Thermal Design Guide V2.3

Fortimo LED SLM platform

PHILIPS
sense and simplicity

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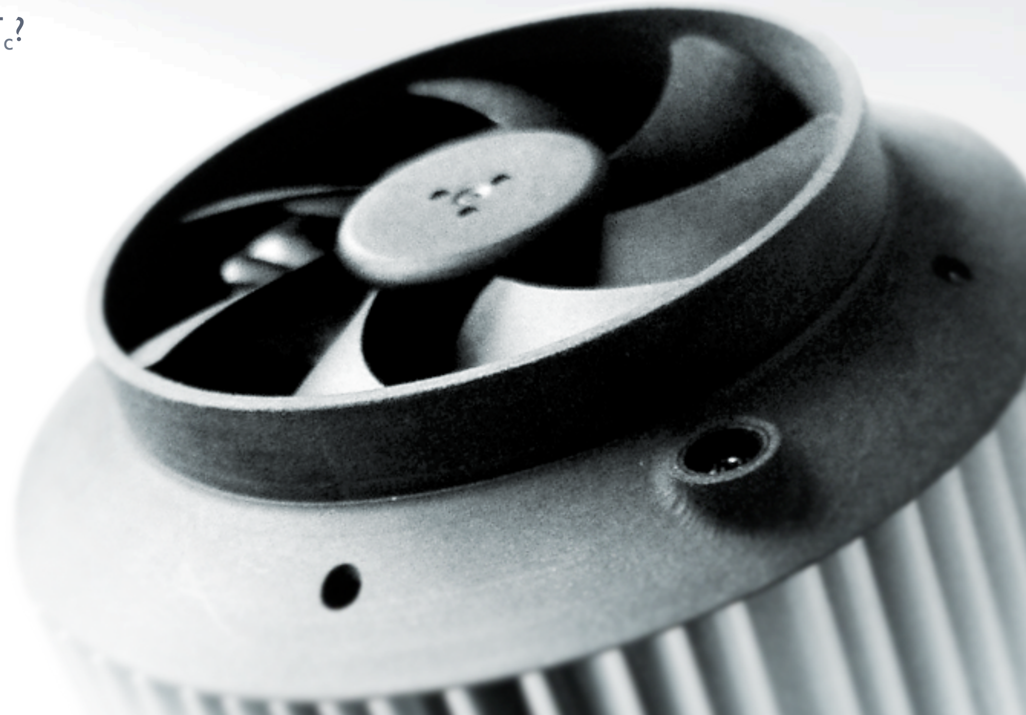
- Complementary partners for thermal solutions (passive/ active)



Thermal specifications Fortimo SLM platform

Fortimo SLM Platform	800 Lm	1100 Lm	1500 Lm	2000 Lm	3000 Lm	Lexel TW	Lexel RGB
Electrical power (typical)	11 W	17 W	20 W	32 W	43 W	22 W	25 W
Dissipated thermal power (typical)	9 W	14 W	17 W	27 W	36 W	18 W	20 W
Max. T_{case} of module	←			65 °C			→
Max. ambient temperature	←			35 °C			→
Thermal impedance requirement T_{case} to $T_{ambient}$	<3.33 °C/W	<2.14 °C/W	<1.76 °C/W	<1.11 °C/W	<0.83 °C/W	<1.67 °C/W	<1.50 °C/W

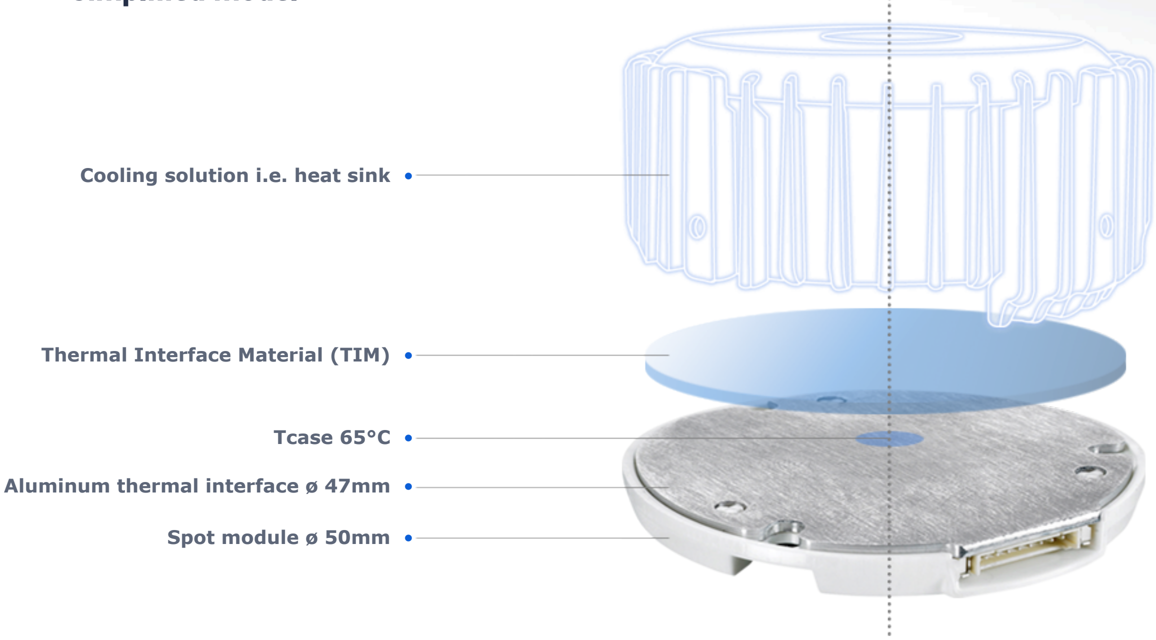
Minimum performance requirement for total cooling solution including TIM, better performance is always preferred and recommended

