Interleaved Parallelogram Fin Module Technology Applied in Whitley platform

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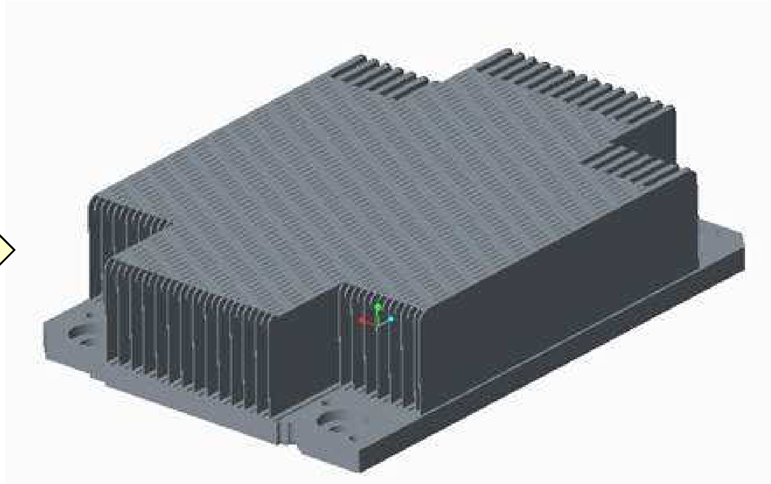
Icelake Intel design guide (Feb. 2018)

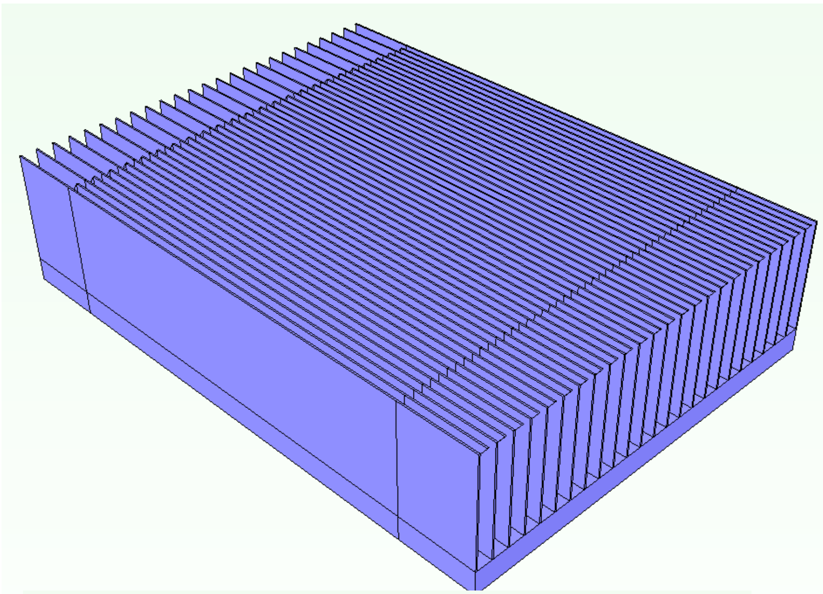
Icelake Intel technical forum reference design (June. 2018)

