Thermal Design for High Light Flux LED Products

Brandon Noska
Applications Engineer - Bridgelux

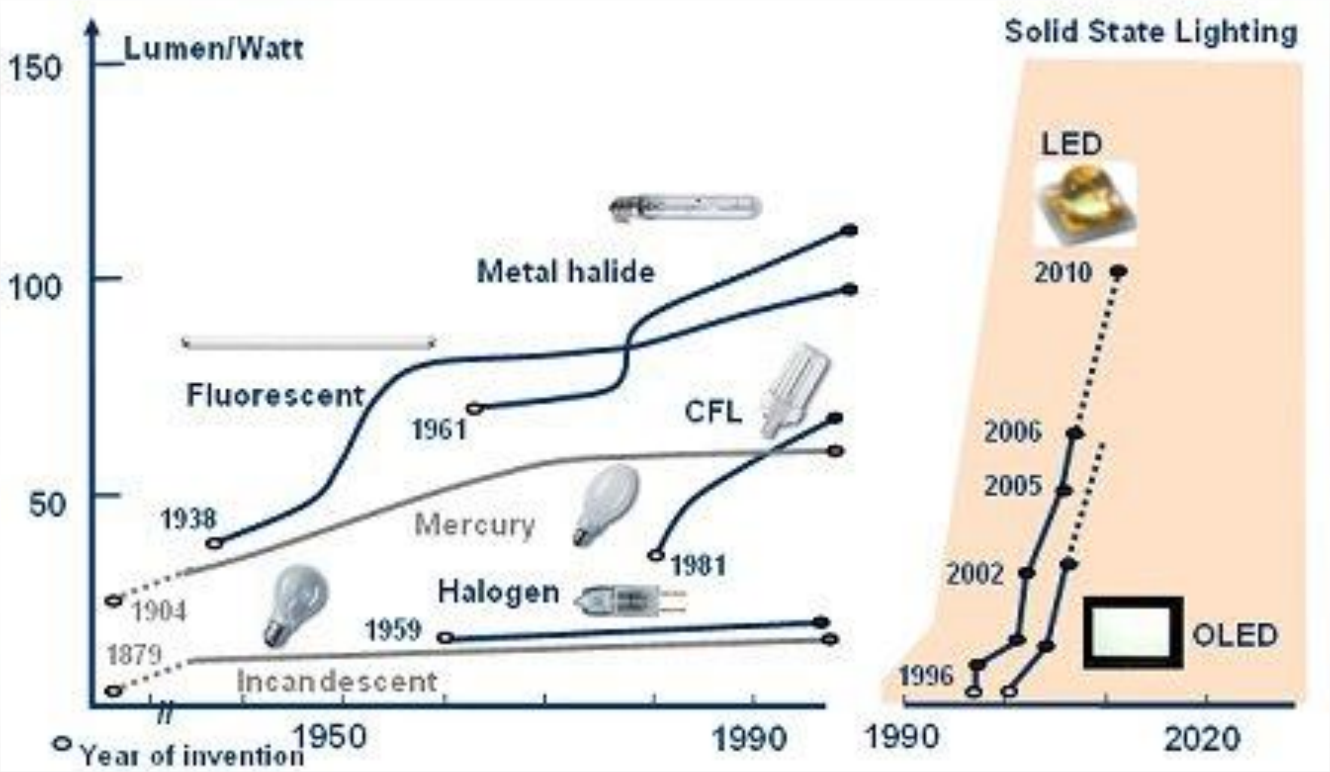
“Heat is On” - MEPTEC March 2012

LED Efficacy and Efficiency

	15th	19th	20th century...		
		GL	FL	HID	LED
Efficacy lm/W	1	10 – 15	70 – 104	70 – 100	Target: >> 100
Efficiency (rel.)	<1%	5 – 9%	25 – 30%	30 – 35%	Target: 30 – 50%

