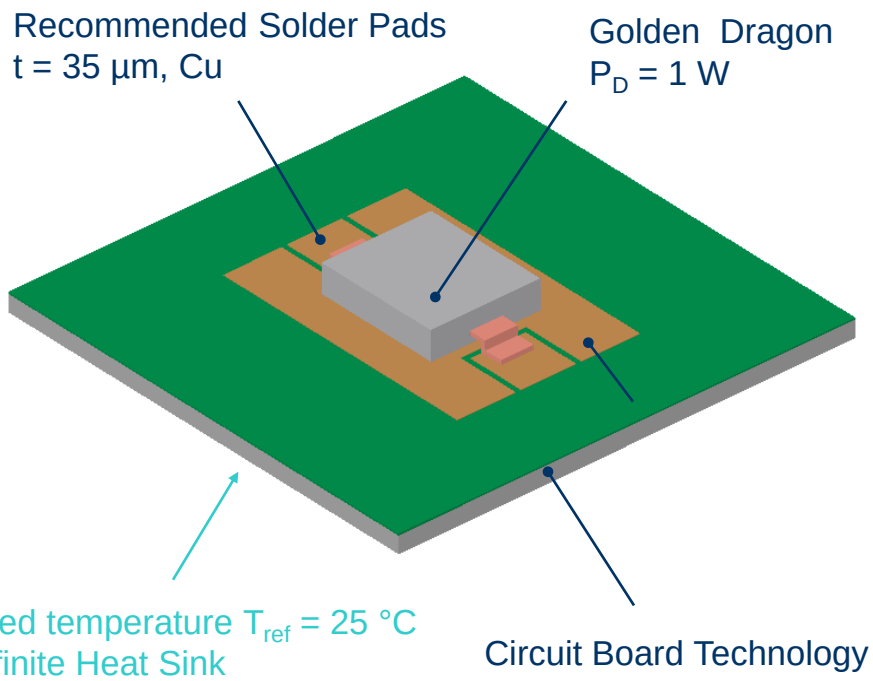
Thermal Resistance R_{thJS}

- max. T_J = 8.97 °C
- T_{leads} = 0 °C
- DT = 8.97 K
- P_D = 1 W

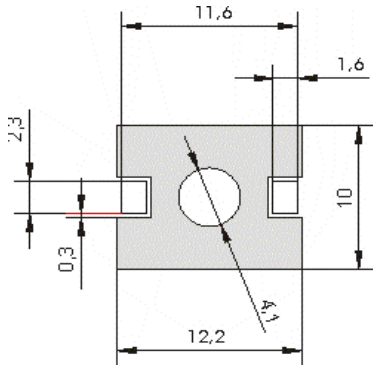
R_{thJS} = 9 K/W

External Thermal Resistance $R_{th\ SB}$

Analysis of different substrate technologies



Recommended
Solder Pad Design



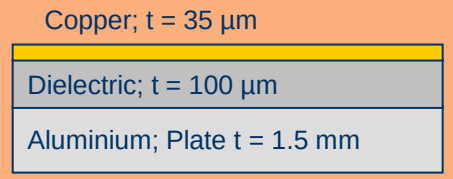
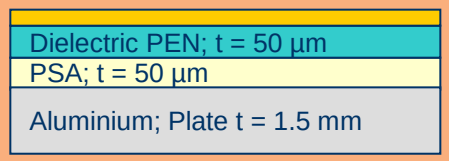
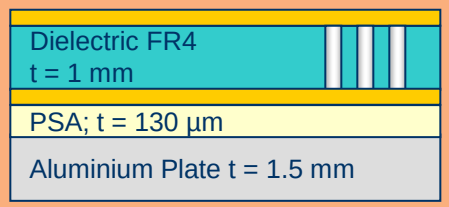
Golden Dragon

- Rth_{JS} = 9 K/W
- Power Dissipation P_D = 1 W
- PCB on cold plate (infinite heat sink)

Substrate Technologies

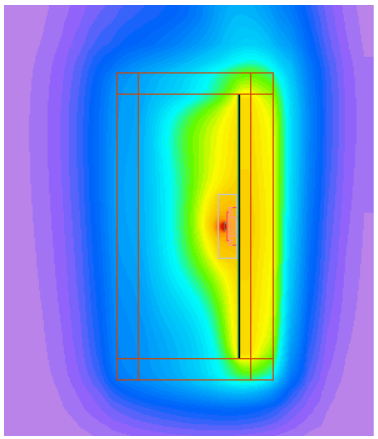
- Insulated Metal Substrate
- Flexible PCB on Aluminium
- FR4 on Aluminium