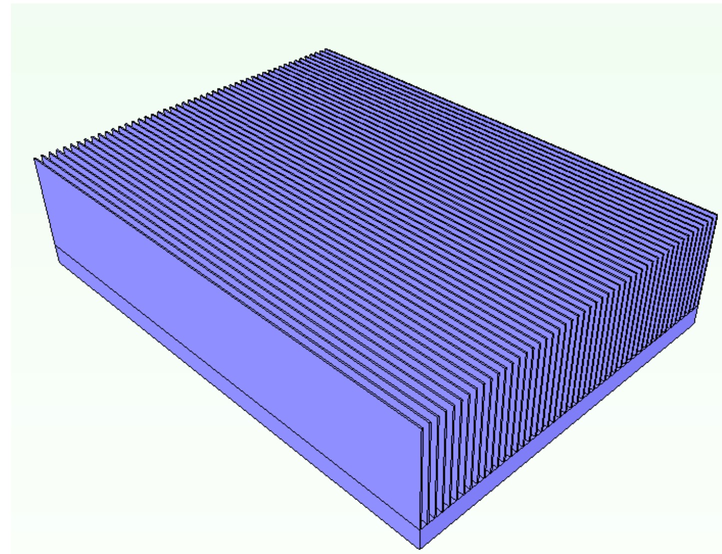


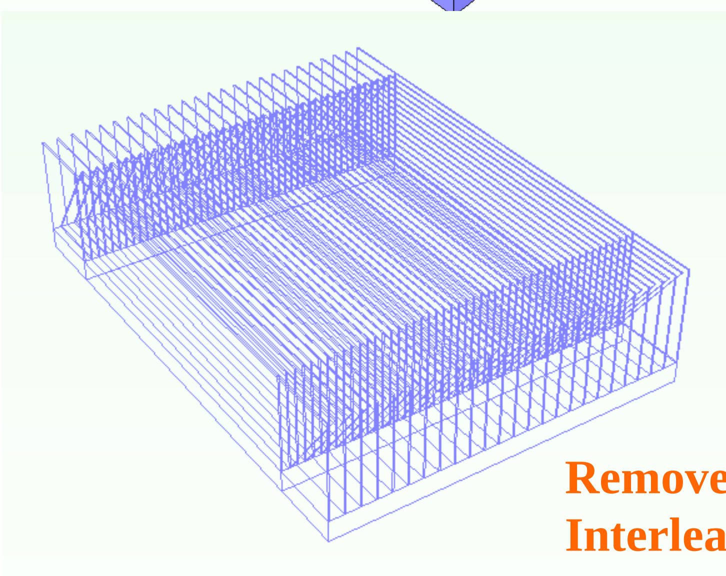
I.P.F.M. technology

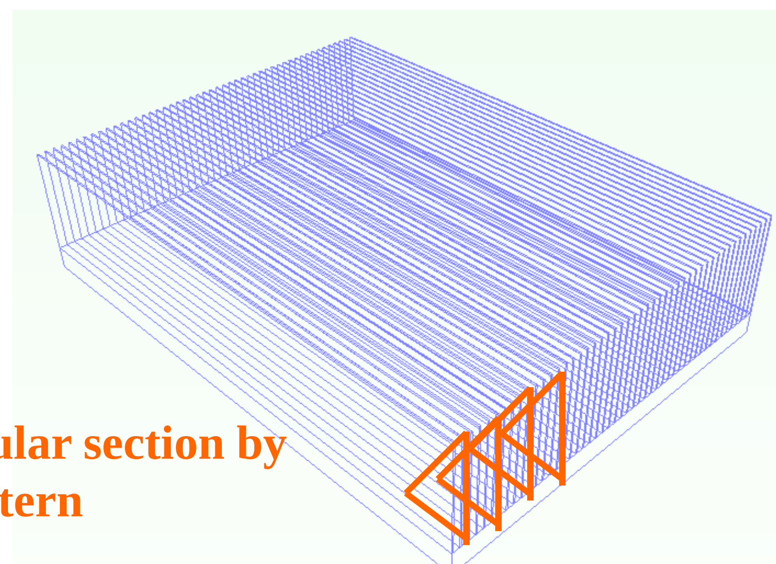
INTERLEAVED PARALLEOGRAM Fin Module

Schematics of IPFM vs. regular fin module



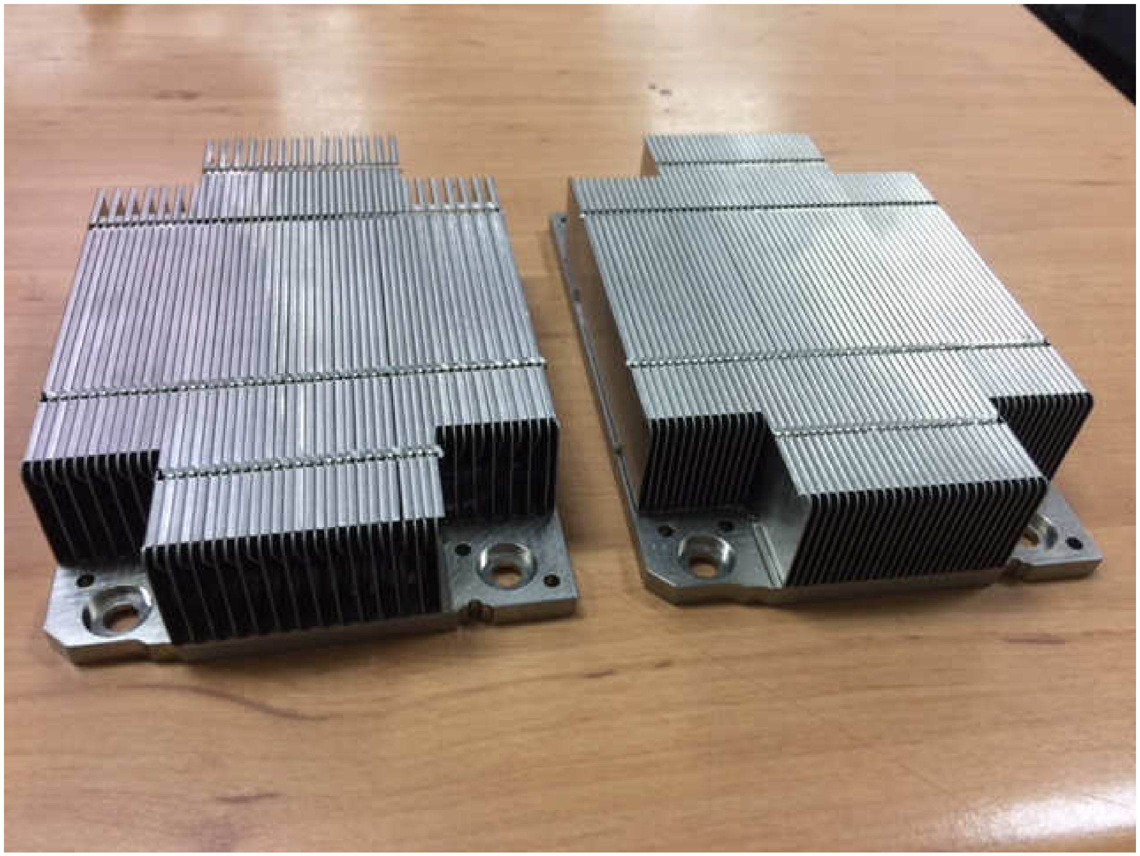


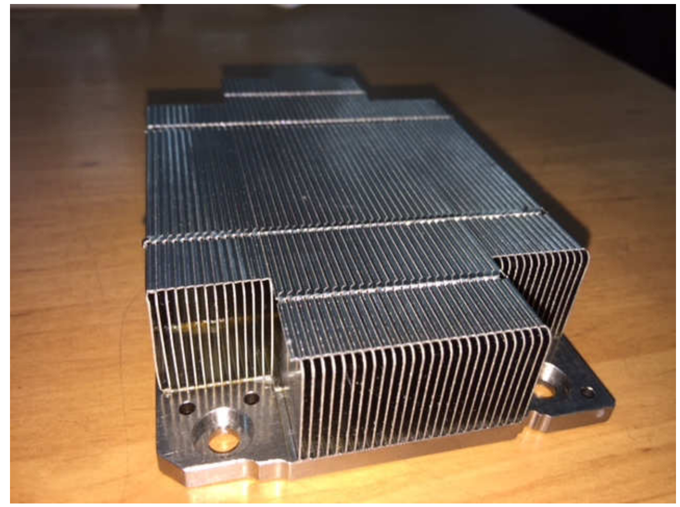




Remove triangular section by Interleaved pattern

Icelake IPFM design *Icelake regular design*



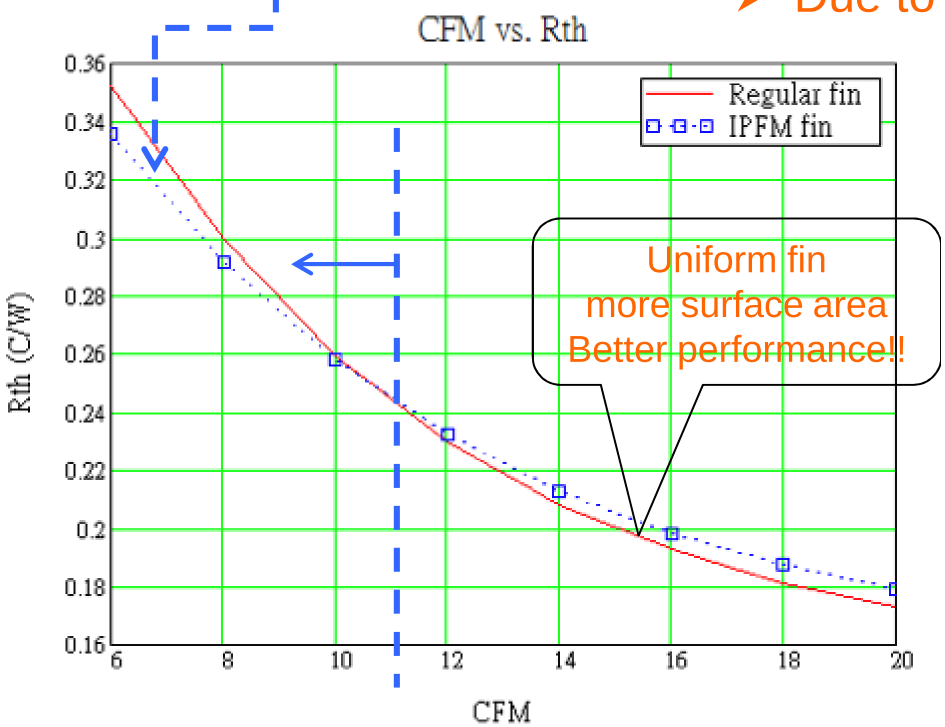


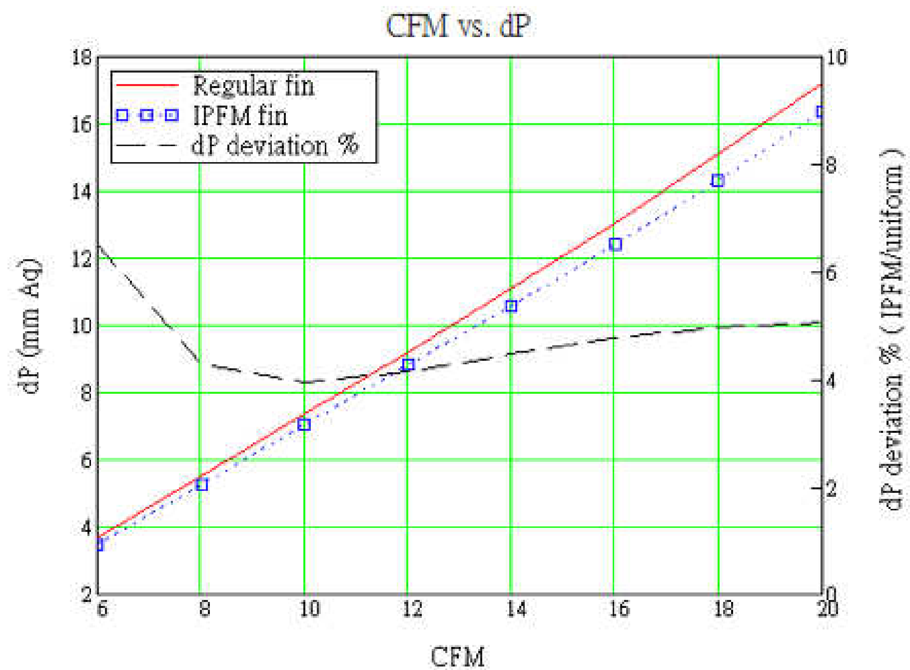
Test Result Analysis

IPFM
Less surface area
Better performance!!

Summary:
- IPFM performs better in lower CFM region
- Uniform fin performs better in higher CFM region

If equal dP is considered:
- IPFM may outperforms uniform fin for high/low CFM
- Due to less dP to gain 5% more airflow



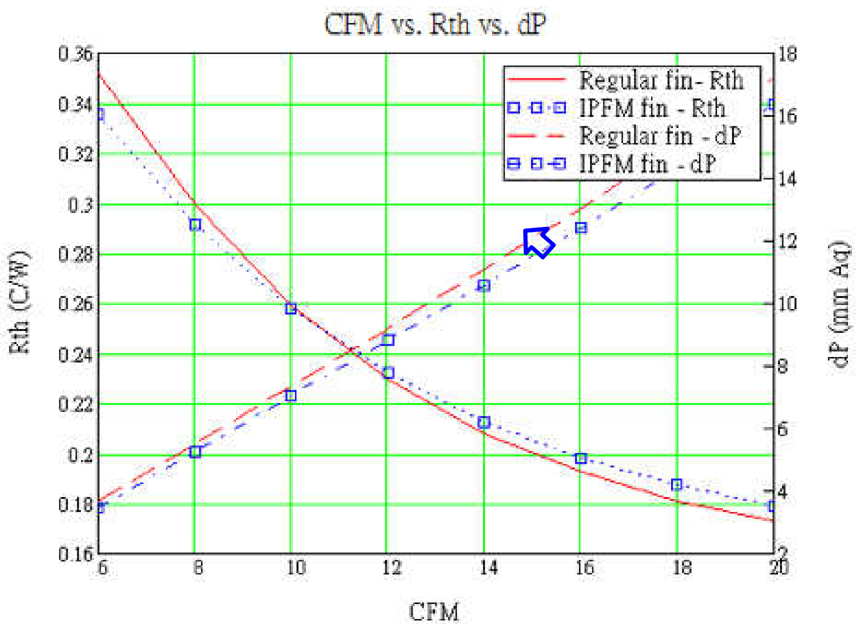


Test of constant CFM vs. constant dP

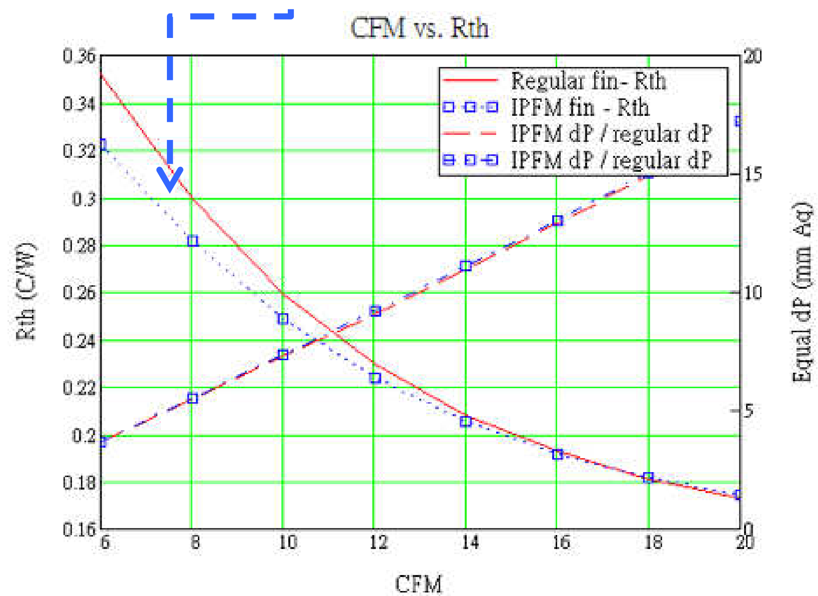
IPFM advantage than uniform fin:

- The lower CFM, the lower Rth
- Lower dP about 5-6%
- More airflow about 6-7%
- Lighter by 3-4 %

IPFM
Outperform uniform fin
In low & high CFM region!!

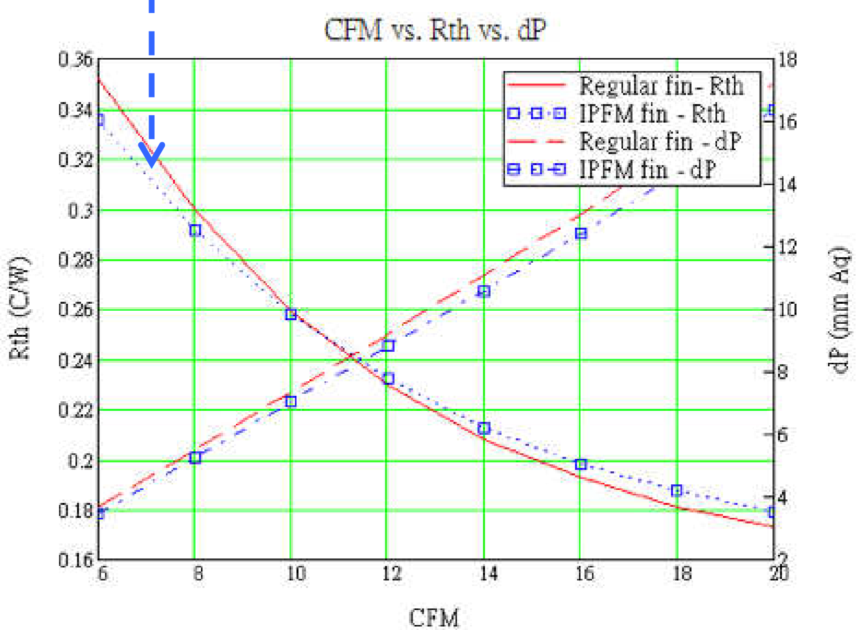


CFM Uniform fin	CFM IPFM fin
6	6.417
8	8.358
10	10.411
12	12.52
14	14.658
16	16.803
18	18.942
20	21.064



Why IPFM excels in lower CFM region ?

IPFM
Outperform uniform fin
In low & high CFM region!!
WHY??

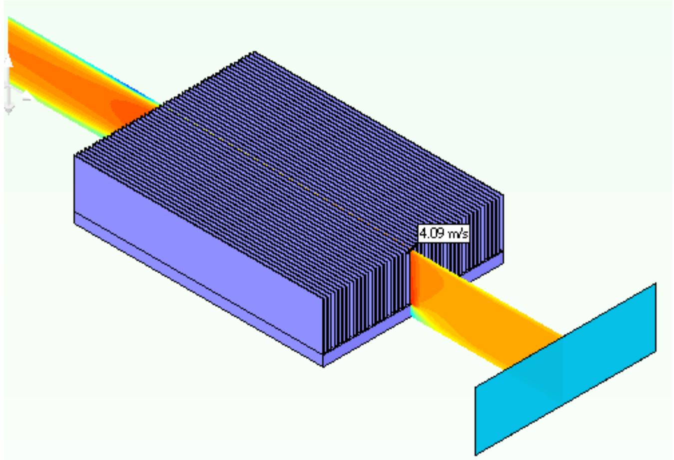


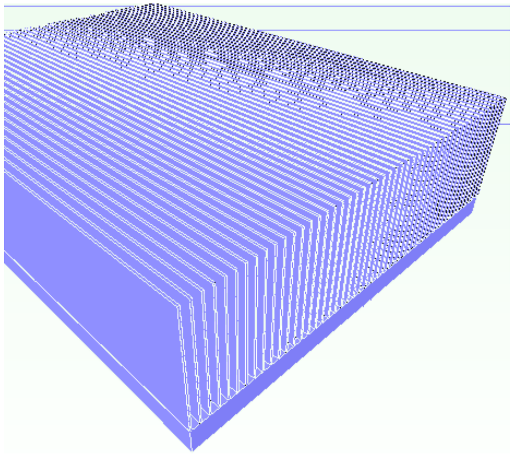
Decode IPFM advantage :

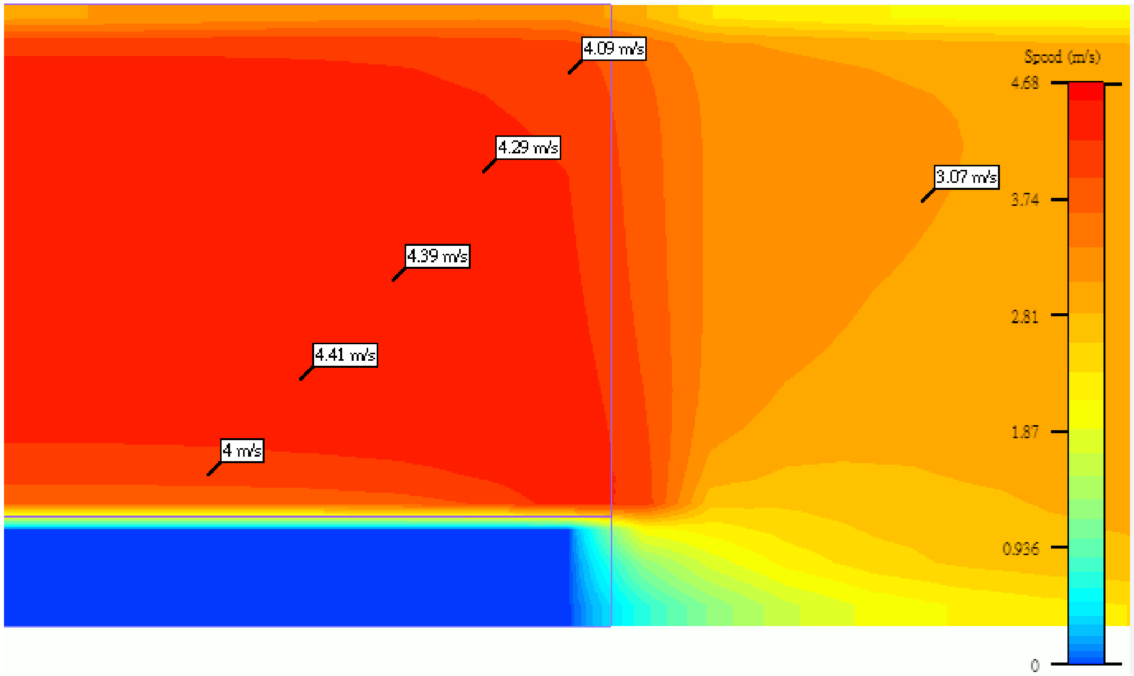
- CFD approach
- Analytical approach

Inlet velocity in recangular fin

- Size: 113x78x25 mm
- Base: 4.5mm Al base / Cu block
- Fin: 113Lx21Hx0.3t, Al
- Power: 165W
- Ambient: 35C
- Flow rate: 11.9CFM