Source for chart images
http://www.osram.com

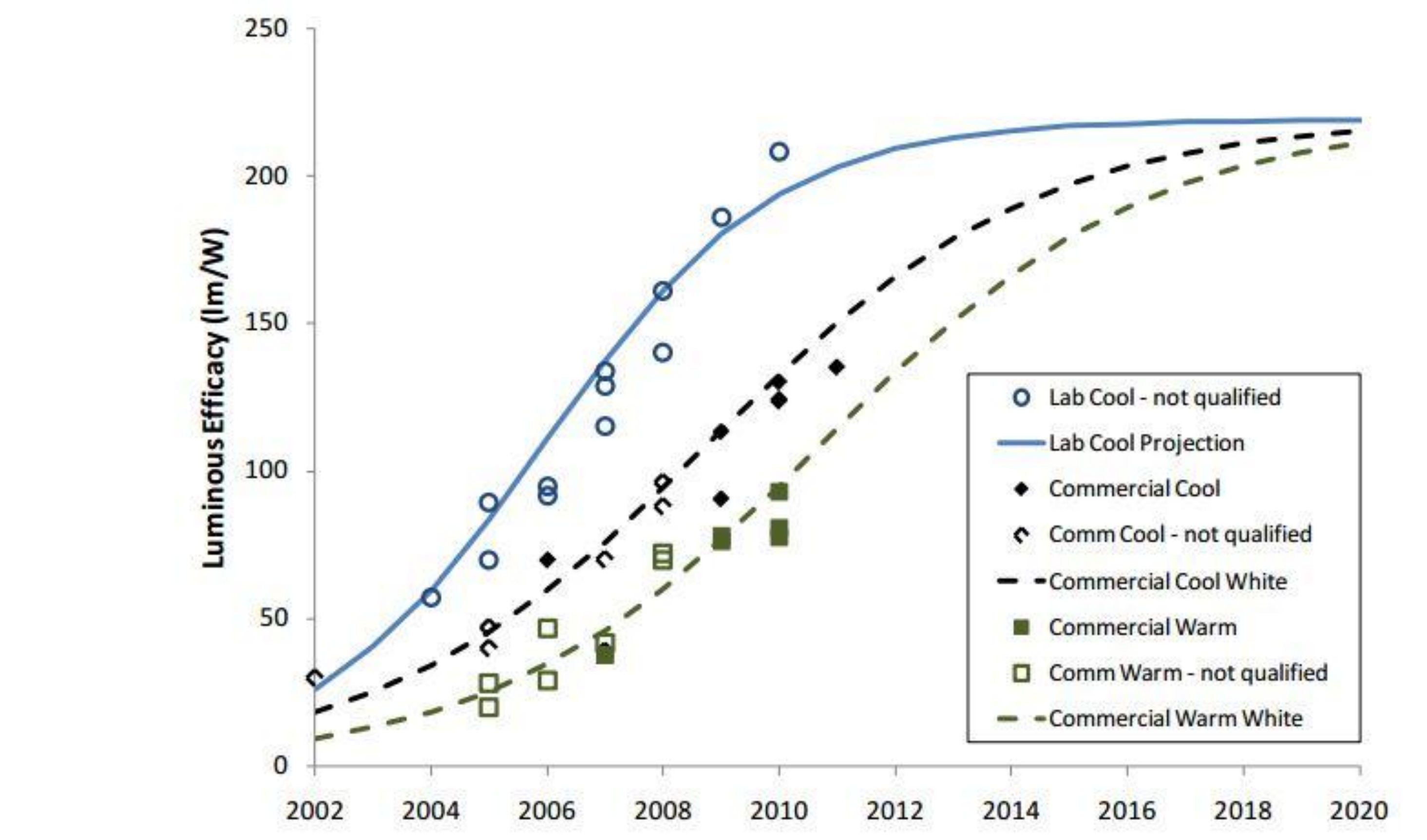
Traditional Source vs. HB LED



HB LEDs have already advanced beyond traditional light sources in efficacy and are still improving at significant rates!

Source for chart images
http://www.osram.com

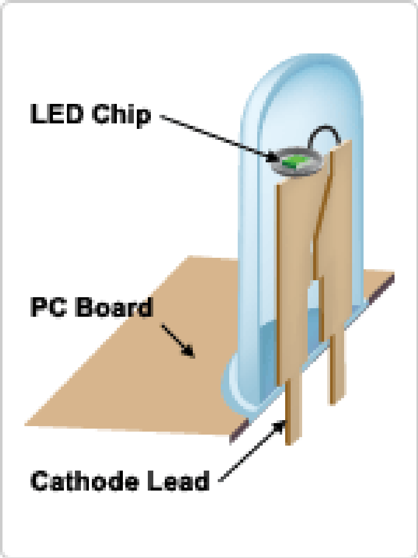
DOE LED Efficacy Roadmap



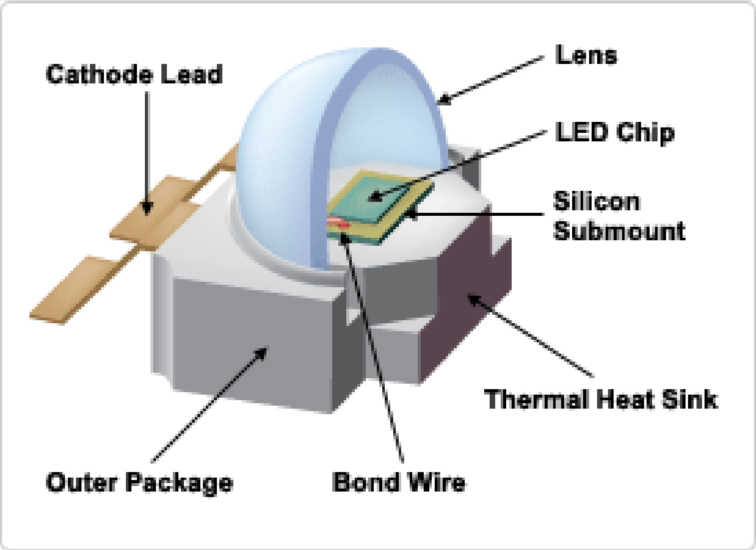
Source: 2011 MYPP

Source Efficacy is in the range of 100 to 120 lm/W
System Efficacy is in the range of 70 to 100 lm/W

