

**iMAPS 2010**  
**MicroChannel in Liquid Cooling Systems for  
Advanced Microprocessors**

September  
2010





# Liquid Cooling with MicroChannel Enhanced Base Plates for the High-End Server Market

## Micro-Channel construction making commercial head way

- Liquid cooling systems have been serving the “over clocker and gaming” markets for some time. The mainstream commercial server industry is closely watching the technical evolution and advancement of this liquid cooling product technology as costs come down and reliability and thermal performance improve.
- New micro-channel construction on the base plate surface is one major factor in the advancement of this liquid cooling segment.
- Several approaches to manufacturing micro-channels
- Review several commercial MicroChannel cold plate surfaces in use today
- MicroCool™ comparison with commercial laser diode cold plate
- Benefits of a manifold single phase systems: IBM, CoolIT and Univ. of MD
- IBM Zero Emissions challenge for a liquid cooled cool plate and cooling loop for a high-end blade server
- Two phase cooling , air cooled micro-channel and other future concepts

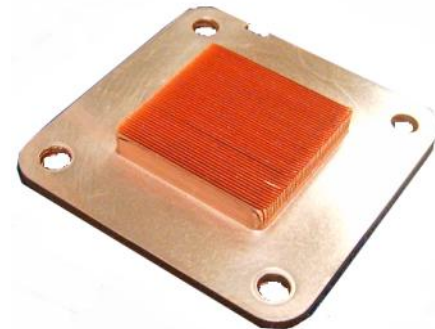
# MicroCool Division

- WLV MicroCool division has taken the same deformation process used on tubes and adapted it to be used on flat plates.
- The flat plate surface enhancement range has been optimized to suit liquid cooling of electronics.
- Leveraging Wolverine's core high temperature joining and fabricated assembly technologies they can turn these enhanced surfaces into complete cold plate assemblies.
- MicroCool is able to create custom, cost effective, high performance mezzo and micro channel cold plates quickly and with a high degree of flexibility.

Enhanced Tube



Enhanced Flat Surface



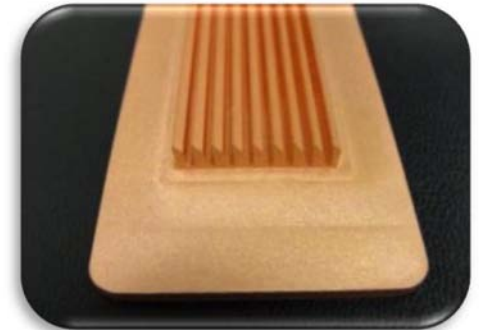
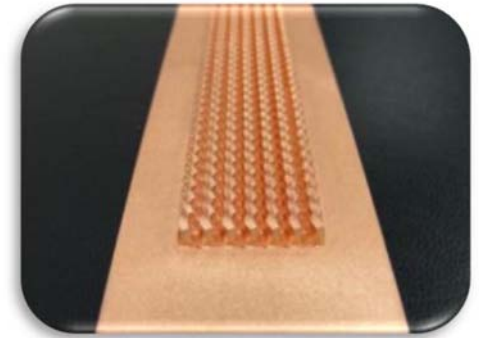
# Manufacturing Methods for Micro-Channel

## There are multiple methodologies for manufacturing straight line micro-channel

- Simple carbide tip dicing saw blade
- Traditional Skiving
- Photo-Resist and etching
- Wire EDM
- Extrusion
- MDT
- Water Jet Cutting