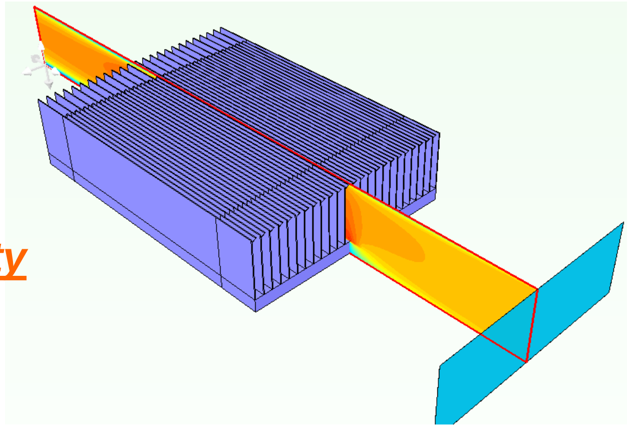


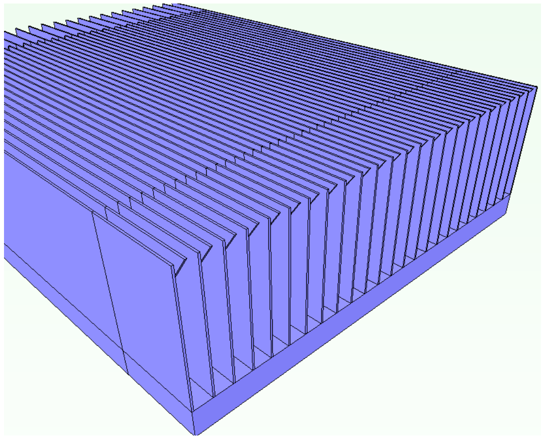
CFD analysis of IPFM

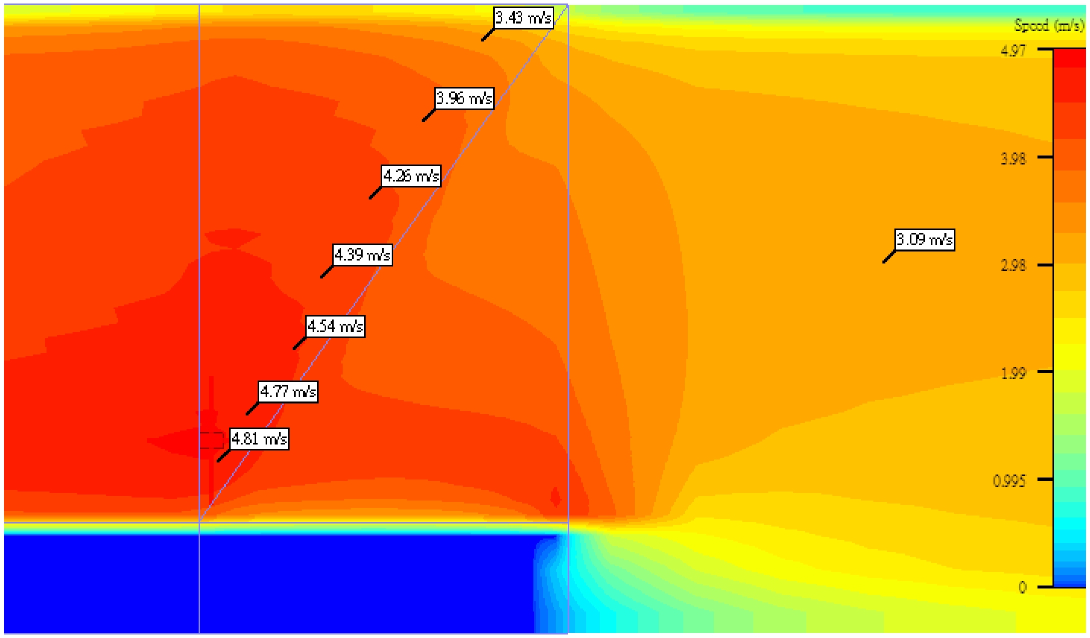
- Size: 113x78x25 mm
- Base: 4.5mm Al base / Cu block
- Fin: 113Lx21Hx0.3t, Al
- Power: 165W
- Ambient: 35C
- Flow rate: 11.9CFM

The 1st HSK with <u>variable velocity</u> in flow channel!

The lower position, the higher velocity!!