LED Packaging Progression

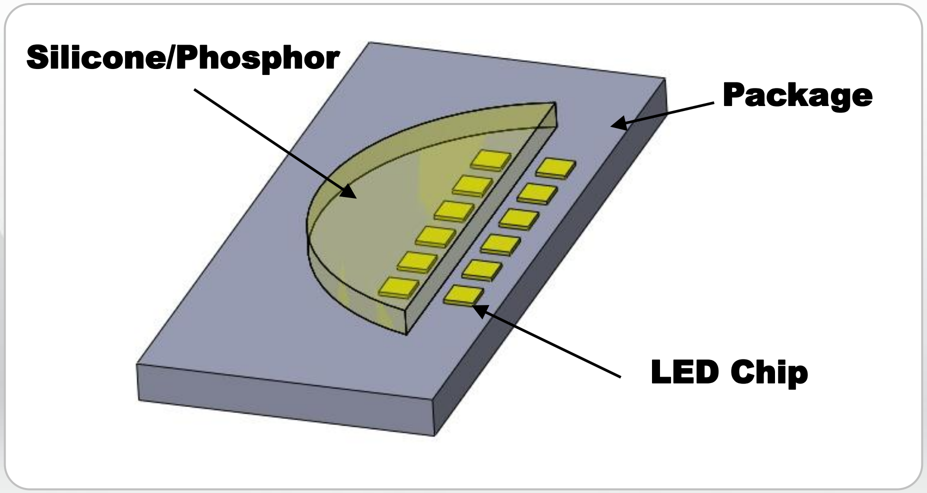


Low power



Medium power single or multi-chip emitters

Source for emitter images
http://www1.eere.energy.gov/buildings/ssl/index.h



High power multi-chip array, usually COB packaging

Examples of Array Products in Market

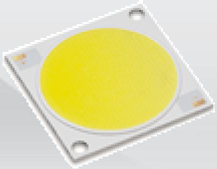
Bridgelux ES & RS

~ 800 to >9000 lm
~ 10 W to 85W

Philips Fortimo LED

~ 800 to 6000 lm
~ 10 W to 49W

Citizen CLL020 – CLL050



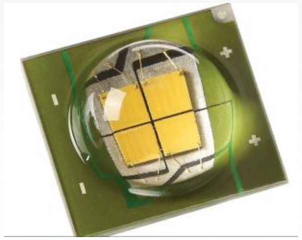
~ 800 to >15000 lm
~10 W to 200W

Source for images and product information from company websites
Complete product information is not included and only presented for referenc
http://bridgelux.com/products/ledarray.html
http://www.lighting.philips.co.uk
http://ce.citizen.co.jp/lighting_led/en/index.html

BRIDGELUX

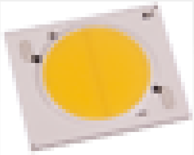
Examples of Array Products in Market

Luminus SSM-80 & CSM-360



1000 to 6000 lm
10W to 90W

Sharp Zenigata & Mega Zenigata



2000 to >6000 lm
25W to 80W

Edison Opto Edipower II

4000 to >9000 lm
50W to 120W

Source for images and product information from company websites
Complete product information is not included and only presented for reference
http://www.luminus.com/products/index.html
http://www.edison-opto.com.tw/06_list_detail.asp?sn=90
http://www.sharpleds.com/ledfamily.html

Why a Concentrated Source is Better?

- Better optical control
- More light uniformity
- Integrated single package is better for manufacturing
- No issues with color consistency variation within a bin of emitters for the same fixture
- Arrays can be tailored to the traditional light source they are replacing

High Flux Applications

- Spot Lighting
  - Aesthetically pleasing (no exposed fins)
  - Lightweight
  - Tight beam angles

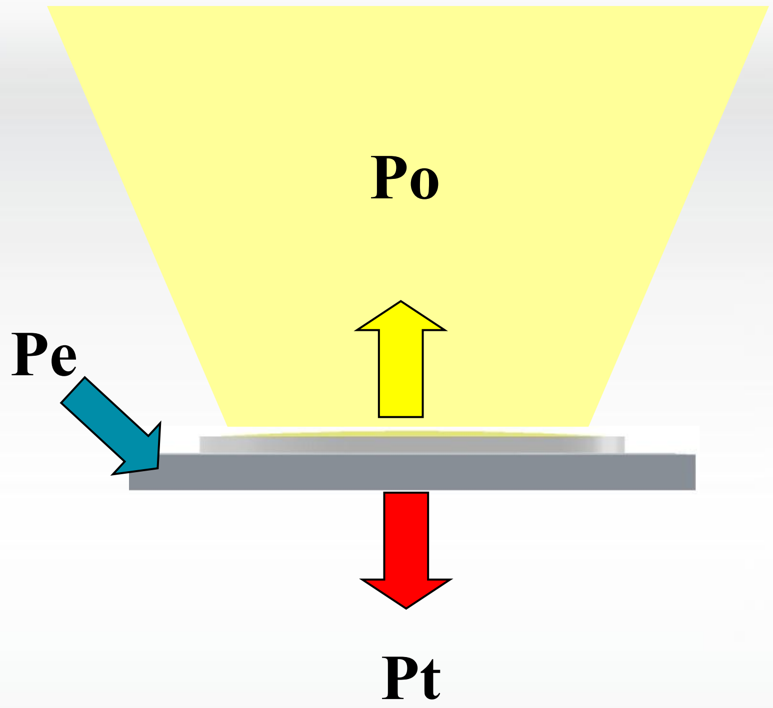
- Low Bay/High Bay
  - Lighter weight is preferred
  - Low maintenance costs
  - High Lux (Light at surface) from high ceiling

- Outdoor Lighting
  - Maximum weight limits
  - Specific lighting patterns on surface
  - Survivability for outdoor environments