Thermal specifications Fortimo SLM platform

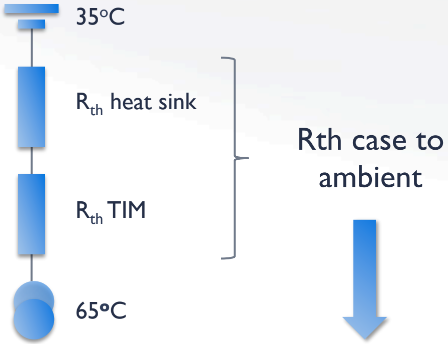
Fortimo SLM thermal specifications :

- Tcase maximum +30°C above ambient
- Max ambient 35°C
- Maximum 65°C Tcase at 35°C ambient

Simplified model



Thermal network



SLM 800lm 9W => Rth case to ambient ≤ 3.33 (°C/W)
SLM 1100lm 14W => Rth case to ambient ≤ 2.14 (°C/W)
SLM 1500lm 17W => Rth case to ambient ≤ 1.76 (°C/W)
SLM 2000lm 27W => Rth case to ambient ≤ 1.11 (°C/W)
SLM 3000lm 36W => Rth case to ambient ≤ 0.83 (°C/W)
SLM LX TW 18W => Rth case to ambient ≤ 1.67 (°C/W)
SLM LX RGB 20W => Rth case to ambient ≤ 1.50 (°C/W)
Note: this includes the TIM

Thermal specifications Fortimo SLM platform

- A maximum surface temperature of 65°C to be guaranteed on the interface between the 'Module' and the 'TIM + cooling solution' at maximum ambient of 35°C

- All types of Fortimo SLM drivers will dim when a temperature over 65°C is sensed by the SLM module

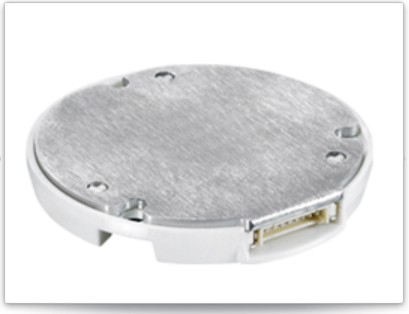
Max. Tcase 65°C
Specification on surface

Aluminum thermal interface ø47 mm

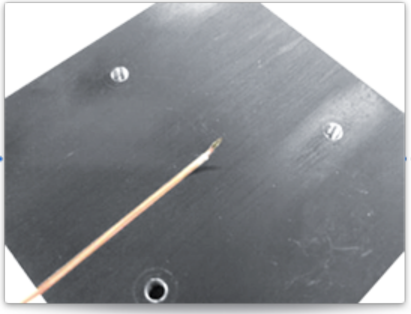
3 screw holes for attachment of module onto heatsink (M3, bolt circle ø42mm)

How to measure critical temperature point Tc?

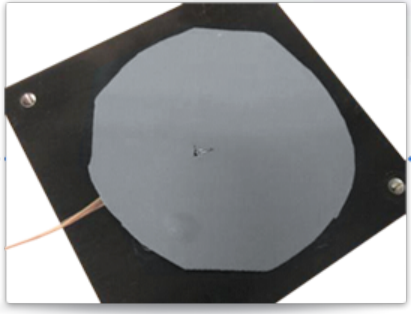
- The Tcase should be measured at its critical temperature point, **centre point at the bottom of the module**
- This can be done **by making a thin v-groove in the heat sink or a small drill hole in the heat sink** to reach bottom of the module at its critical temperature point, make sure to measure the bottom of the module and not the TIM