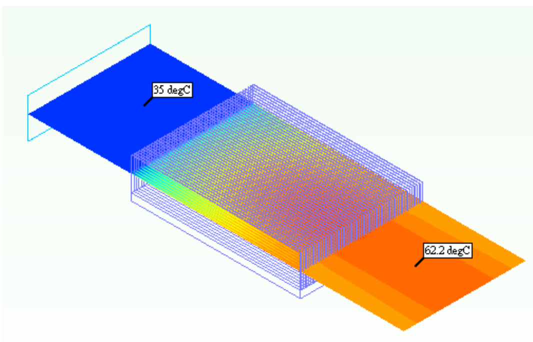


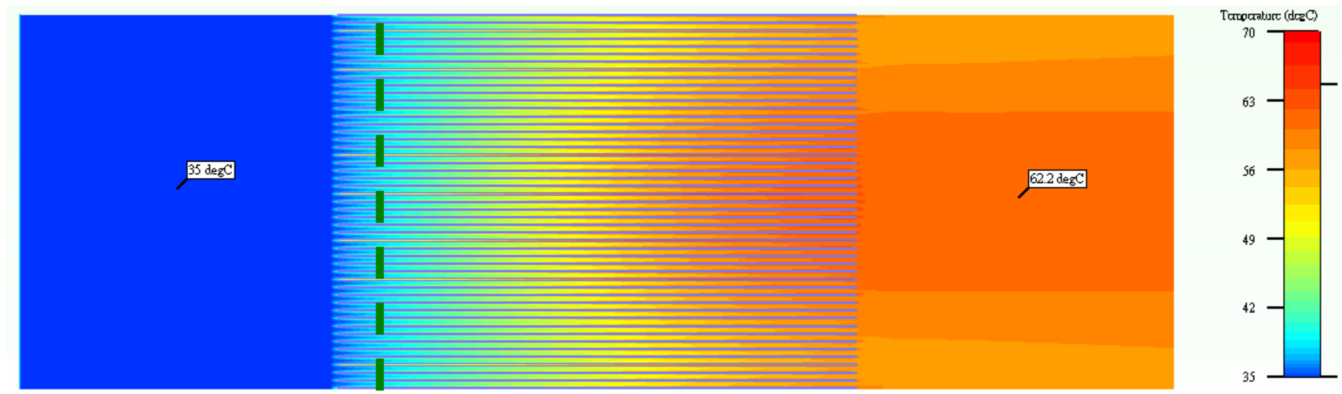


Inlet & outlet temperature

REC

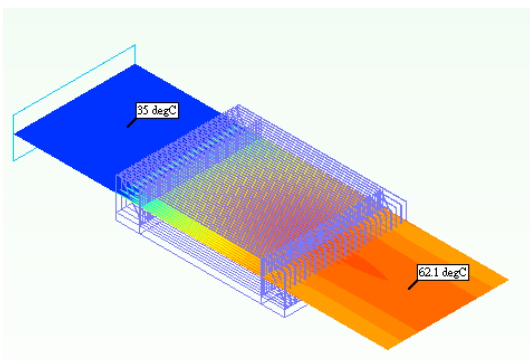
Boundary layer merge line

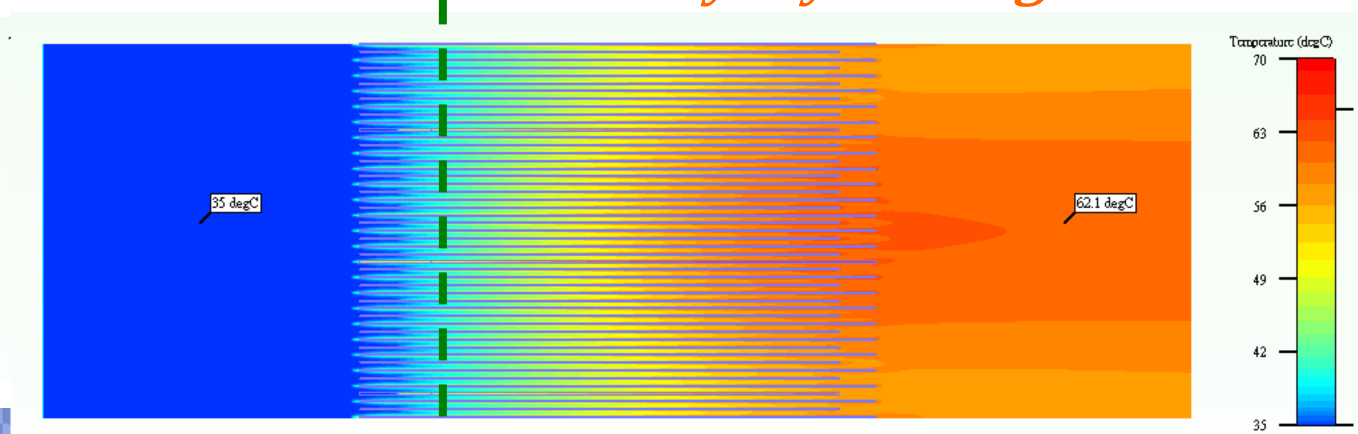




IPFM

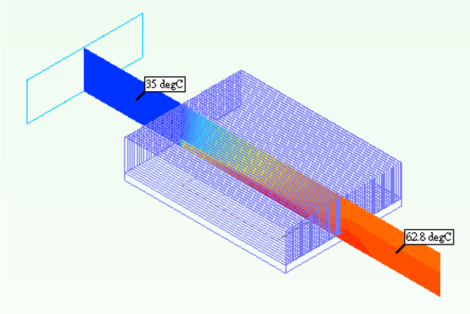
Boundary layer merge line

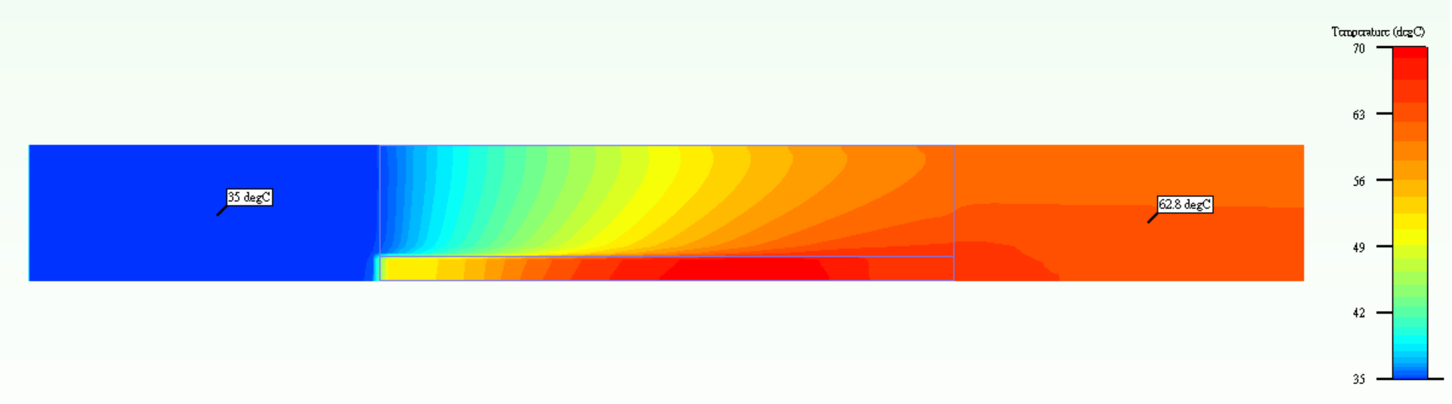




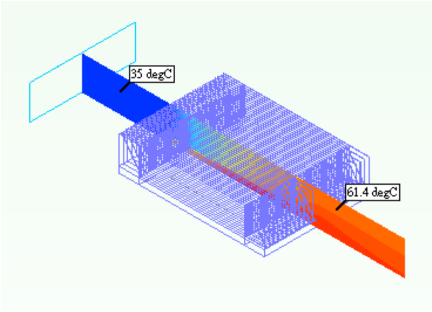
Inlet & outlet temperature

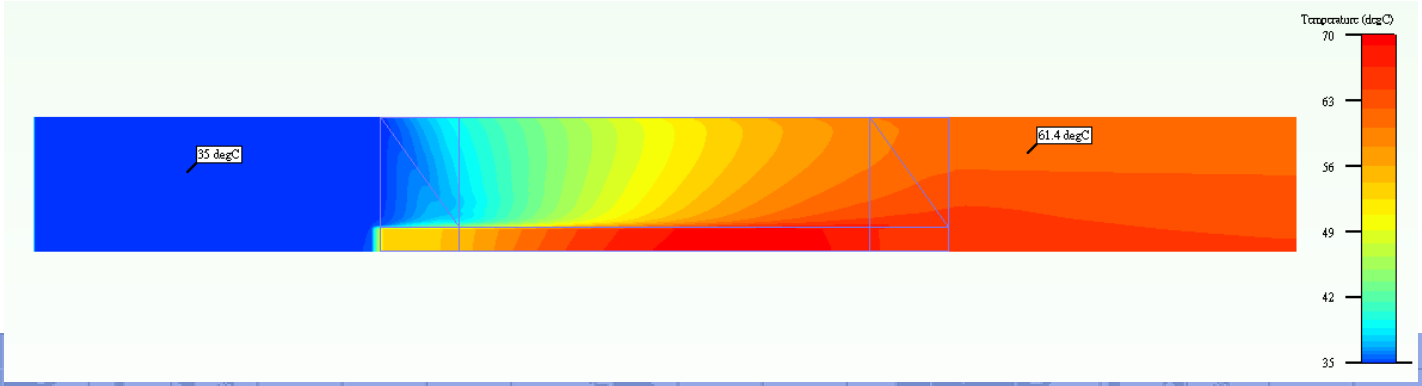
REC





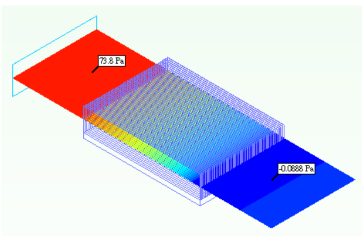
IPFM

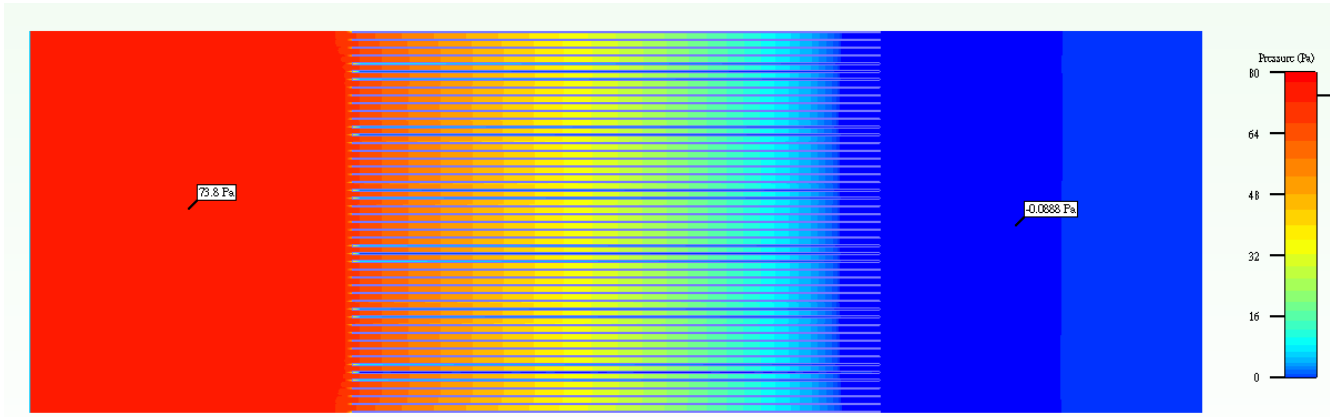




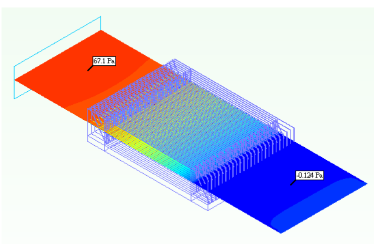
Pressure field

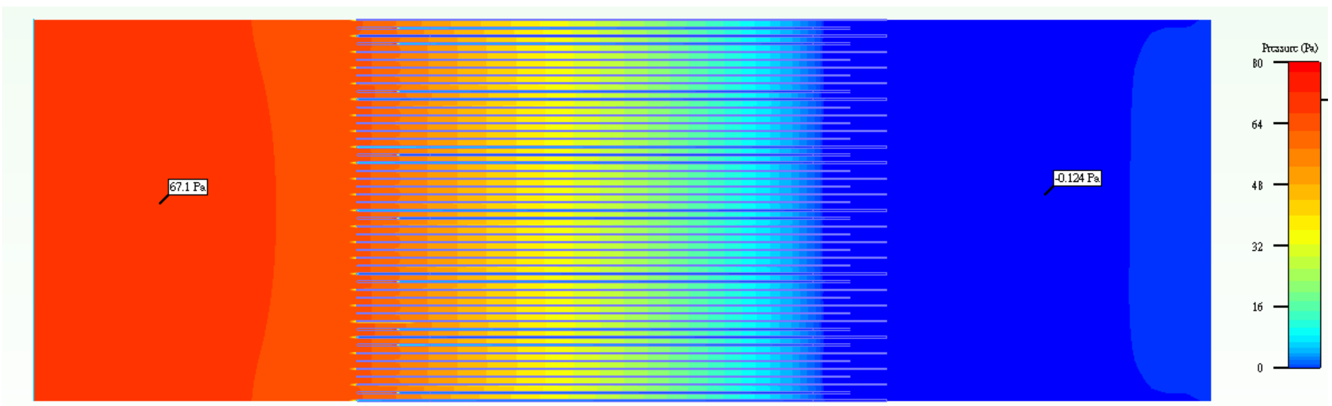
REC





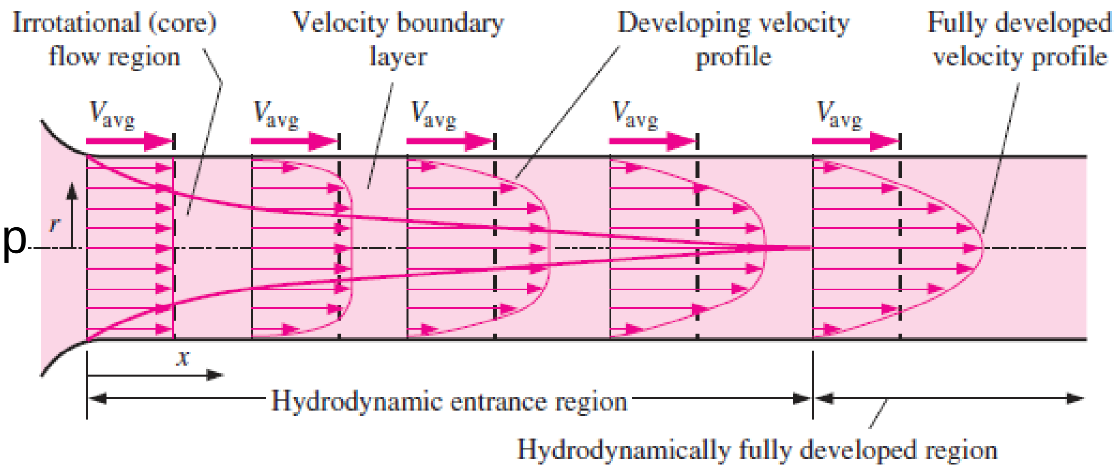
IPFM

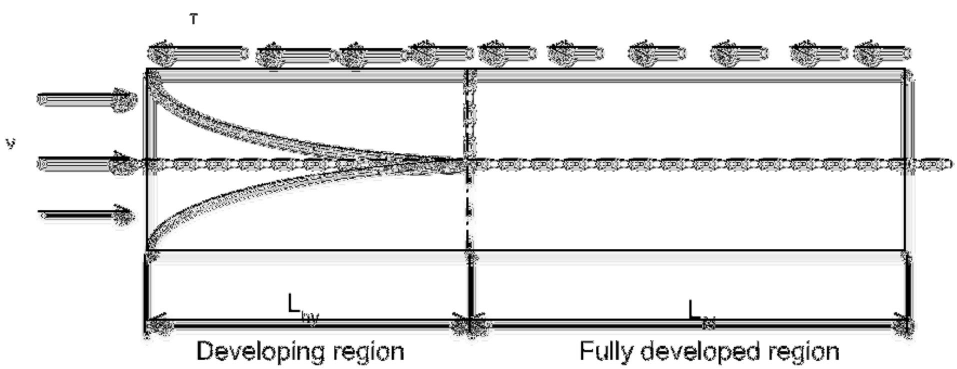


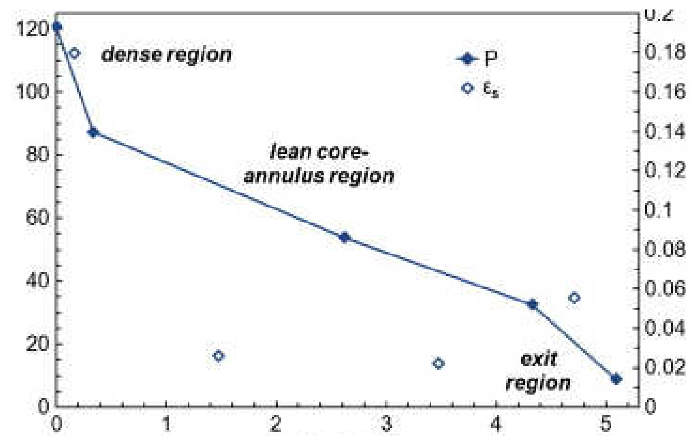


Pressure Drops of fin module

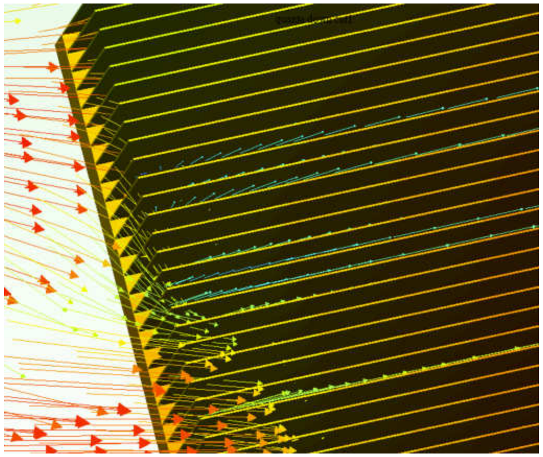
- Inlet pressure drop
- Developing pressure drop
- Fully developed pressure drop
- Expansion pressure drop
- Acceleration pressure drop