Typical Thermal Requirements

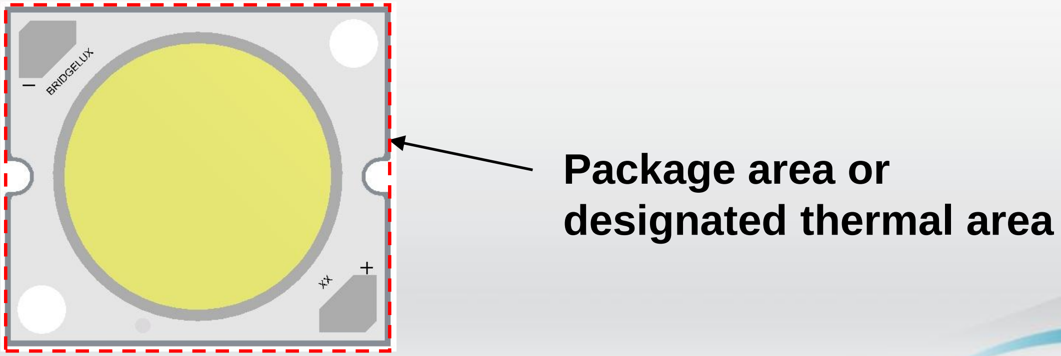
- Pt = εPe, where

  Pt = thermal power
  Pe = electrical power to LED array
  Po = Radiant power
  ε = 1-Po/Pe



- ε = ranges from 70% to 85% depending on CCT for phosphor converted arrays

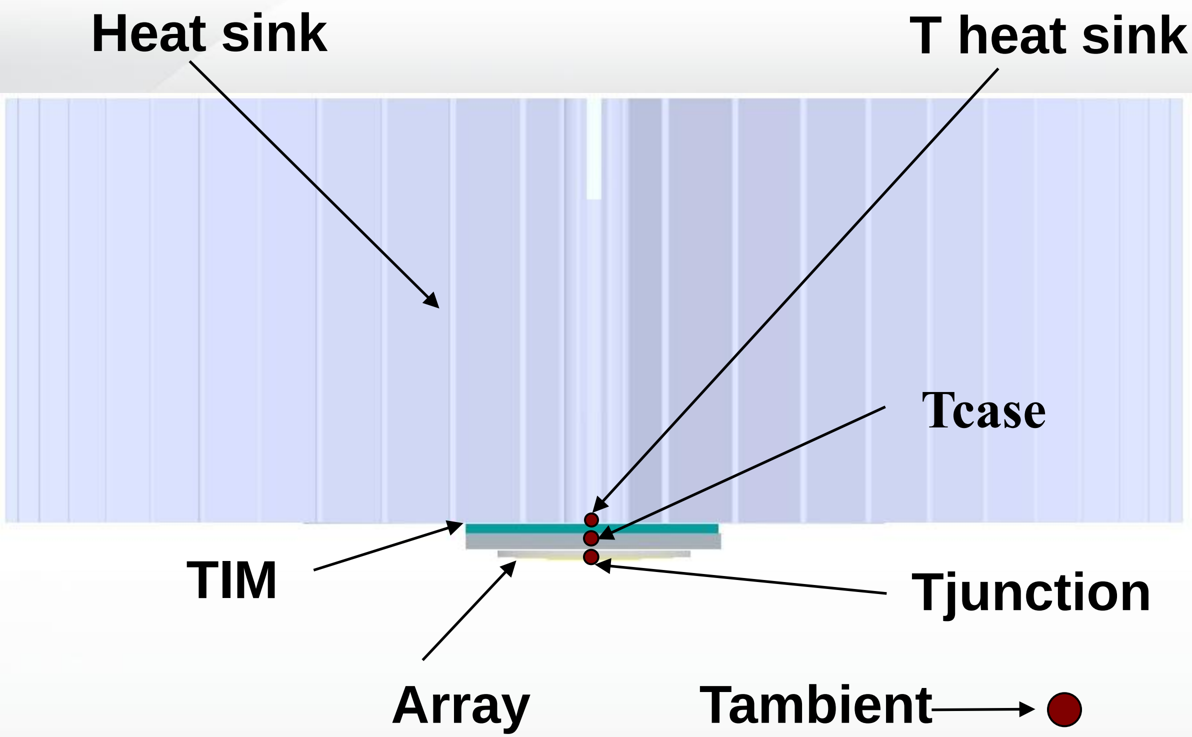
- q” = Pt/package area

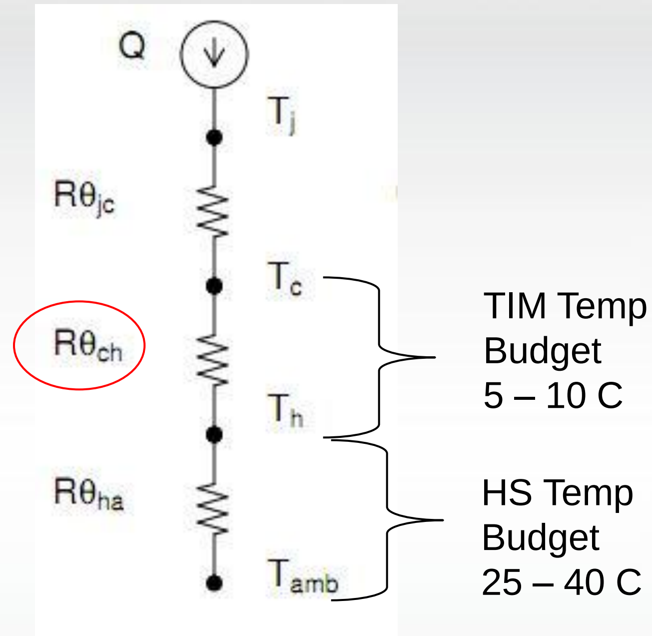


Array Heat Flux is a Challenge

- Higher flux means higher power
  - Better cooling performance is needed
- Small source means higher heat flux
  - Spreading resistance can be 20% to 50% of the total thermal resistance
- Package heat flux ranges from 2 W/cm^2 to 15 W/cm^2
  - Increasing with need for higher flux out of the same package or reducing package sizes

Typical Thermal Requirements





Although most published maximum operating junction temperatures are 150 C, the case temperature requirements for good efficacy and lifetime or on the order of 70 C to 85 C.