Critical temperature point Tc



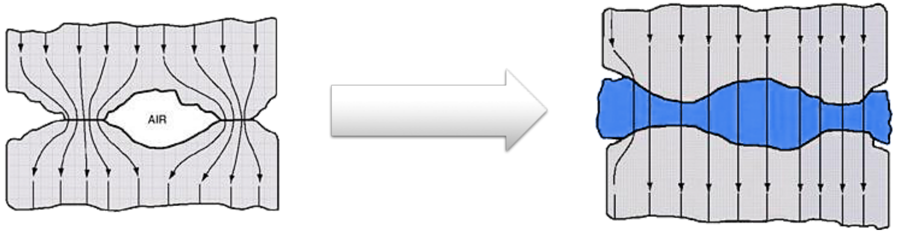
Thin v-groove in the heatsink to embed a thermocouple



Tip of thermocouple sticking out on top of the thermal pad (TIM)

Thermal Interface Materials (TIM)

- Function is to reduce thermal impedance between two solid surfaced
- Replaces air (thermal insulator c=0.024W/mK) by filling the gaps with better conductive thermal interface material (order c=1W/mK)



- In general:
  - *Thermal pastes performs better than thermal pads*
  - *The higher the thermal conductivity the better*
  - *The thinner the TIM the better*

- **In practice:**
  - Actual thermal impedance [°C/W] of TIM in application is more important than conductivity of material
  - Each thermal interface can have a significant contribution to the total thermal impedance of module to ambient
  - Limiting the # of thermal interfaces from module to ambient is strongly recommended)

Contact information complementary partners

Thermal interface materials (TIM)

- The Bergquist Company

  www.bergquistcompany.com

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Designing a passive cooled luminaire

Design based on Fortimo SLM 1100lm:

- Performance requirement cooling $R_{th} < 2.14$ °C/W

$$R_{th\ case\ to\ ambient} = \frac{T_{case} - T_{amb}}{\text{Thermal dissipation}} = \frac{65°C - 35°C}{14W} = 2.14 \frac{°C}{W}$$

$$R_{th\ case\ to\ ambient} = R_{th\ heatsink} + R_{th\ TIM}$$

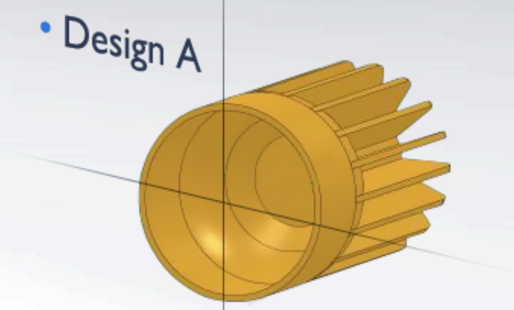
$$R_{th\ case\ to\ ambient} = \frac{1}{htc * \text{effective cooling surface}}$$

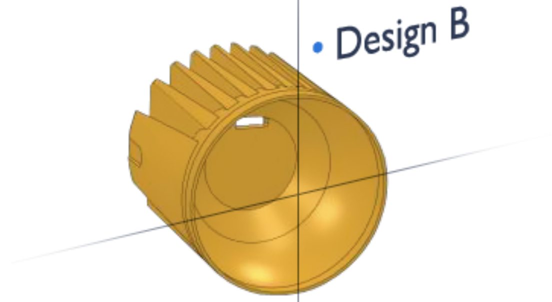
- Assuming a conservative heat transfer coefficient (htc) = 5 W/m^2K and the contribution of the thermal interface material R_{thTIM}= 0.1 °C/W a first estimate of the required cooling surface can be calculated

$$\text{Minimum cooling surface} = \frac{1}{htc * R_{th\ heatsink}} = \frac{1}{5\frac{W}{m^2K} * 2.04°C/W} = 0.098m^2$$

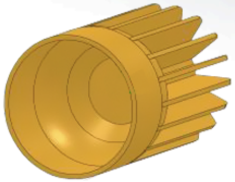
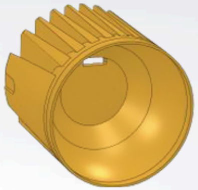
Design of Experiments (DoE)

- Based on the previous calculation a minimum surface area of 0.098 m^2 is required
- This corresponds to a cylinder of ø120mm and 260mm long
- In order to reduce overall size of the luminaire, cooling fins should be introduced
- To optimization the thermal performance a DoE should be set up
- Example of simple DoE with CFD analysis:
  - Comparison of Design A and B
  - Effect of thermal radiation, blank metal surface or black anodized





Design of Experiments (DoE)