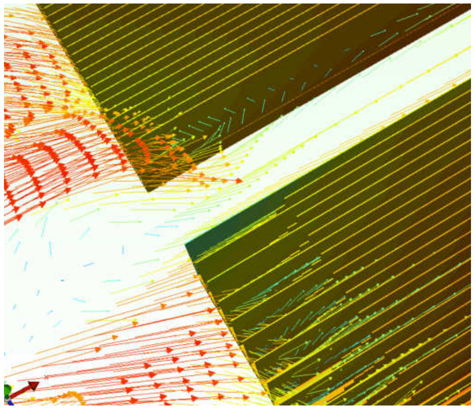


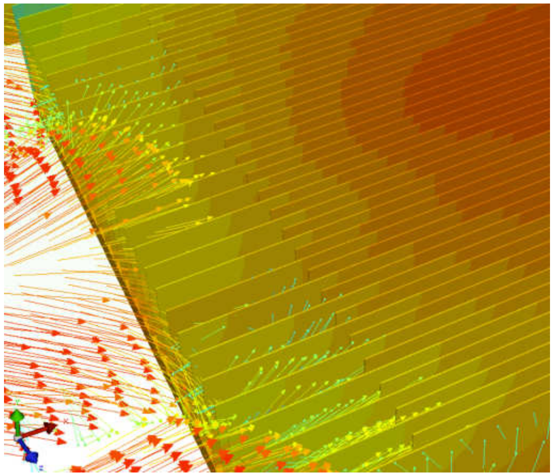


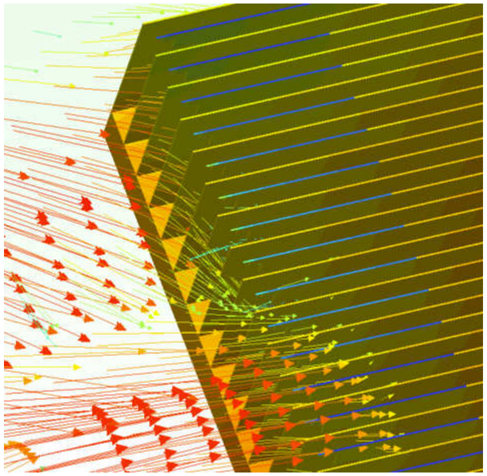


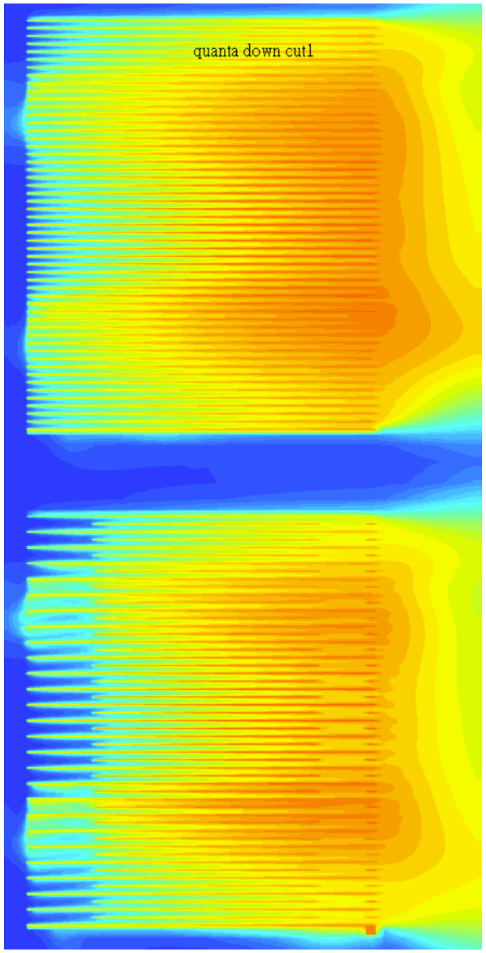
Huge Entrance Pressure in Fan Swirling





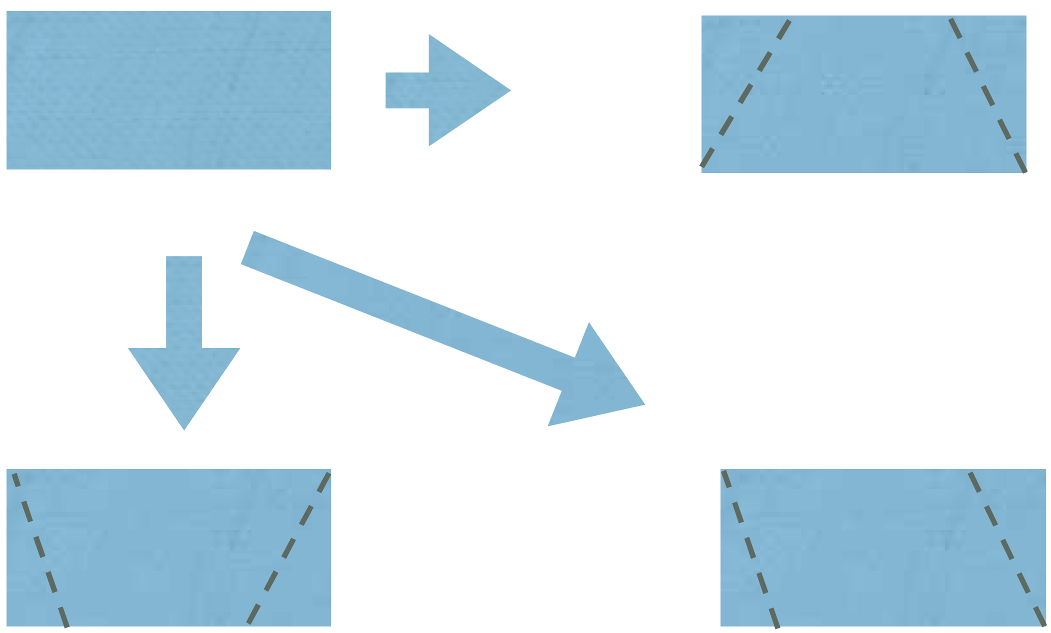




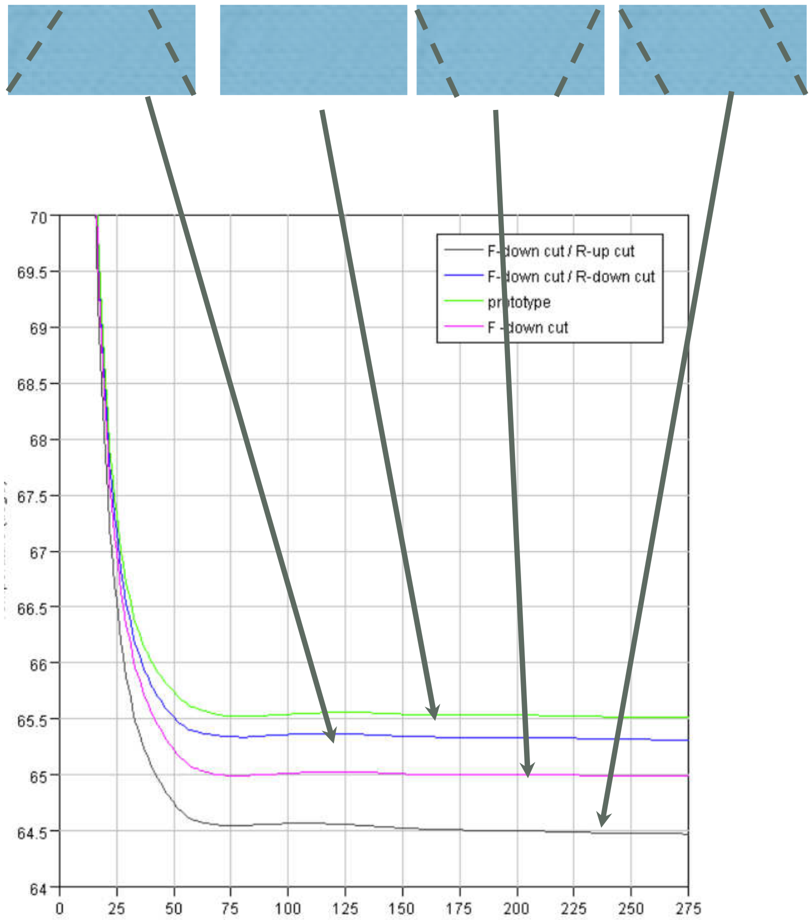


IPFM is the optimized configuration??

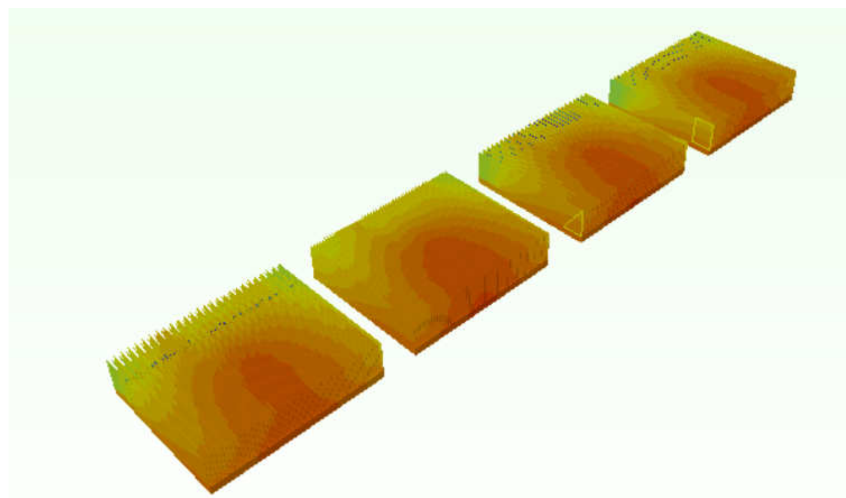
- Model I
  – regular shape
- Model II
  – trapezoidal
- Model III
  -inversed trapezoidal
- Model IV
- - parallelogram



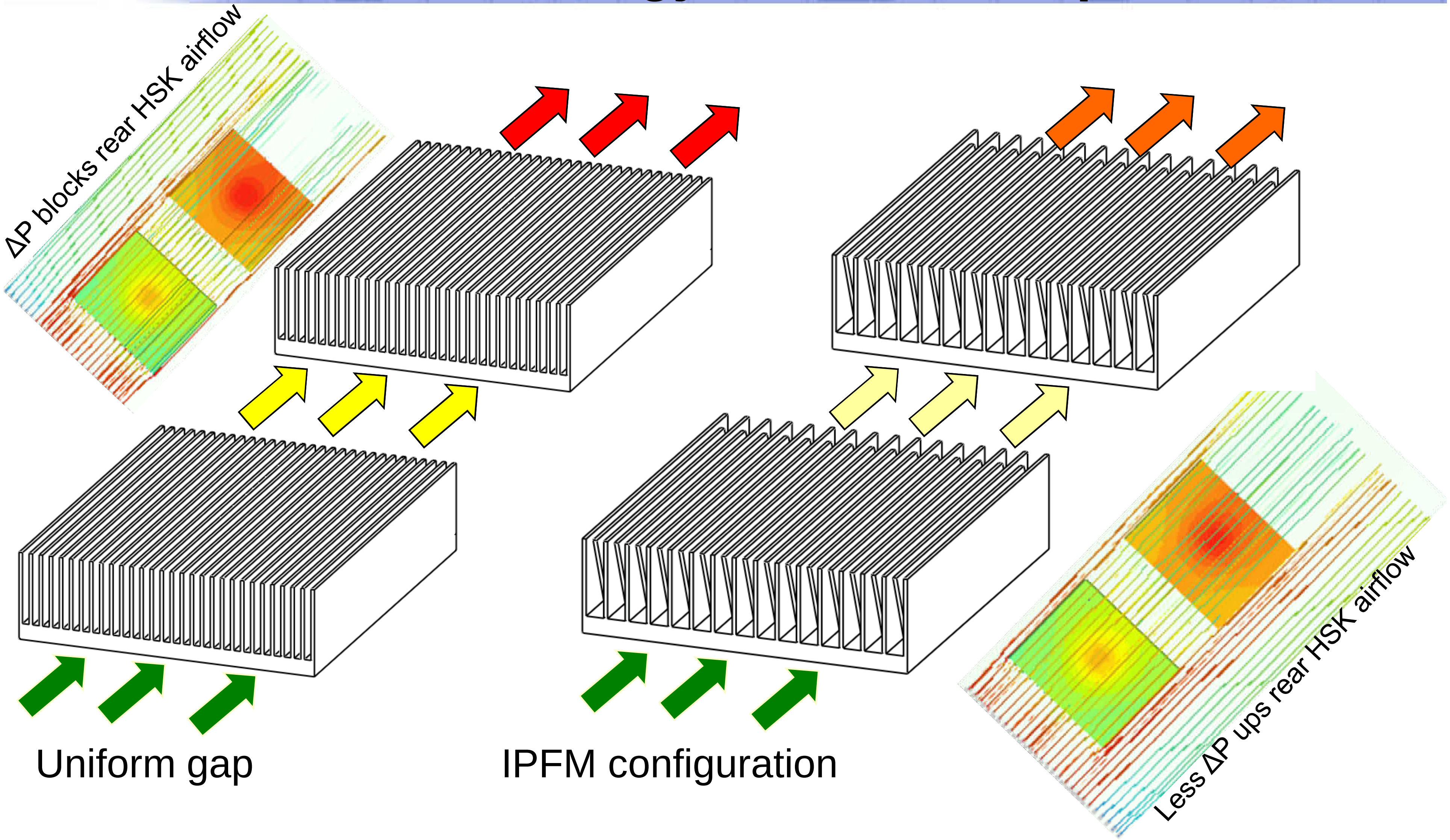
Result Analysis



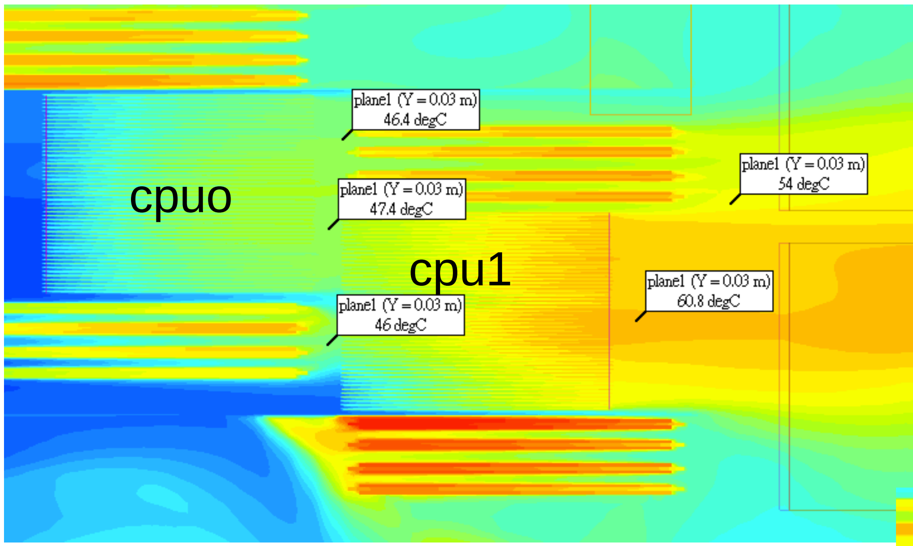
Volume Flow High (cfm)	Mass Flow High (kg/s)	Heat Flow High (W)	Temperature High (deg C)
9.52733	0.0052221	277.53	52.868
8.89739	0.0048768	264.64	53.985
9.64641	0.0052874	280.26	52.733
9.85724	0.005403	284.47	52.383