Pt, W	Rsa, C/W
60W to 80W	0.2
	0.6
30W to 40W	0.8
	1.5

Typical Heat Sink Volumetric Resistance

Typical Heat Sink Volumetric Thermal Resistances

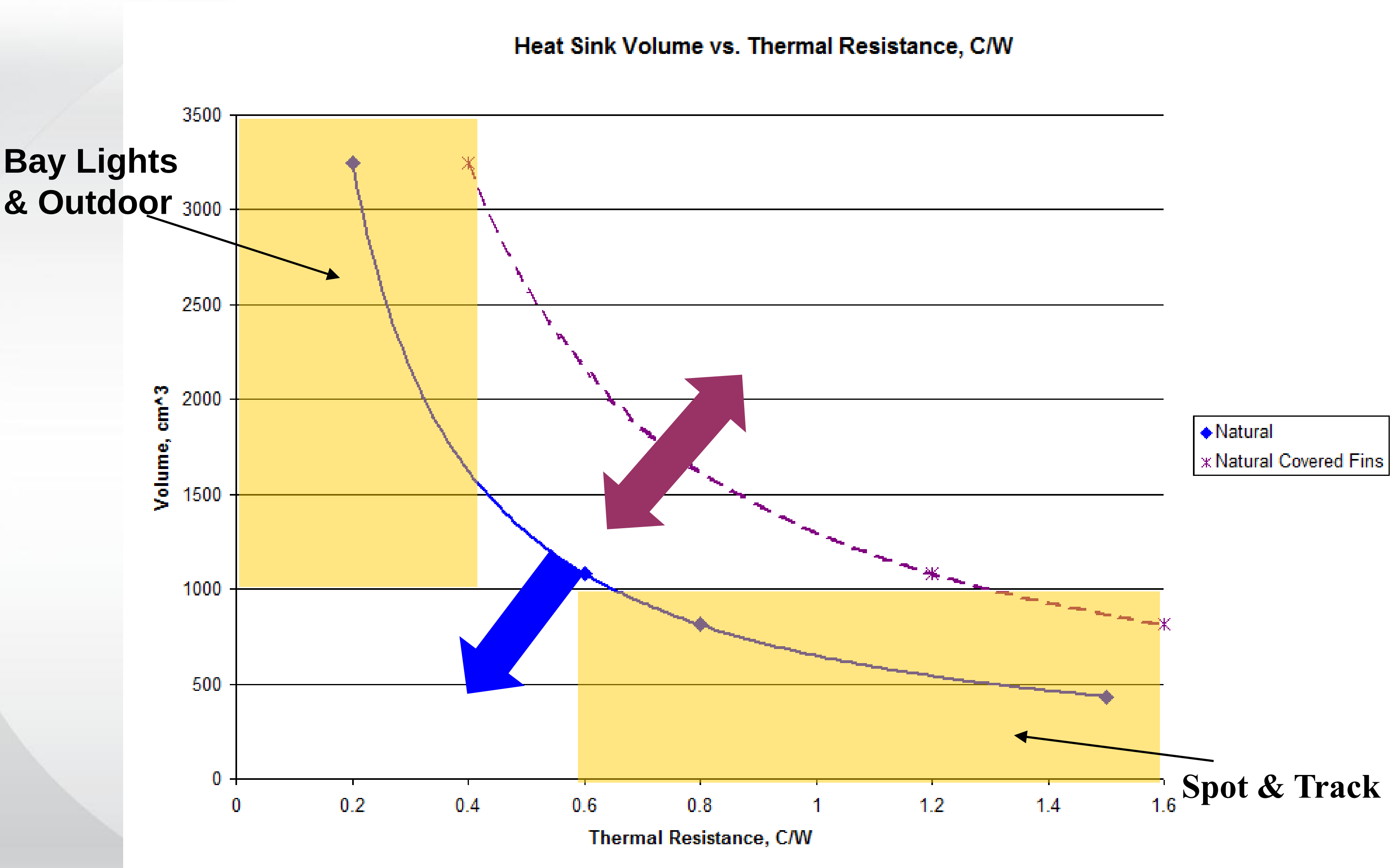
	Flow condition m/s (lfm)	Volumetric Resistance cm3 °C/W (in3 °C/W)	
	natural convection	500-800	(30-50)
Slow	1.0 (200)	150-250	(10-15)
Medium	2.5 (500)	80-150	(5-10)
Fast	5.0 (1000)	50-80	(3-5)
	Table 2: Range of volumetricthermal resistance		

Source:
Seri Lee http://www.electronics-cooling.com/1995/06/how-to-select-a-heat-sink/

Heat Sink Volume, cm^3					
Pt, W	**Rsa, C/W**	***Natural***	***Forced Slow***	***Forced Medium***	***Forced Fast***
60W to 80W	0.2	3250	1000	575	325
	0.6	1083	333	192	108
30W to 40W	0.8	813	250	144	81
	1.5	433	133	77	43