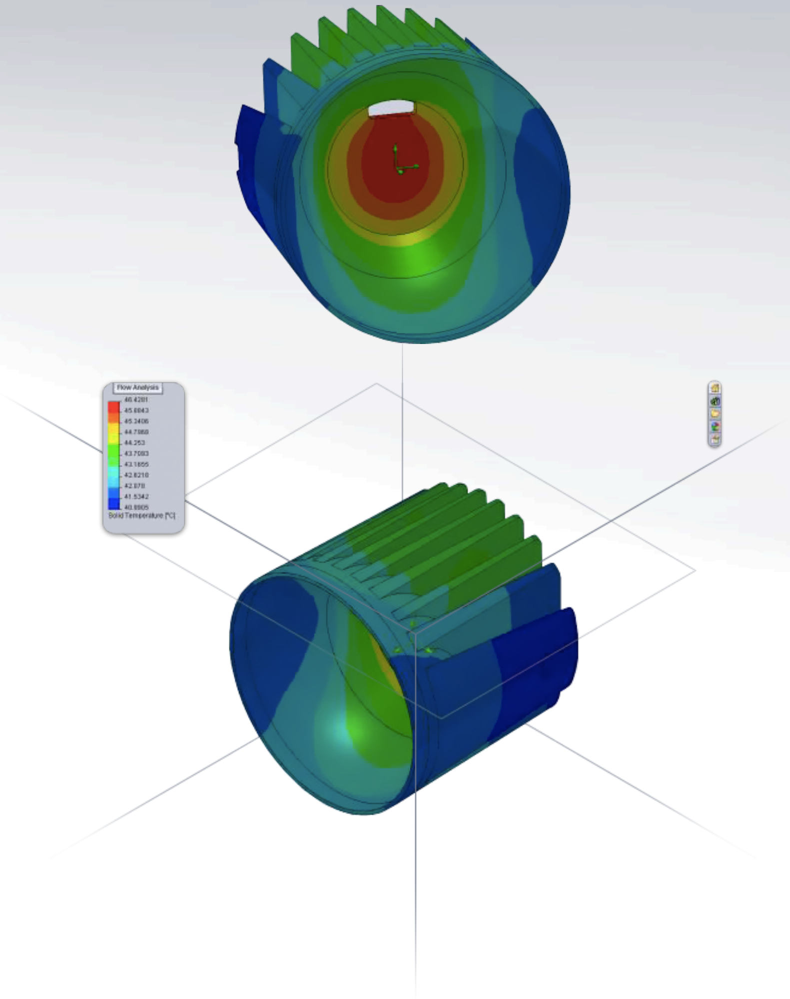
Results DoE	Design A		Design B	
				
Area (m^2)	0.236	0.236	0.158	0.158
Emissivity (-)	0.1	0.9	0.1	0.9
$R_{th\ heatsink}$ (°C/W)	1.33	0.99	1.76	1.39
HTC average (W/m^2K)	3.2	4.3	3.6	4.6

A DoE can of course be much more extensive:

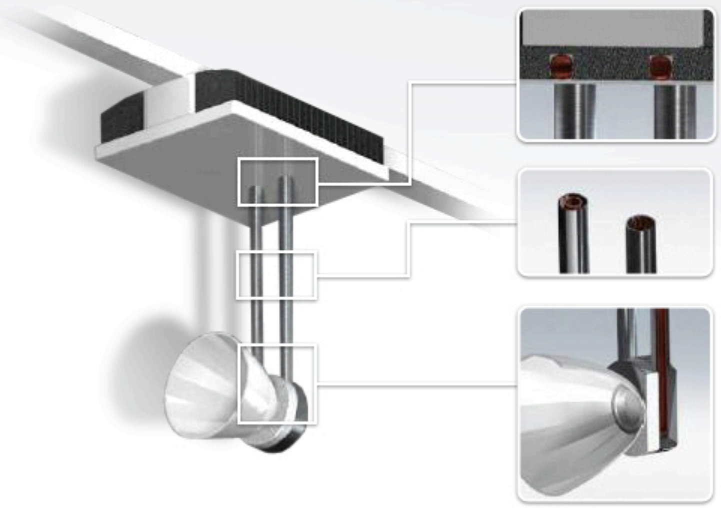
- Different material (thermal conductivity)
- Orientation; horizontal or vertical (here horizontal is assumed as worst case, so both heat sinks will also work in vertical orientation)

Detailed analysis

- Both designs are feasible, but choice is to focus on design B
- The fins are place in line with the flow direction for maximum efficiency, this way it is possible to keep the overall luminaire size and weight small.
- Analysis with CFD can further optimize the design:
  - i.e. optimization of fin thickness and fin spacing



Passive cooled luminaire designs



- After design optimization a passive luminaire design could look like this:
- Another passive cooled design, but with heat pipes:

Some design guidelines for passive cooling

- Limit the # of thermal interfaces in the thermal path from module to ambient **=> strongly recommended**
- Thick fins conduct heat better than thin fins
- Large spacing between fins is better than small spacing between fins
- Make cooling surfaces more effective by using proper conductive materials, appropriate thickness and sound orientation
- Thermal radiation plays a significant role **=> anodized surfaces are preferred over blank surfaces**