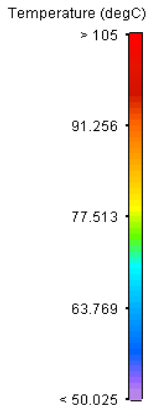
Thermal Resistance $R_{th\ SB}$ of Board Materials

Construction	Board Material	R_{thSB}
	IMS with thermal enhanced dielectric	**3.5 KW^{-1}**
	IMS with thin FR4 dielectric	**7.3 KW^{-1}**
	Flexible PCB on Al with standard PSA	**9.5 KW^{-1}**
	Flexible PCB on Al with enhanced PSA	**7.6 KW^{-1}**
	FR4 with standard PSA and thermal vias	**9.7 KW^{-1}**

External Thermal Resistance Rth_{BA}

Housing Material
Standard Plastic
$\lambda = 0.3\ Wm^{-1}K^{-1}$

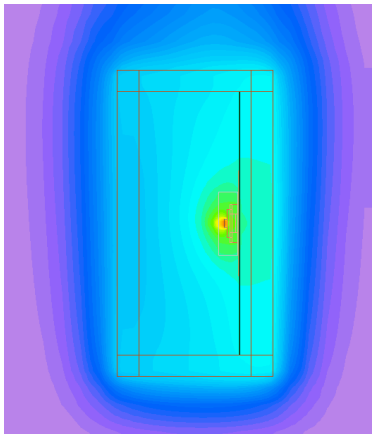




T_J = 103°C
$\Delta T = T_J - T_{amb} = 53°C$

- 19%

Housing Material
Thermal Enhanced Plastic
$\lambda = 8\ Wm^{-1}K^{-1}$



T_J = 93°C
$\Delta T = T_J - T_{amb} = 43°C$

Influencing Factors

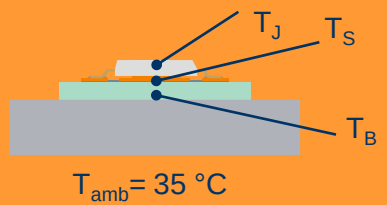
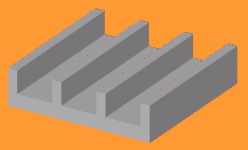
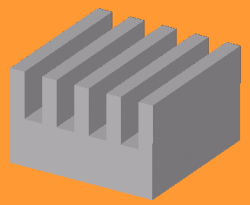
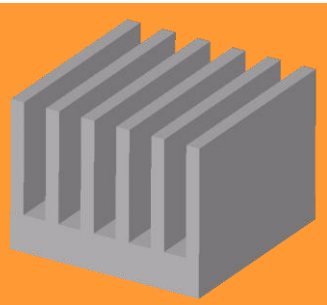
- Attachment of PCB to housing
- Housing material with high thermal conductivity
- Attachment of heat sink
- Active cooling (fan)