BRIDGELUX

Natural Convection vs. Application Requirements



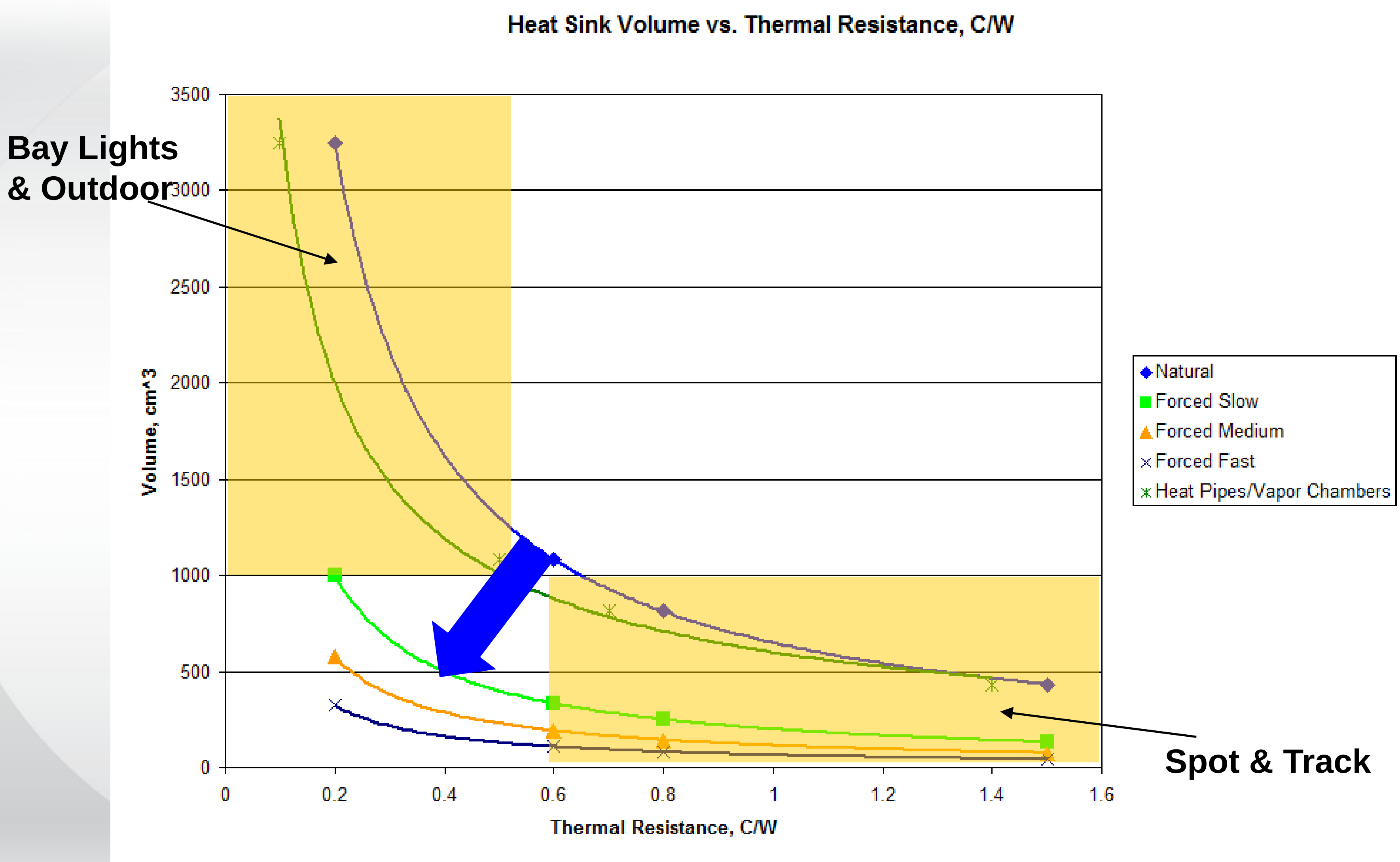
Technologies to Reduce Volumetric Resistance, Weight, & Size

- 2 phase technologies
  - Heat pipes & vapor chambers
    - Reduce spreading resistances and conduction losses
    - Lower weight due to less material used

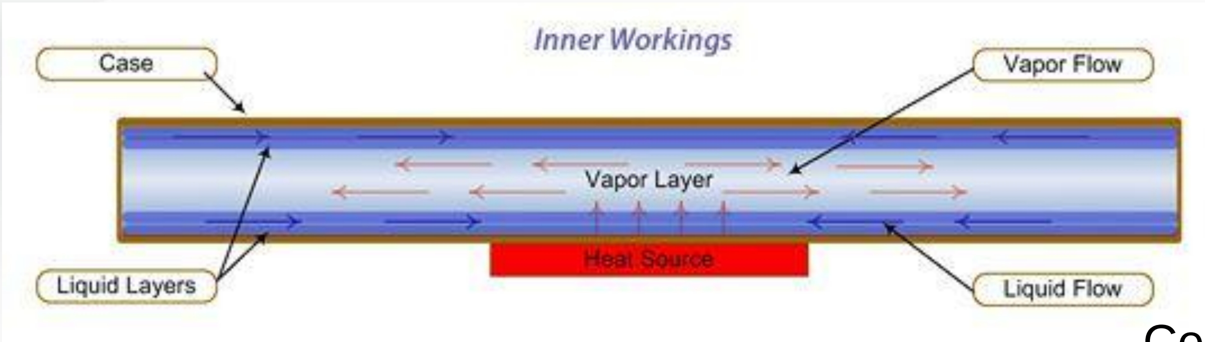
- Forced Convection
  - Synthetic jets and fans
    - Reduce surface area and volume
    - Lower weight due to less material used
    - Less orientation dependence