Designing an active cooled luminaire

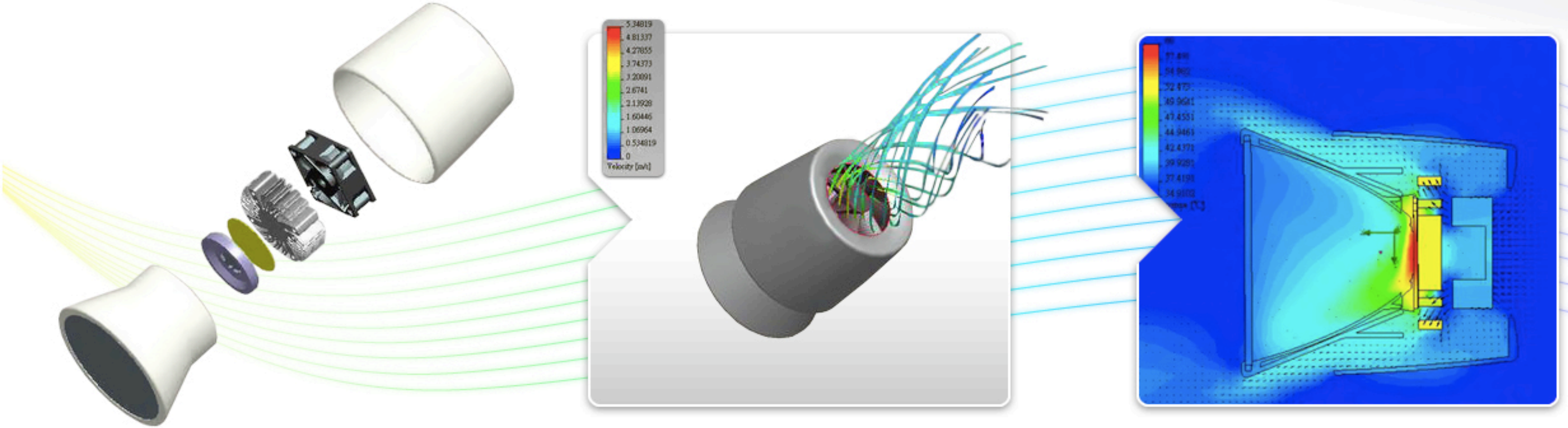
Design based on Fortimo SLM 2000lm:

- Performance requirement cooling R_{th}< 1.11 °C/W
- Assuming passive cooling conditions:
  - Heat transfer coefficient (htc) = 5 W/m^{2}K and
  - Contribution R_{thTIM}= 0.1 °C/W
- A calculated cooling surface of 0.180m^2 is required
- This corresponds to the surface a cylinder of ø120mm and 478mm long!

Goal of an active solution is to actively move air over the cooling surfaces to increase the heat transfer coefficient, therefore enabling small, compact and light weight cooling solutions (and systems)

CFD analysis

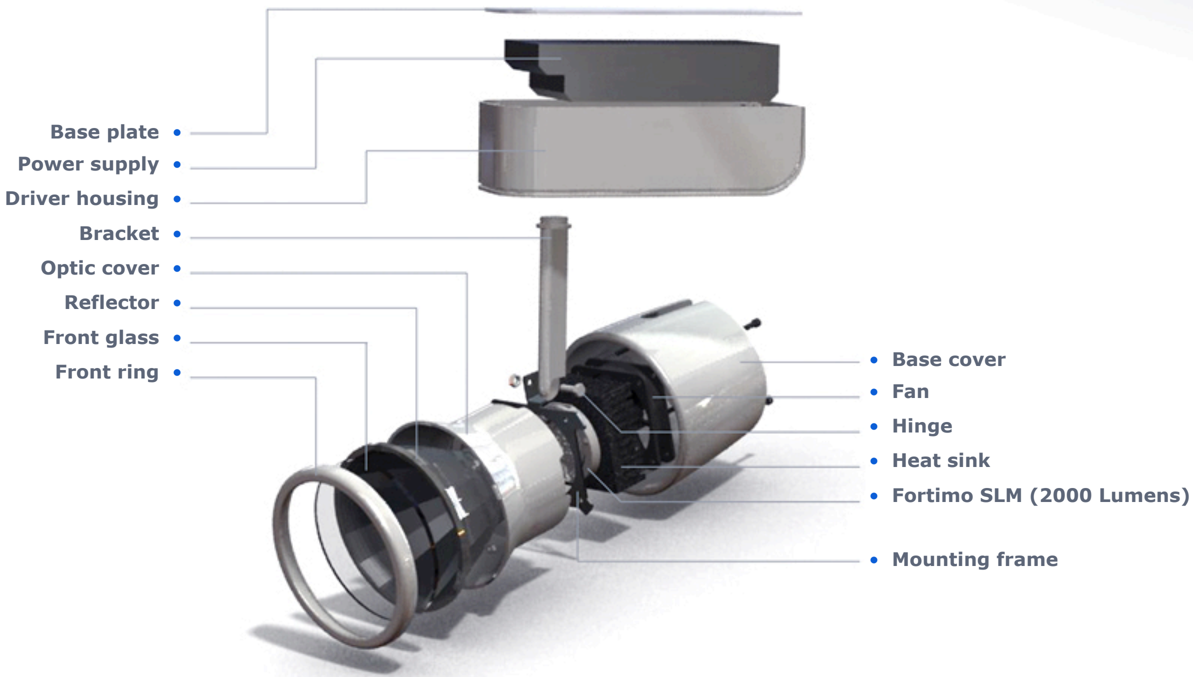
- CFD analysis can be a great way to help design a good active cooled luminaire
- A possible design is shown below
- The complete cooling solution has reduced to a small, compact and light weight solution of ø70mm and 40mm in height