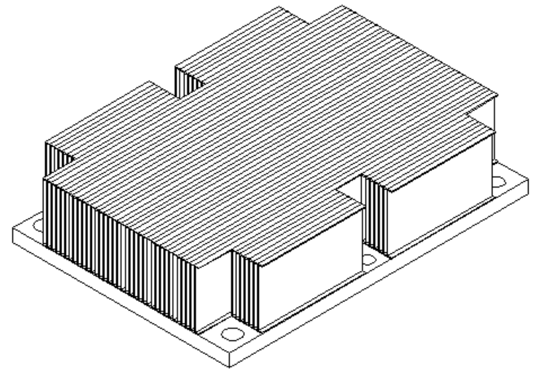


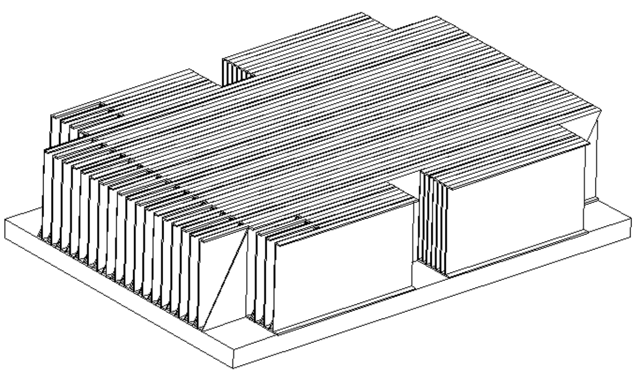
IPFM Technology in shadowed placement

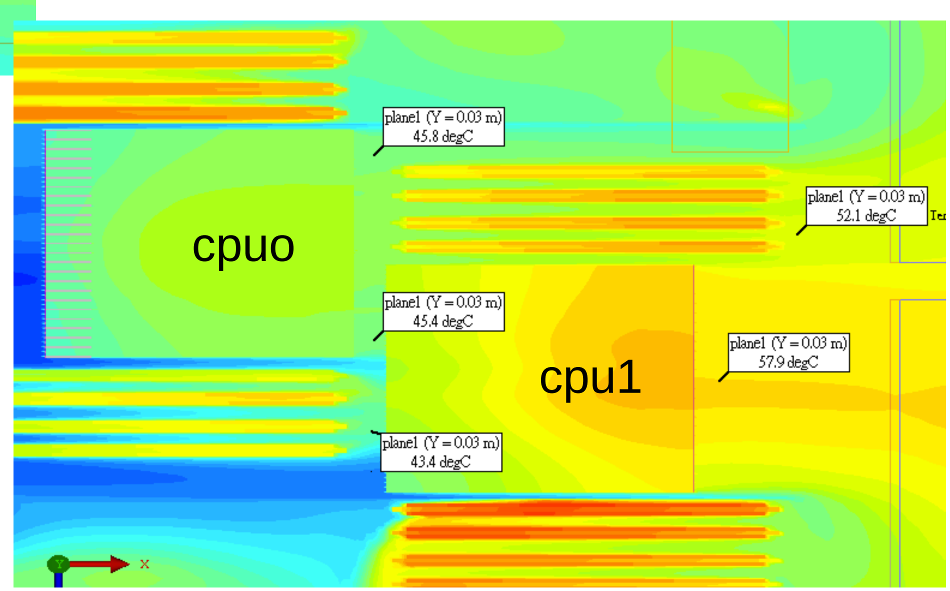


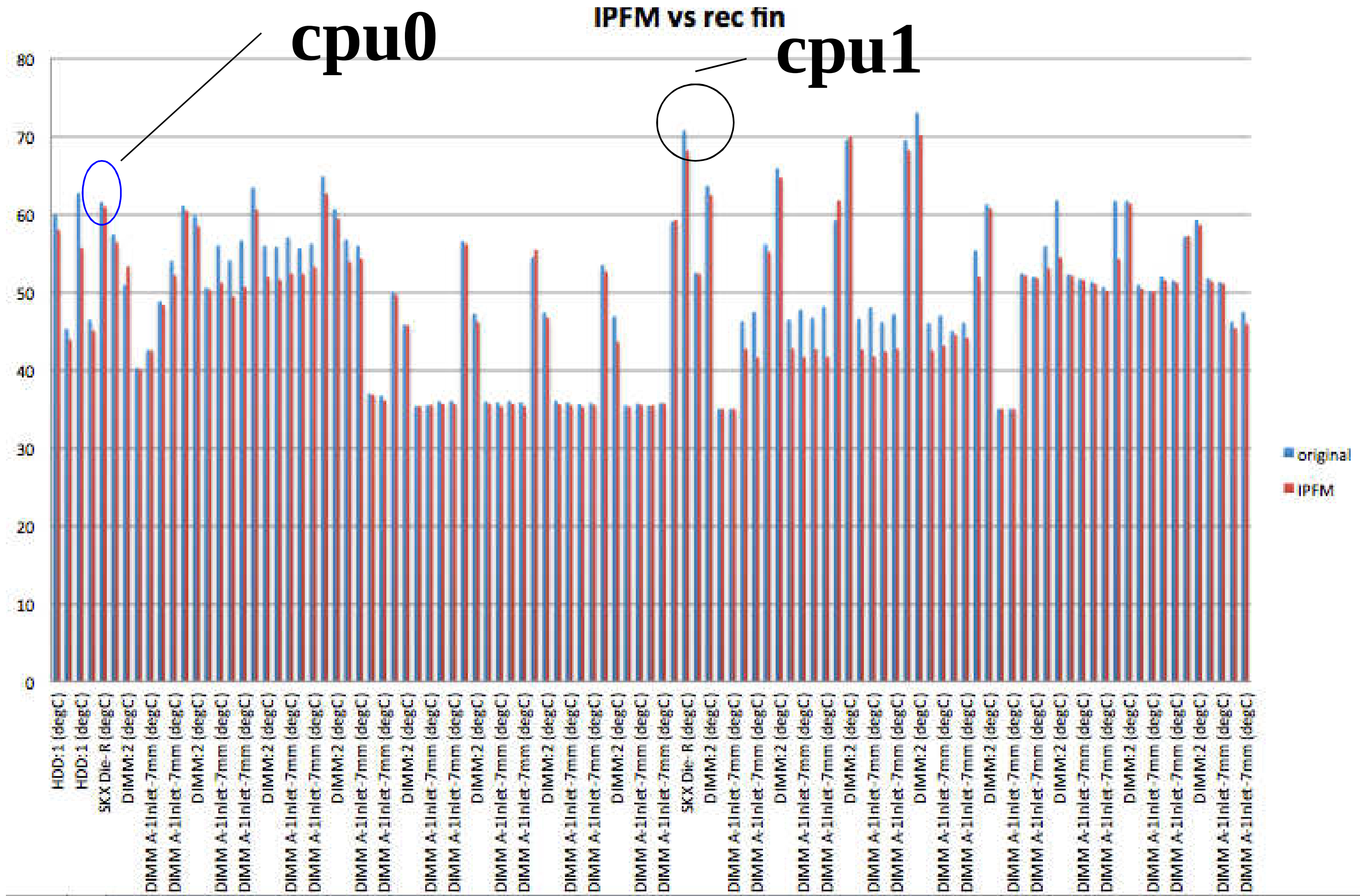
IPFM v.s rectangular fin design











DIMMs / HDD / ODD are much more beneficial from IPFM!!

CFD hard to see the trend?

Theoretical / Mathematical Analysis

Pressure drop calculation process

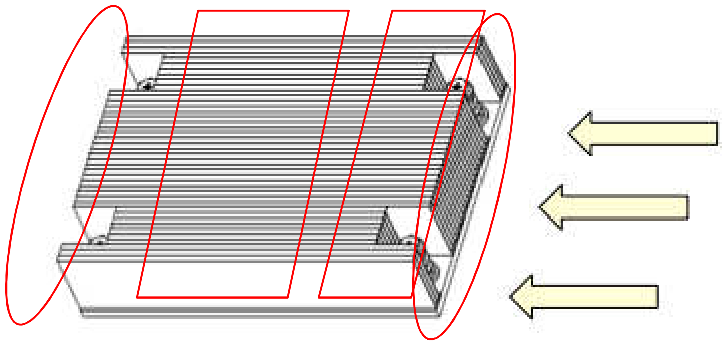
Inlet pressure drop

$A_c := b \cdot gap \qquad A_f := b \cdot pitch$

$\sigma := \frac{A_c}{A_f} = 0.83 \qquad K_c := 0.6$

$G_c := \frac{\rho_a(T_{in})\, v_f}{\sigma} = 5.484 \cdot \frac{kg}{sec \cdot m^2}$

$dP_i := \frac{G_c^2}{2} \cdot \left(\frac{1 - \sigma^2 + K_c}{\rho_a(T_{in})} \right) = 11.937 \cdot Pa$



Hydraulic developing length

$L_{hy} := D_h \cdot \left(\frac{.315}{.0175 + Re + 1} + .01 \cdot Re \right) = 24.833 \cdot mm$

Fully developed length

$L_{fd} := L - L_{hy} = 83.167 \cdot mm$

$dP_{fd} := \frac{4L_{fd}}{D_h} \cdot \frac{24}{Re} \cdot \frac{1}{2} \cdot \rho_a(T_{in}) \cdot v^2 = 42.123 \cdot Pa$

Developing pressure drop region

$$f_{dev} := \frac{1}{Re} \cdot \left[\frac{3.44}{\sqrt{\frac{L_{hy}}{D_h}}} + \frac{\left(24 + \frac{.674}{\frac{L_{hy}}{D_h}}\right) - \frac{3.44}{\sqrt{\frac{L_{hy}}{D_h}}}}{\left[1 + \frac{2.9 \cdot e^{-5}}{\left(\frac{L_{hy}}{D_h}\right)^2}\right]} \right] = 0.028$$

$G_c(f) := \frac{\rho_a(T_{in})\, v_f}{\sigma(f)} \qquad G_c(f) = 5.132 \cdot \frac{kg}{sec \cdot m^2}$

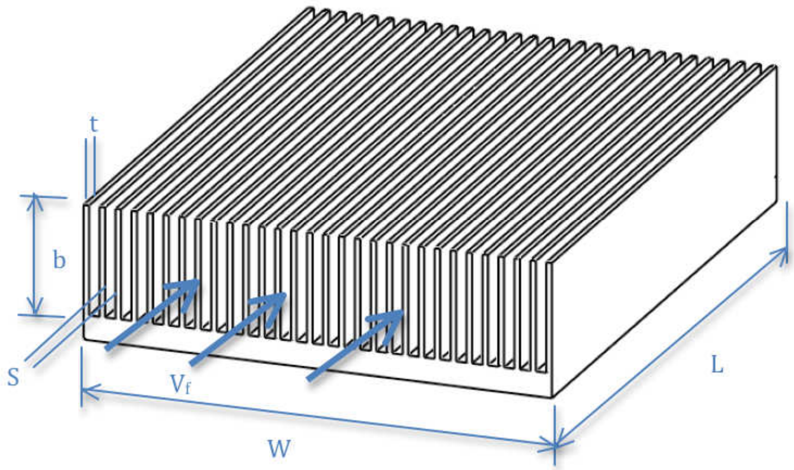
$dP_e(f) := \frac{G_c(f)^2}{2} \cdot \left(\frac{1 - \sigma(f)^2 + K_e}{\rho_a(T_{in})} \right) \qquad dP_e(f) = 4.747 \cdot Pa$