External Thermal Resistance R_{thBA}

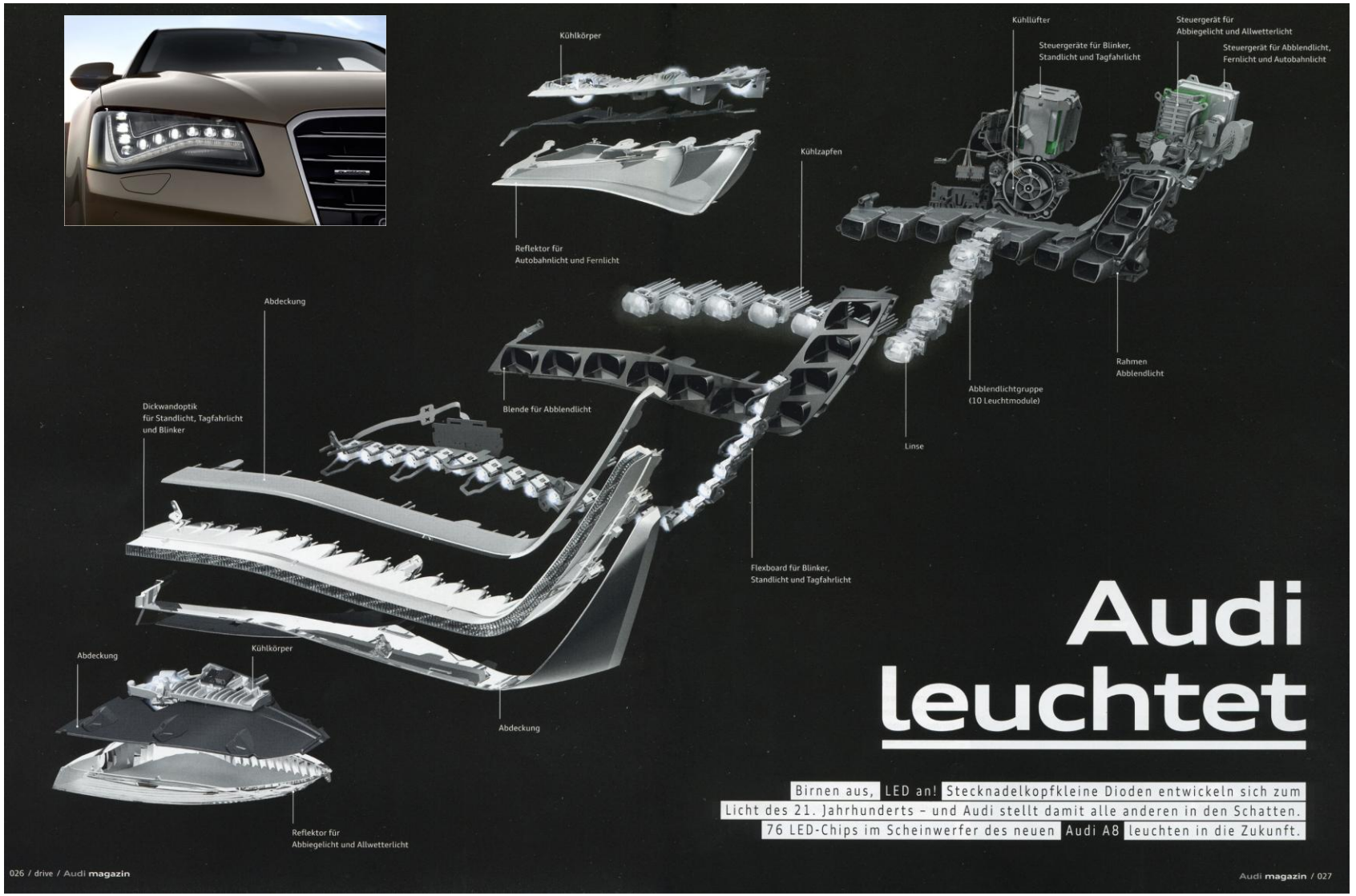
Characterize the heat transfer from the board to the environment.

External Thermal Resistance Rth_{BA}

Thermal Systems with LEDs on heat sinks

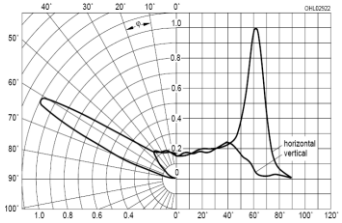
Reference Points:  T_{amb}= 35 °C Golden Gragon on IMS in free convection	 30 x 30 x 10 mm³	 30 x 30 x 20 mm³	 50 x 50 x 40 mm³
Junction Temperature T_J	**75 °C**	**67 °C**	**55 °C**
Solder Point Temperature T_S	**66 °C**	**58 °C**	**46 °C**
Board Temperature T_B	**63 °C**	**55 °C**	**43 °C**
Thermal Resistance Rth_{BA}	**28 K/W**	**20 K/W**	**8 K/W**
Thermal Resistance Rth_{JA}	**40 K/W**	**32 K/W**	**20 K/W**