Active cooled luminaire designs

- Goal of an active solution is to actively move air over the cooling surfaces to increase the heat transfer coefficient, therefore enabling small, compact and light weight cooling solutions (and systems)

After optimization an active cooled luminaire design could look like this:



Some design guidelines for active cooling

Design considerations for active cooling are:

- Provisions in luminaire design for inlet and outlet of respectively cool and hot air
- Ensure smooth airflow from inlet to outlet and prevent restrictions in the flow path (to limit vibration, recirculation and possible noise)

Always take care to:

- Design for reliability (dusty environments)
- Design for performance (differentiator)
- Design for low noise (differentiator)

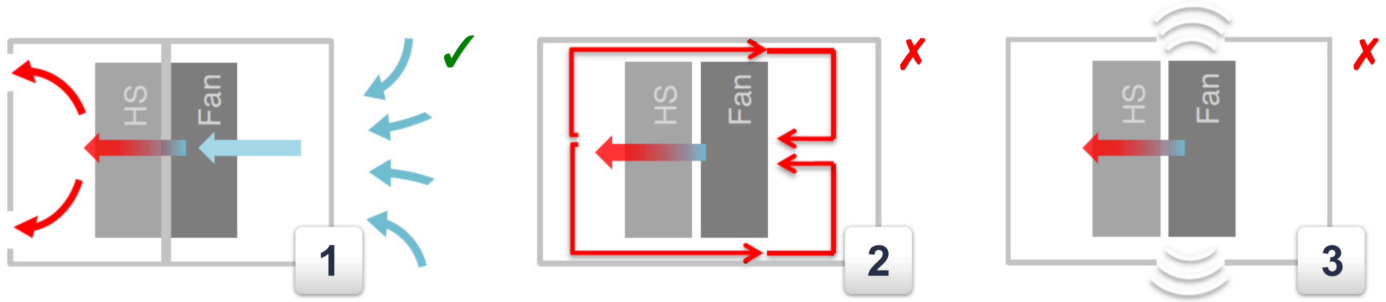
Some design guidelines for active cooling

Design considerations for active cooling are:

- Provisions in luminaire design for inlet and outlet of respectively cool and hot air (1) Ensure smooth airflow from inlet to outlet and prevent restrictions in the flow path (to limit vibration recirculation and possible noise)

- Avoid recirculation of hot air (2) inside the luminaire, which leads to lower thermal performance and higher noise level.

- Enclose fan noise avoiding unnecessary openings near the fan in the luminarie's housing (3)



Thermal solution validation

When testing the thermal performance of your luminaire pay special attention to these 2 numbers!

- Max temperature of the module Tc=65C°
- Max ∆T 30°C (Tc=65°C when your ambient temperature is 35°C)

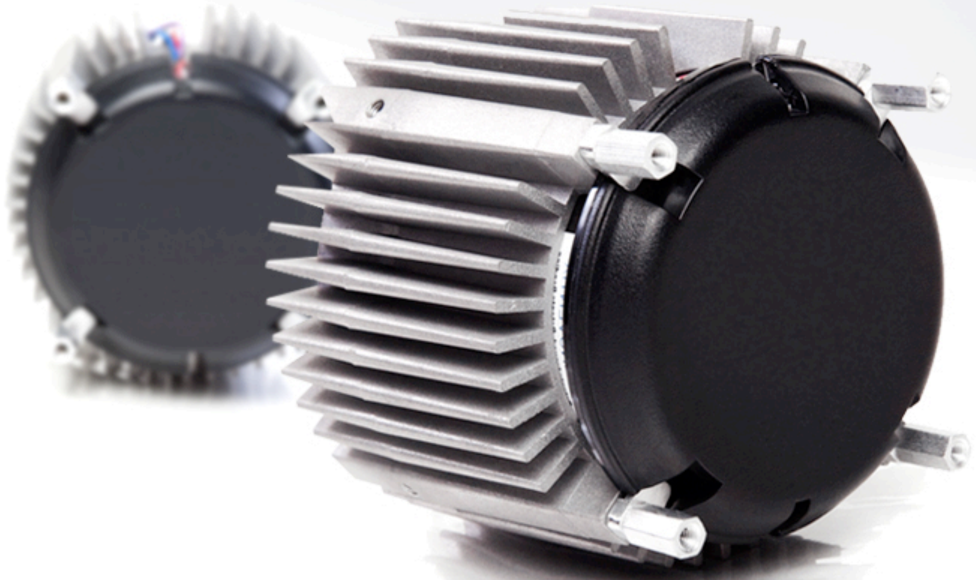
Operating the system under those parameters will guarantee its proper performance in terms of:

- Lumen output
- Light consistency
- Life time

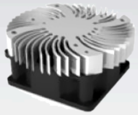
Complementary partners for thermal solutions

Overview of our complementary partners and their cooling solutions that are especially designed for the Fortimo SLM platform

- AVC (active and passive solutions)
- Sunon (active solutions)
- Nuventix (active solutions)
- Wisefull (active solutions)
- FrigoDynamics (passive solutions)



AVC


Module Type	Fortimo SLM 800Lm Passive Solution	Fortimo SLM 1100Lm Passive Solution + ø9mm heatpipe	Fortimo SLM 1100Lm Active Solution	Fortimo SLM Lexel 1500Lm Active Solution	Fortimo SLM 2000Lm Active Solution	Fortimo SLM 3000Lm Active Solution
Heatsink Type	Sunflower Heatsink	Sunflower Heatsink	Sunflower Heatsink	Sunflower Heatsink	Sunflower Heatsink	Sunflower Heatsink
Heatsink Model	FSLM-P1000-1	FSLM-HP1100	FSLM-A1100-G1	FSLM-ALexel-G1	FSLM-A2000-G2	FSLM-A3000-G3
Total Height (Heatsink + module)		105mm	30mm	40mm	40mm	40mm
Heatsink Geometry	Extrusion	Extrusion	Extrusion	Extrusion	Extrusion	Extrusion
Heatsink Dimensions	ø70mm*H30mm	ø100mm*H105mm	ø65mm*H10mm	ø65mm*20mm	ø70mm*20mm	ø75mm*H50mm
Dimensions Weight (kg)		0.685	0.080	0.128	0.150	TBC
Heatsink Material	AL6063-T5	AL6063-T5	AL6063-T5	AL6063-T5	AL6063-T5	AL6063-T5
Surface finish	Black Anodized	Anodized	Anodized	Anodized	Black Anodized	Black Anodized
LED Thermal Power	10W	17W	17W	18W	31W	40W
Ambient Temperature	35°C	35°C	35°C	35°C	35°C	35°C
Case Temperature	<=65°C	<=65°C	<=65°C	<=65°C	<=65°C	<=65°C
Thermal Resistance	<3°C/W	<1.75°C/W	<1.75°C/W	<1.65°C/W	<0.95°C/W	<0.95°C/W
Lower-noise FAN	N/A	N/A	DS0520_12L	DS0520_12L	DS6020_12E	DS0715
Fan dimensions	N/A	N/A	50mm*50mm*H20mm	50mm*50mm*H20mm	60mm*60mm*H20mm	70mm*70mm*H15mm
Fan rated voltage	12V	N/A	12VDC	12VDC	12VDC	12VDC
Fan Noise Level	N/A	N/A	<21dB	<21dB	<21dB	<21dB
Fan RPM speed	N/A	N/A	3000RPM±15%	3000RPM±15%	2200RPM±15%	2200RPM±15%
Thermal interfaces materials	TIG780-50	TIG780-50	TIG780-50	TIG780-50	TIG780-50	TIG780-50

Sunon

SUNON®

LED Fortimo SLM 2000Lm
LED Power 31W
Cooling Module Model No. TA003-10001
Cooling Module Diameter ø86x37mm
Fan Dimension 60x60x15mm
Fan Rating Voltage 12VDC
Fan Rating Current 24mA
Fan Speed 2200RPM
Cooling Module Noise @ 1M 18dB(A)
Heat Sink Material Aluminum
Weight 235g

SLM 2000Lm gen 2 (TA003-10003) solution improved for use in track luminaires

SLM 3000lm (TA004-10003)

- Prototypes available
- Limited engineering samples available end march 2011
- MP release in April 2011