BRIDGELUX

Natural Convection vs. Application Requirements



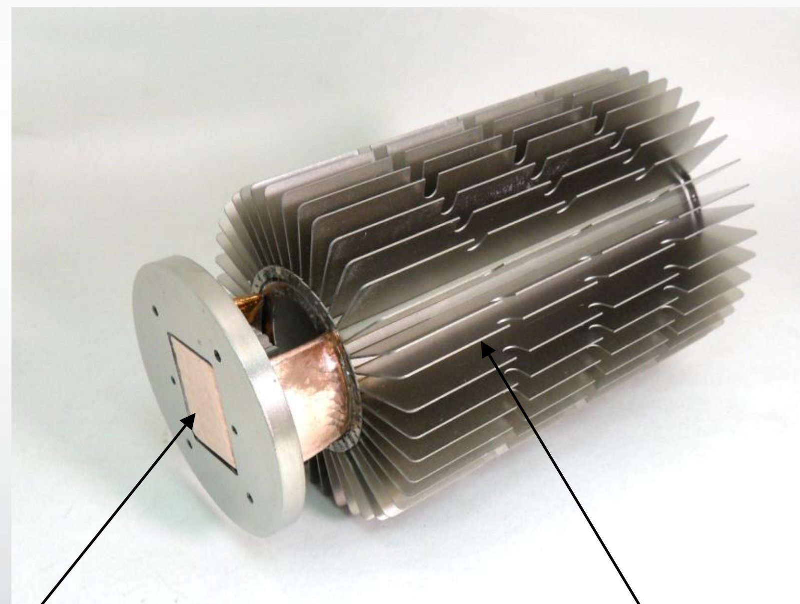
Two Phase Technology - Nanospreader™



Source
http://www.celsiatech.com/nanospreader_technology.asp

- Volume ~ 950 cm^3
- Rsa = 0.8 C/W
- Volume Resistance = 760 cm^3 C/W
- 33% lower volume resistance than comparable extrusion solution
- 60% less mass than comparable extrusion solution

Celsia HA021-W3500



Two Phase Technology – Heat Pipe

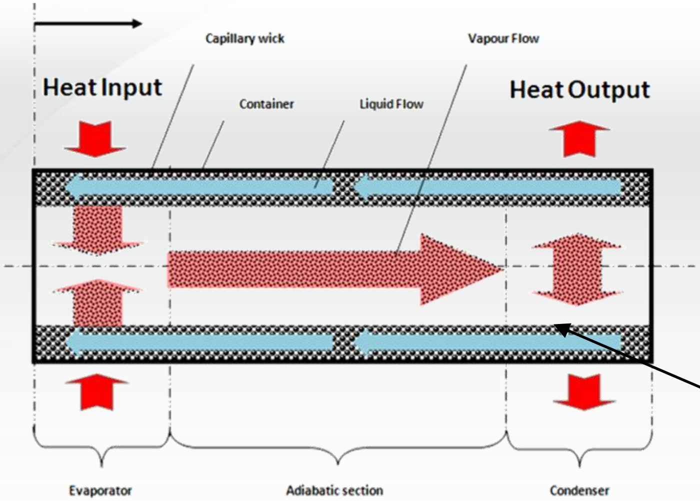
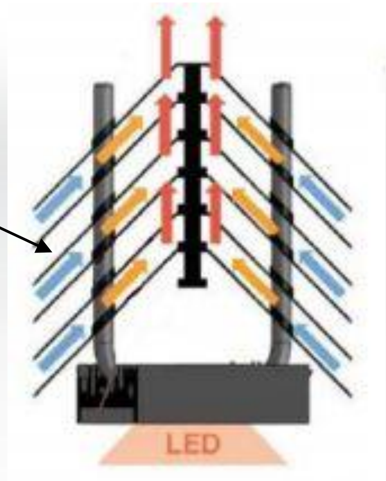


Figure 1: Operational principle of a 2-Phase heat transfer device (FrigoDynamics®)

Source
http://www.frigodynamics.com/

Unique fin design



Heat pipes for moving heat from source to fins

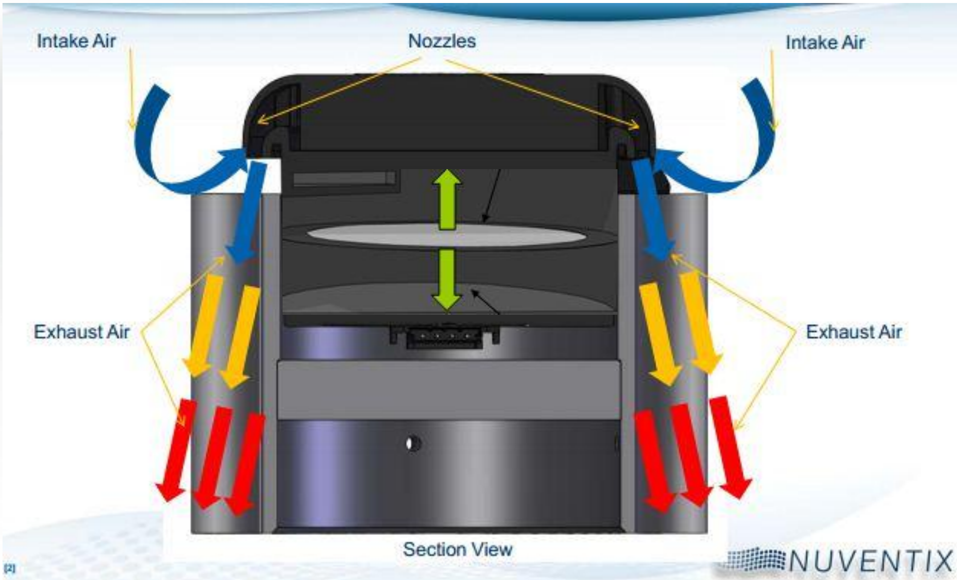
Frigodynamics© HPK Fin™-230

Less material used

- Volume ~ 1660 cm^3
- Rsa = 0.54 C/W
- Volume Resistance = 896 cm^3 C/W
- 22% lower volume resistance than comparable extrusion solution
- 70% less mass than comparable extrusion solution