LED Headlamp – System Assembly

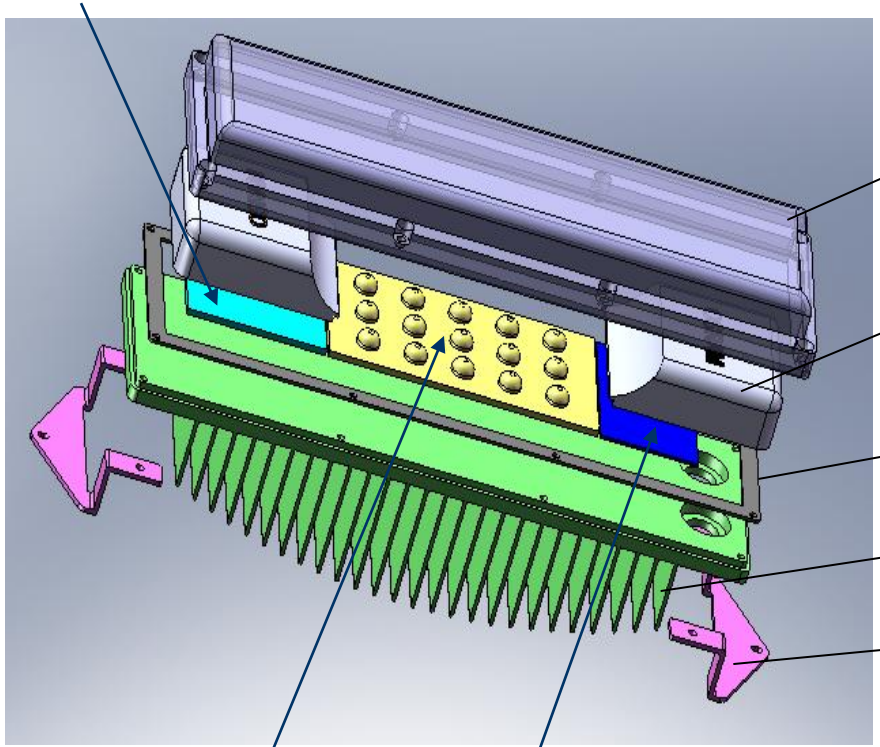


Source: Audi magazin

LED Street lighting possibilities

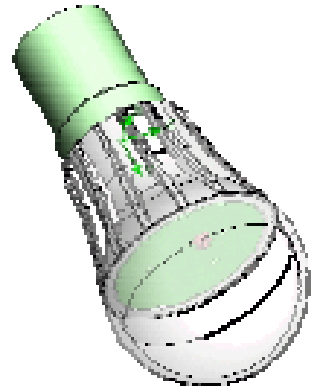


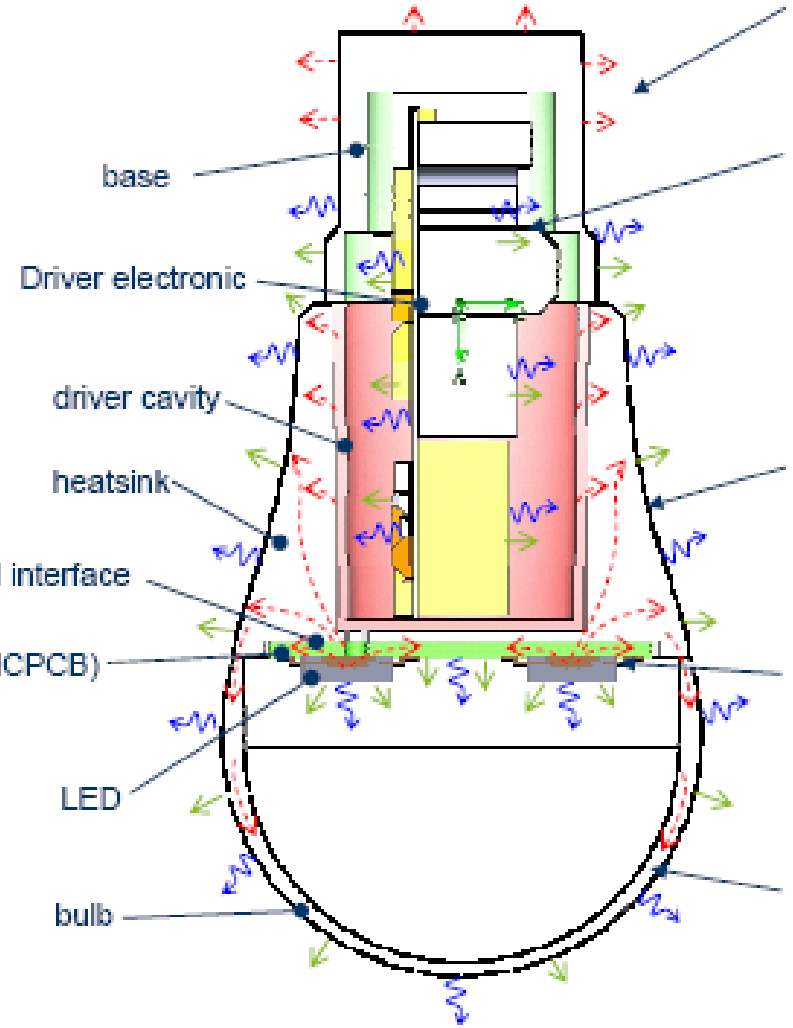
Oval Dragon:
Perfect light shape for street lamp.
No need of secondary optical design