SLM 1100Lm + SLM 1500Lm also to be released March April

Nuventix

NUVENTIX

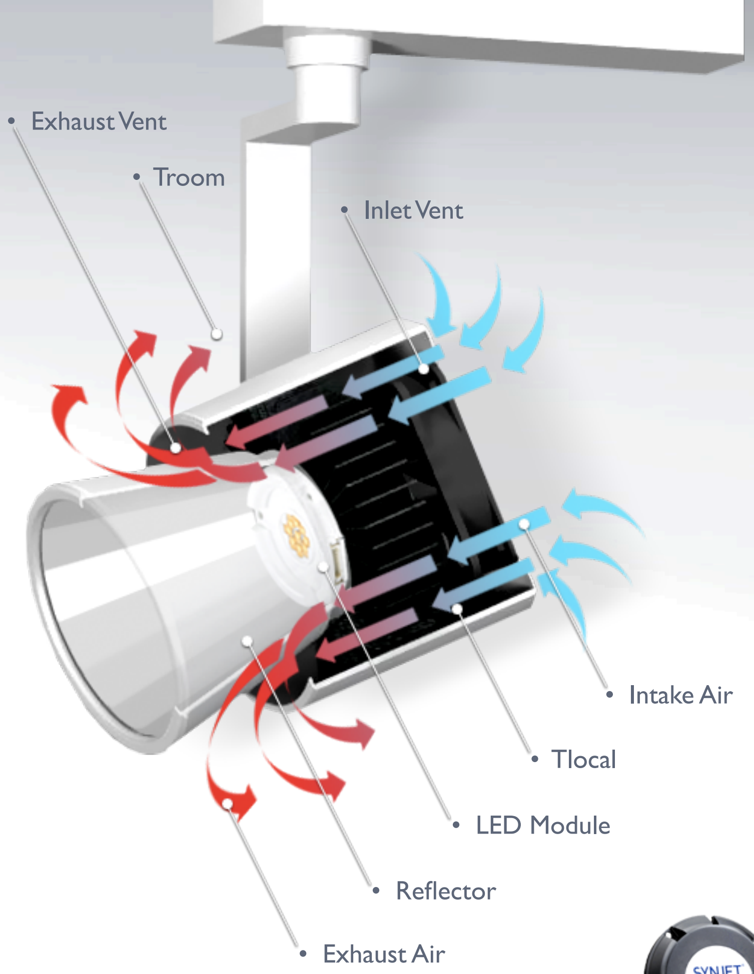
- Solution for SLM 800Lm, 1100Lm and 1500Lm
- Solution for SLM 2000Lm, 3000Lm recommended for open air applications, for track applications design-in guidelines of Nuventix to be followed to ensure performance, assess case by case

Track and Recessed Applications	Spotlight Cooler 38W Standard	Spotlight Cooler 34W High Performance	Spotlight Cooler 34W Mid Performance	Spotlight Cooler 34W Standard	Spotlight Cooler 31W High Performance	Spotlight Cooler 31W Mid Performance	Spotlight Cooler 31W Standard	Spotlight Cooler 21W Standard
Fortimo LED SLM 1100 840, Tamb = 35°C	✓	✓	✓	✓	✓	✓	✓	✓
Fortimo LED SLM 1100 835, Tamb = 35°C	✓	✓	✓	✓	✓	✓	✓	✓
Fortimo LED SLM 1100 830, Tamb = 35°C	✓	✓	✓	✓	✓	✓	✓	✓
Fortimo LED SLM 2000 840, Tamb = 35°C	✓	✓	✓	✓	✓			
Fortimo LED SLM 2000 835, Tamb = 35°C	✓	✓	✓	✓	✓			
Fortimo LED SLM 2000 830, Tamb = 35°C	✓	✓	✓	✓	✓			

SynJet® Airflow Basics

Enclosure Guidelines

- Inlet vents can either be on back, sides or both
- Exhaust vents can be on sides, front or both
- Vents should be designed to allow maximum airflow into and out of the enclosure
- T_{room} is the temperature around the outside of the fixture far enough removed to not be impacted by fixture
- T_{local} is the temperature within the fixture near the nozzles and is higher in temperature than Troom
- Enclosure should be designed to minimize the difference between T_{room} and T_{local}



Wisefull Technology Ltd.

东莞智富五金制品有限公司
DongGuan JIFU Metallic Products CO.Ltd.

Active solution

Sample		Testing time (min)	Temperature (°C)		Δ T(°C)	Rth(°C/W)
	Test runs		Ta	Tc	Tc-Ta	Δ T/power
1#	Run 1 (Free air, downward lighting direction)	30	23.9	45.4	21.5	0.693
	Run 2 (free air, upward lighting direction)	30	24.0	47	23	0.742
	Run 3 (Test in luminaire, 5mm air exit width)	60	23.8	59.7	35.9	1.159
	Run 4 (Test in luminaire, 10mm air exit width)	60	24.2	56.4	32.2	1.039
2#	Run 1	30	23.7	44.7	21	0.677
	Run 2	30	24.1	46.8	22.7	0..732
	Run 3	30	24.6	60.4	35.8	1.155
	Run 4	30	23.9	56.3	32.4	1.045

Note: Rth is calculated by using 31W as the assumed heat dissipation

But also Passive

P/N WF1006-16-24
For Philips Fortimo LED SLM 1100Lm

LED Power: 17W
Thermal resistance: 1.584 °C/W
Material: AL6063
Weight: 417g
Dimension: Ø 110mm x 65mm
Finish: Black anodize

Thermal solutions for Philips LED module

Solutions for SLM 800lm, 1100lm and 1500lm

Solution for SLM 2000lm only suitable in free air

Frigo Dynamics GmbH

- Tested solution suitable for SLM 800lm, 1100lm and 1500lm in free air

Please contact FrigoDynamics for commercial information

Contact information complementary partners 1/2

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Cooling solutions

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