$dP_{dev} := \frac{4L_{hy}}{D_h} \cdot \frac{24}{Re} \cdot \frac{1}{2} \cdot \rho_a(T_{in}) \cdot v^2 = 12.578 \cdot Pa$

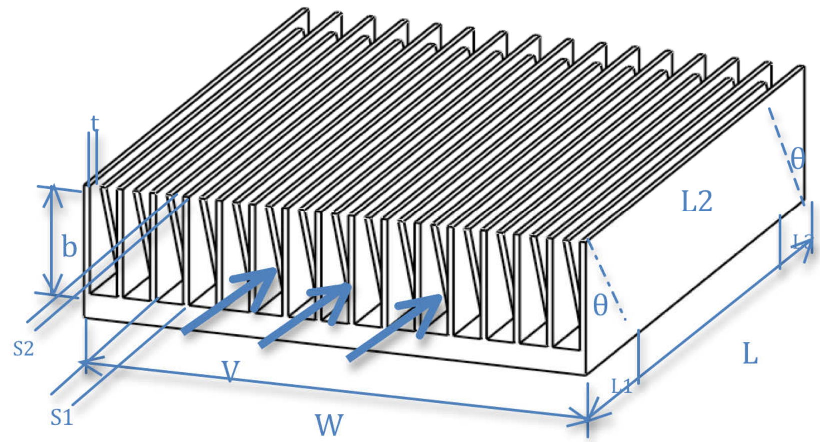
$dP(f) := dP_i(f) + dP_{dev}(f) + dP_{fd}(f) + dP_e(f) \qquad dP(f) = 53.86\,Pa$

Theoretical analysis ✓

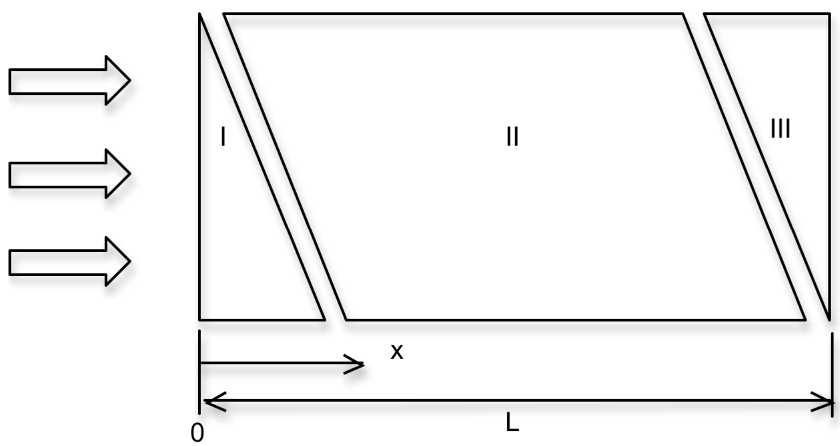
Theoretical analysis ??



Uniform gap



Non-uniform gap



$$\Delta P_{fd,3} = \lim_{p\to 0}\int_p^{L_3} \frac{4}{D_{h3}(x)}dx\, f_{fd,3}\frac{1}{2}\rho v_3^2$$

$$= \lim_{p\to 0} \frac{2\,(\mathrm{b}\,(\mathrm{L}_3\ \text{-}\ \mathrm{p}) + \mathrm{L}_3\ 2\mathrm{s}\ (\mathrm{Ln(L)}\ \text{-}\ \mathrm{Ln(p)})}{b2s} f_{fd,3}\frac{1}{2}\rho v_3^2$$

$$= \lim_{p\to 0} \frac{2\,(\mathrm{b}\,(\mathrm{L}_3\ \text{-}\ \mathrm{p}) + \mathrm{L}_3\ 2\mathrm{s}\ (\mathrm{Ln}(\frac{\mathrm{L}}{p})\,)}{b2s} f_{fd,3}\frac{1}{2}\rho v_3^2$$

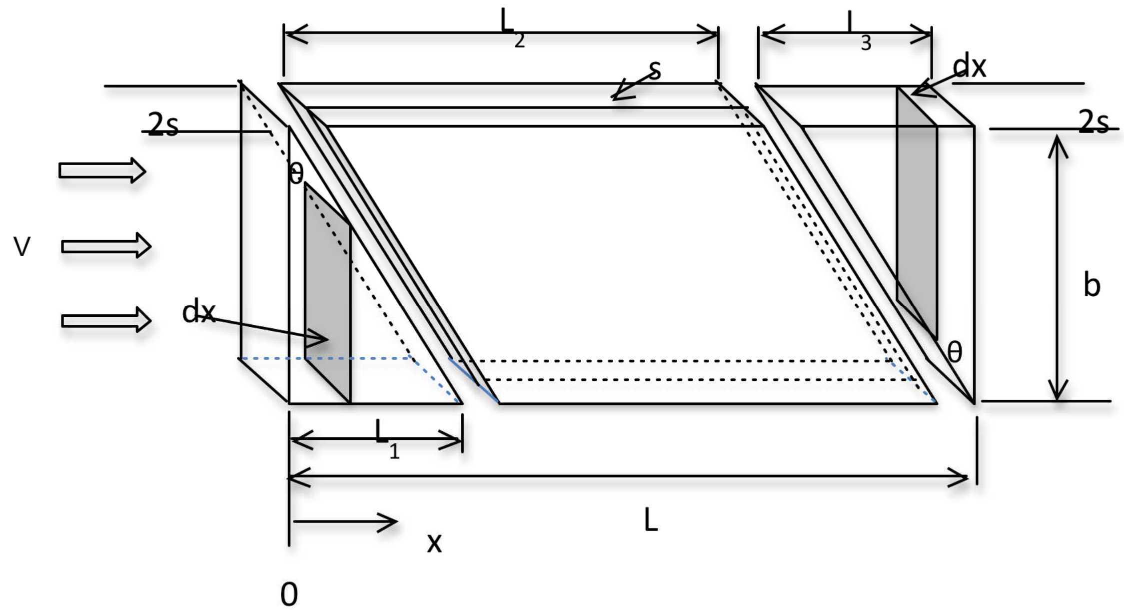
$$= \frac{2bL_3}{b2s} f_{fd,3}\frac{1}{2}\rho v_3$$

$$\Delta P_{fd,3} = \frac{L_3}{s} f_{fd,3}\frac{1}{2}\rho v_3^2$$

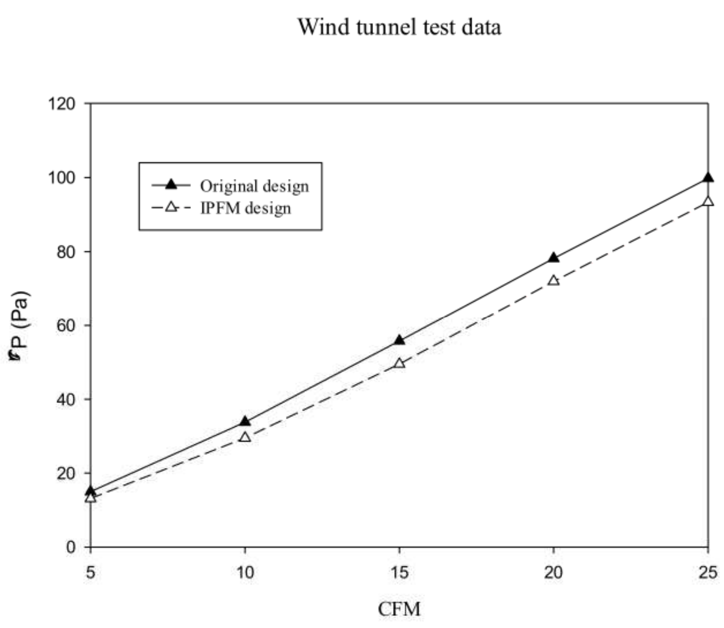
$$x_1^+ = \int_0^{L_1} \frac{dx}{\mathrm{Re}(x)D_h(x)}$$

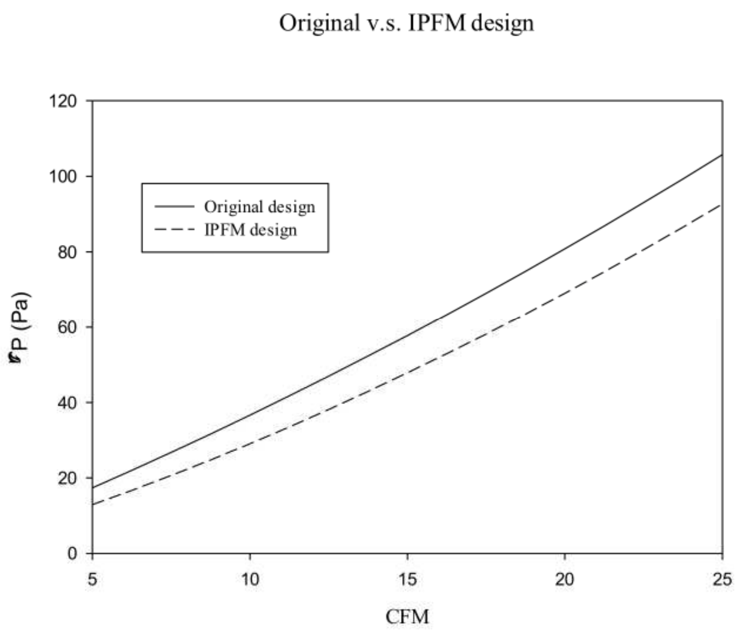
$$x_1^+ = \lim_{p->L_1}\int_0^p \frac{\mu}{\rho v_1 D_{h1}(x)^2}dx$$

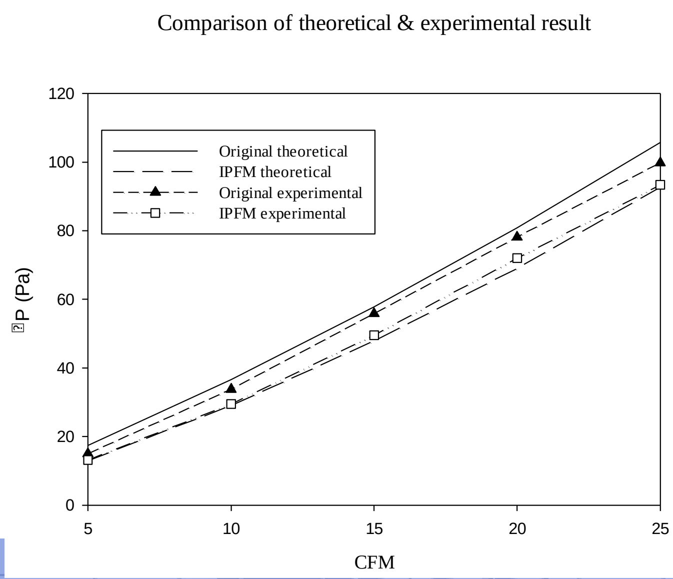
$$x_1^+ = \lim_{p->L_1}\int_0^p \frac{\mu}{\rho v_1\left[\dfrac{2(b\dfrac{L_1-x}{L_1}2s)}{b\dfrac{L_1-x}{L_1}+2s}\right]^2}dx$$



Comparison of analytical & experimental results





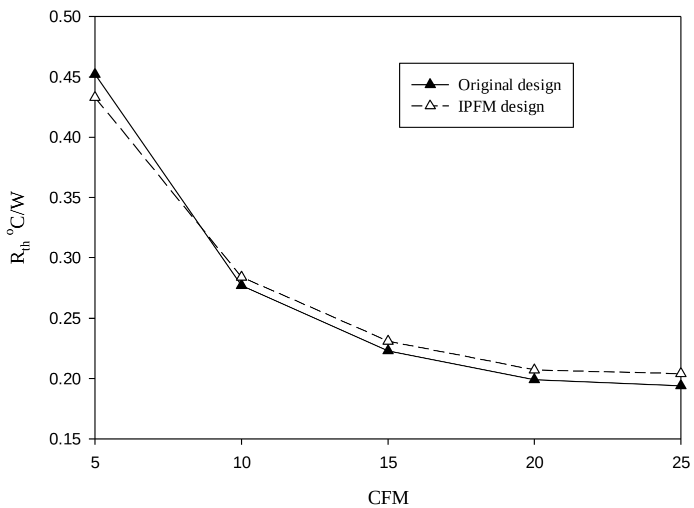


Derived analytical estimation is close to experimental results within acceptable accuracy!