Carries heat directly to fins

Forced Convection – Synthetic Jet



Source
http://www.nuventix.com

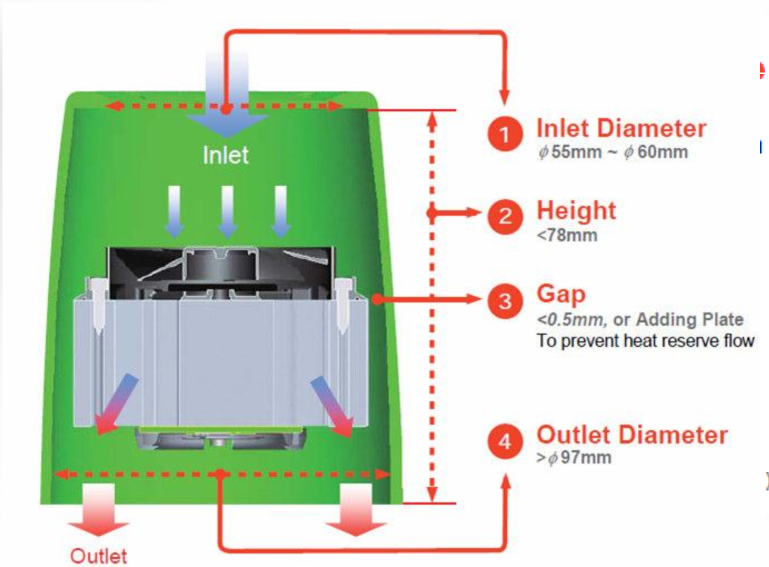
- Volume ~ 817 cm^3
- Rsa = 0.55 C/W
- Volume Resistance = 450 cm^3 C/W
- 61% lower volume resistance than comparable extrusion solution
- 54% less mass than comparable extrusion solution

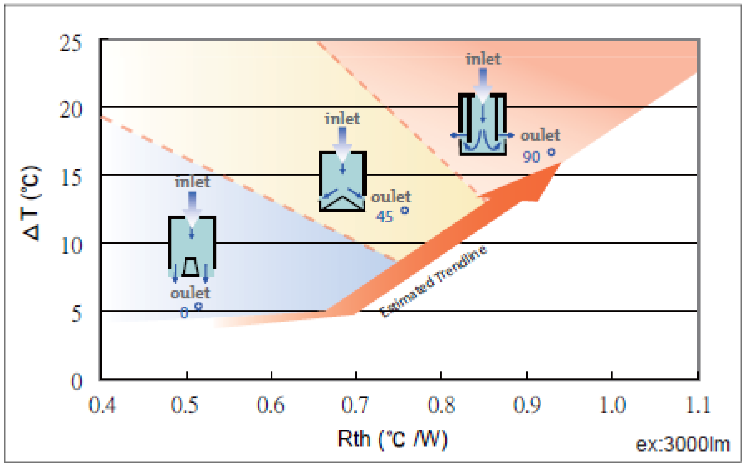
SynJet Spot Cooler 70W

Compact Design

Integrated SynJet

Forced Convection – Sunon LED Cooler

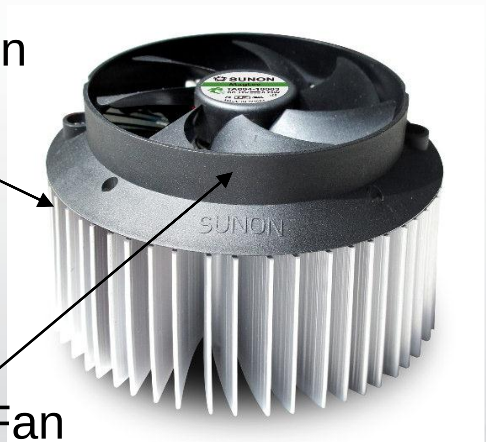




Source
http://www.sunon.com

- Volume ~ 304 cm^3
- Rsa = 0.52 C/W
- Volume Resistance = 158 cm^3 C/W
- 82% lower volume resistance than comparable extrusion solution
- 82% less mass than comparable extrusion solution

Sunon TA004-10003



BRIDGELUX

Summary

- LED efficacy has seen significant improvement over last 10 -15 yrs
- Packaging has progressed from low technology low power to high power high flux COB or multi chip/ multi emitter arrays
- There are many examples of high light flux arrays in the market due to their inherent design advantages
- The concentration of heat is difficult to manage given other design constraints on size and weight
- Higher performance cooling technologies are needed to keep designs functional and within the geometric and form factor requirements
- There are solutions utilizing technologies such as thin vapor chambers, synthetic jets, heat pipes, and fans that can enable lighting designers to meet form, fit, and function requirements for applications where space and weight are of a concern

BRIDGELUX

Q&A

Thank You

BRIDGELUX®

The Magic of Light®

Thank you