Source: Audi magazin

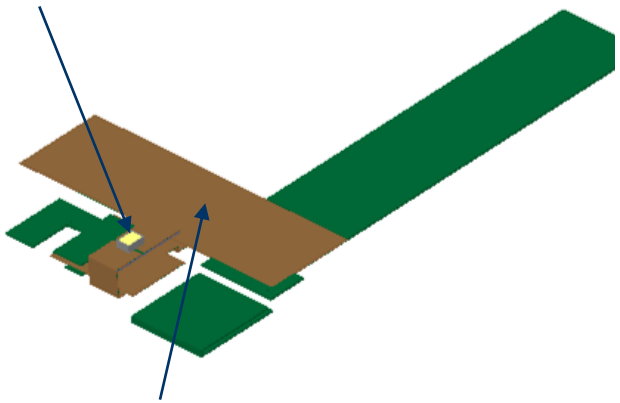
LED Retrofit – schematic assembly and thermal paths





Thermal consideration: Flashlight Concept on flexible PCB

Ceramos flash

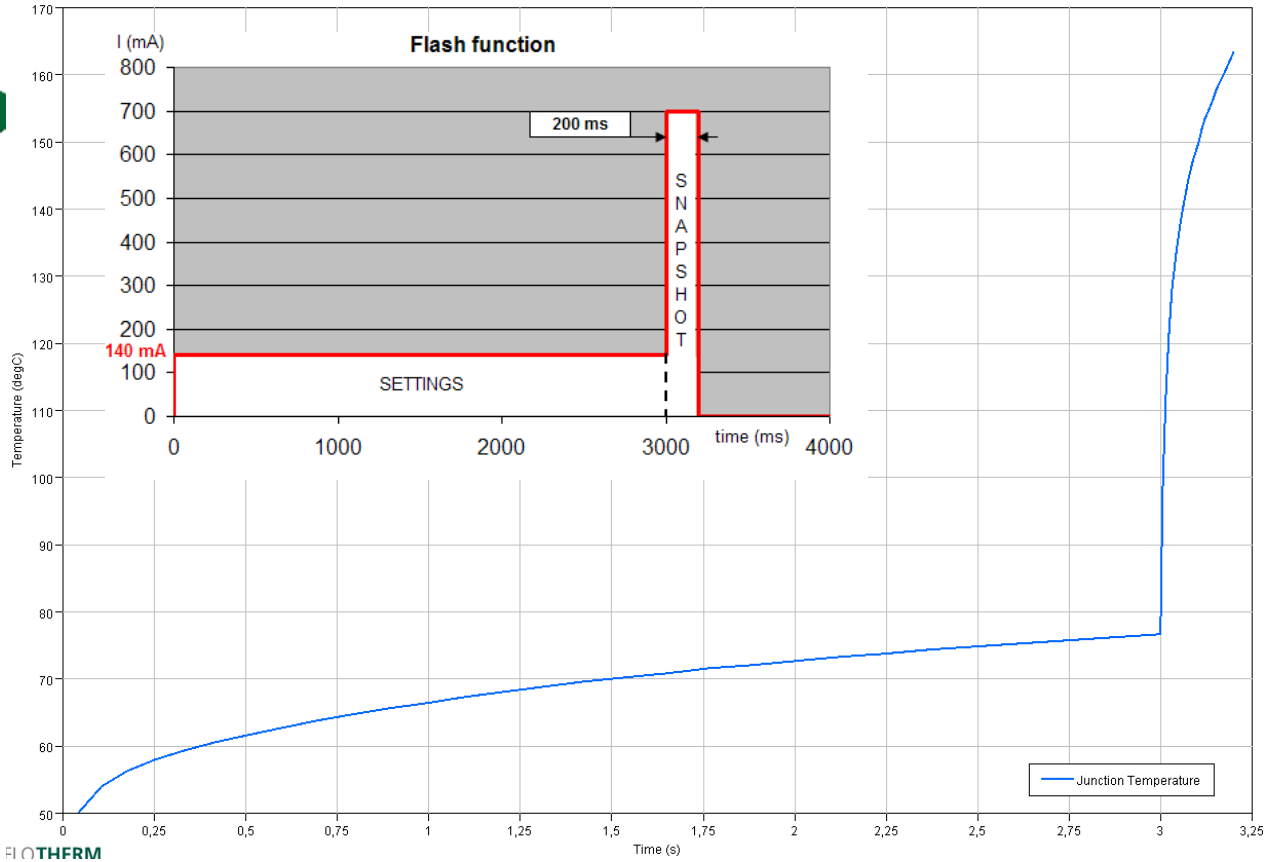


Flex PCB (Cu layer)

Power Dissipation (based on typical forward voltage)

typ. V_F (700mA) = 3.6 V

-> max. P_D = 2.52 W



- I = 700 mA: max. T_J (3.2s = 200ms) = **163 °C** @ T_{amb} = 40 °C

Source: Audi magazin

Thank you for your attention

join us @ www.osram-os.com