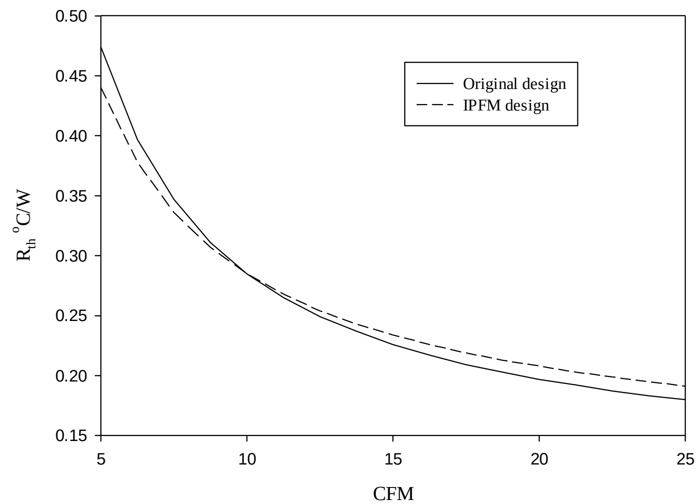
This derived algorithm can be used to predict The relationship of cutting angle vs. dP vs. Rth

Relationship of CFM vs. Rth

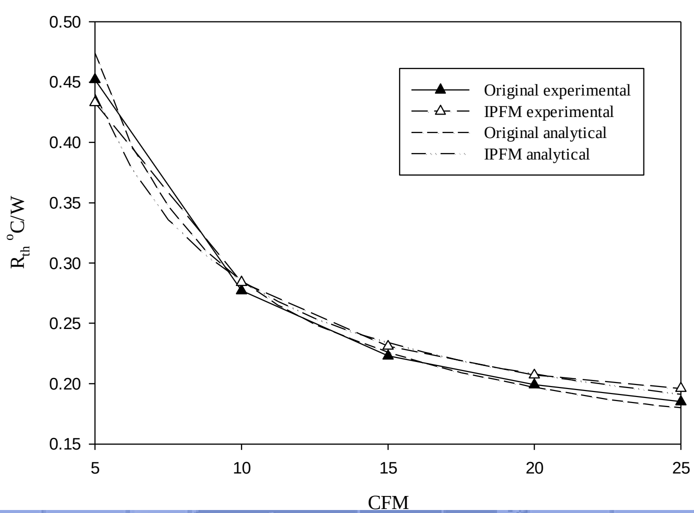
Wind tunnel test data



Comparison of analytical results



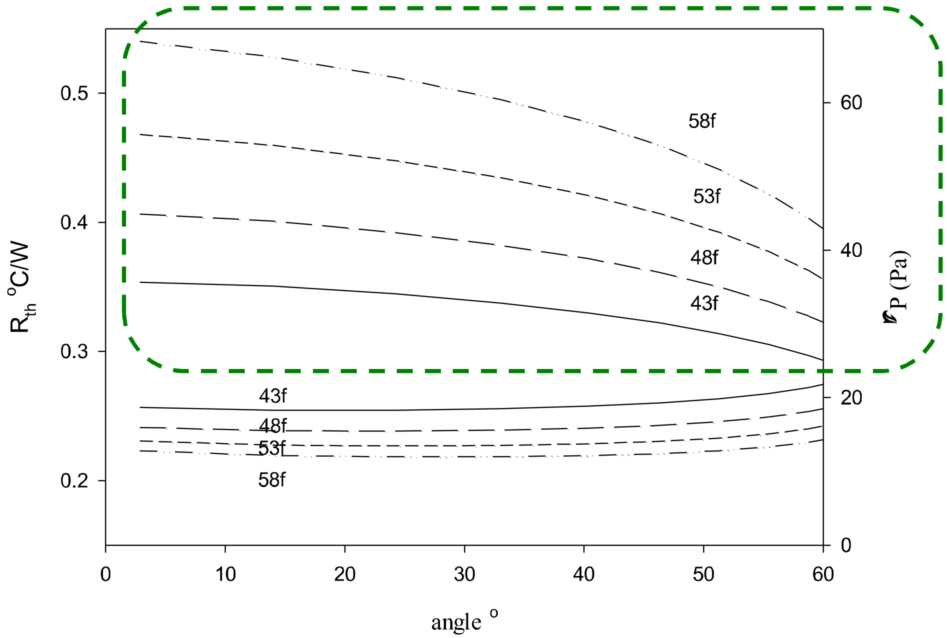
Comparison of analytical and experimental results

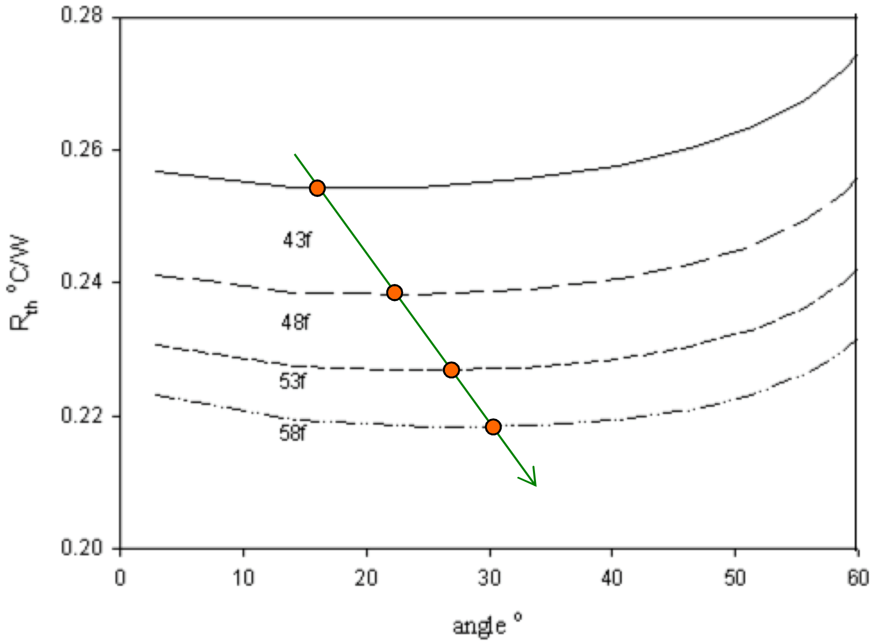


Derived analytical estimation is close to experimental results within acceptable accuracy!

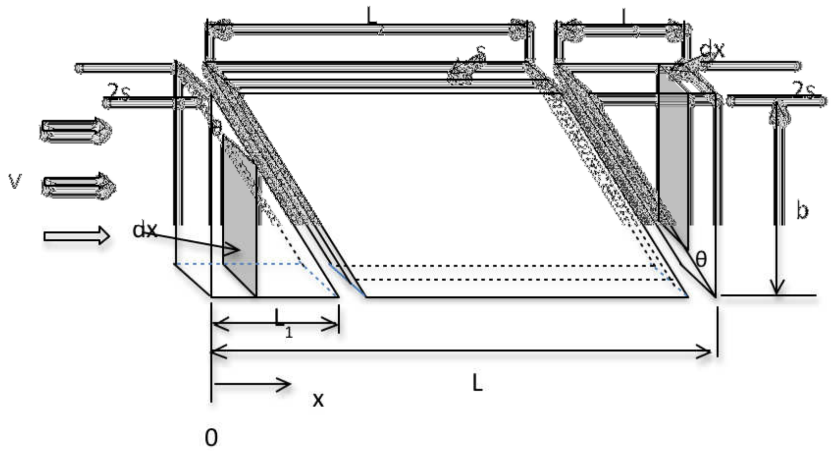
This derived algorithm can be used to predict The relationship of CFM vs. Rth

Relationship of cutting angle vs. fins vs. dP vs. Rth





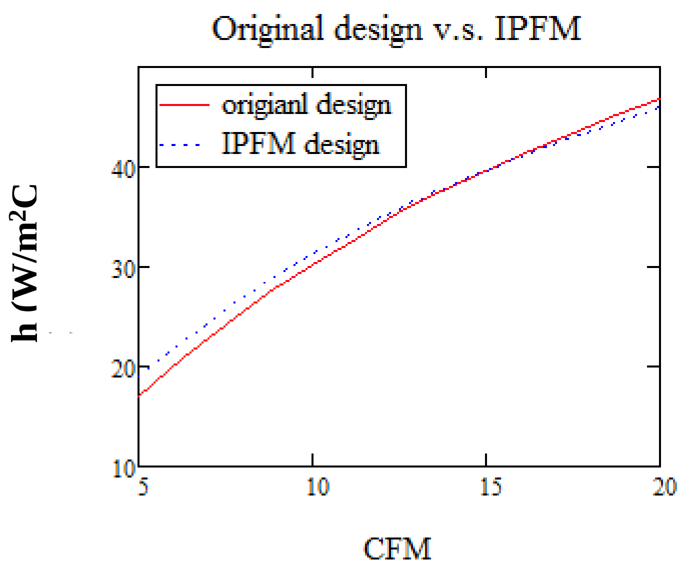
Reasons of IPFM unique characteristics for h value

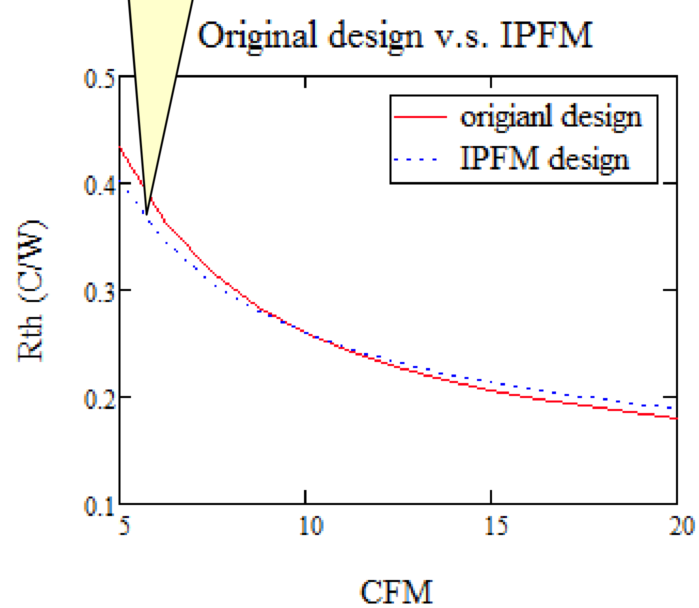


$$Nu = C * Re^m * Pr^n$$

$$Re = (V * 2s)/\nu$$

Why IPFM is better?



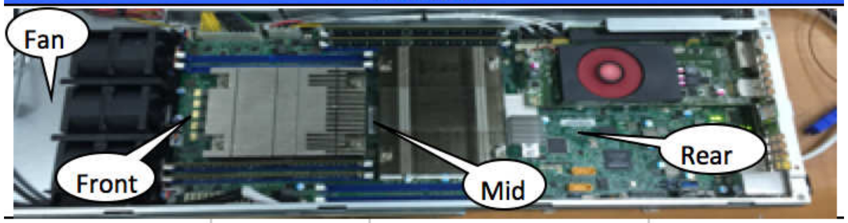


Supermicro server system

- Platform: Dual socket R3 (LGA 2011) supports
- Intel® Xeon® processor E5-2600
- Layout: Full shadowed

Test of velocity

Location

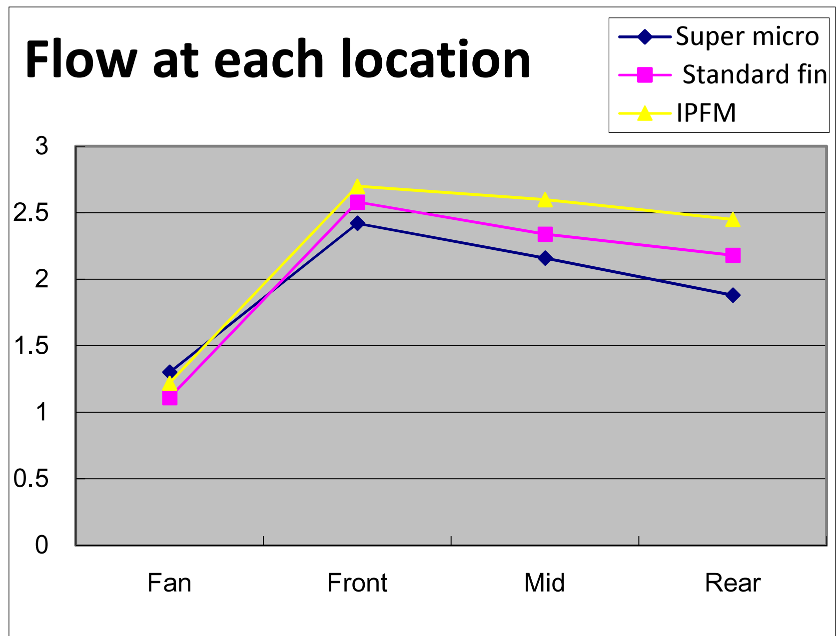


Module

- Standard fin

- IPFM

Flow test			
Flow (m/s)	Super micro	Standard fin	IPFM
Fan	1.3	1.11	1.22
Front	2.42	2.58	2.7
Mid	2.16	2.34	2.6
Rear	1.88	2.18	2.45



Thanks for your attention!