## Multiple Approaches for Pin Fin Geometries

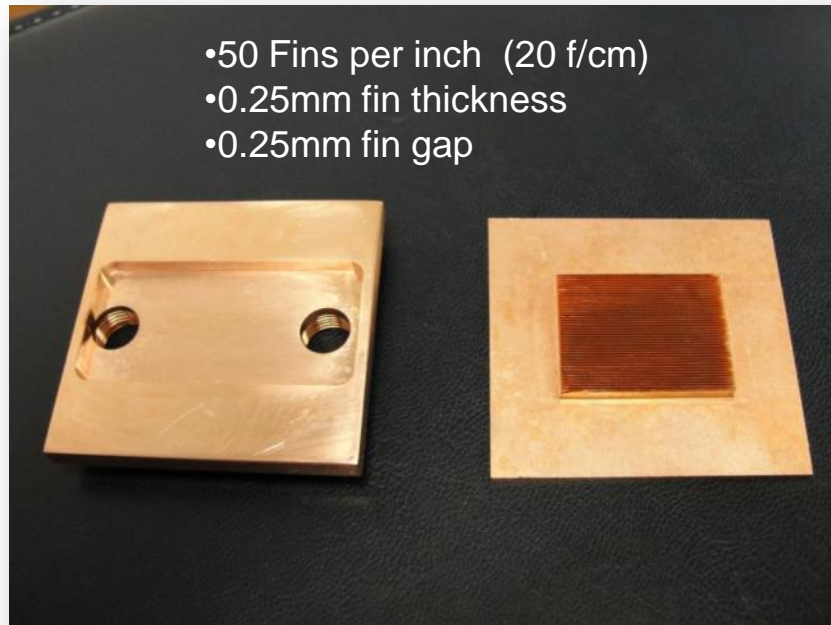
- Metal Injection Molding (MIM)
- Cold forged Al and Copper
- Forged Al and Copper Castings
- MDT
- Water Jet Cutting



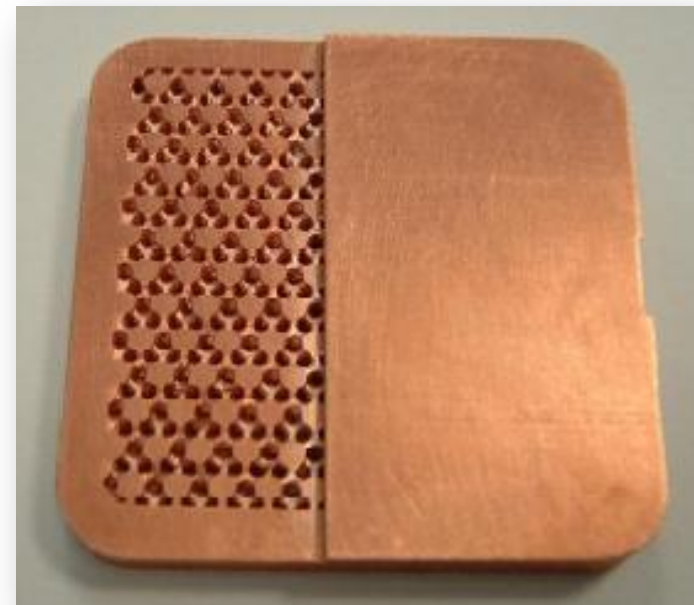
# MDT vs Leading Competitor

The MicroCool™ coldplate was tested against the leading competitor by the Fraunhofer Institute for Integrated Systems and Device Technology. As you can see the below the construction of our cold plate is very simple unlike the competitors.

## MicroCool™ Cold Plate

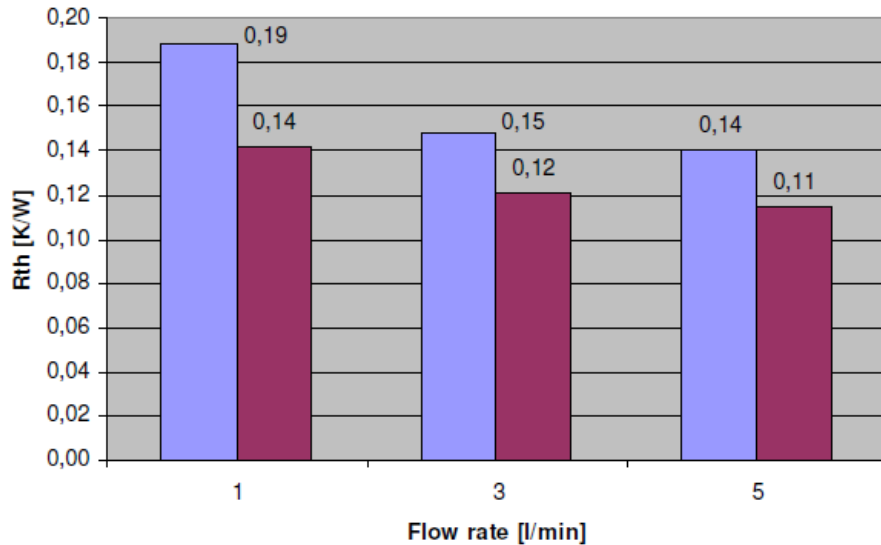


## Leading Competitor

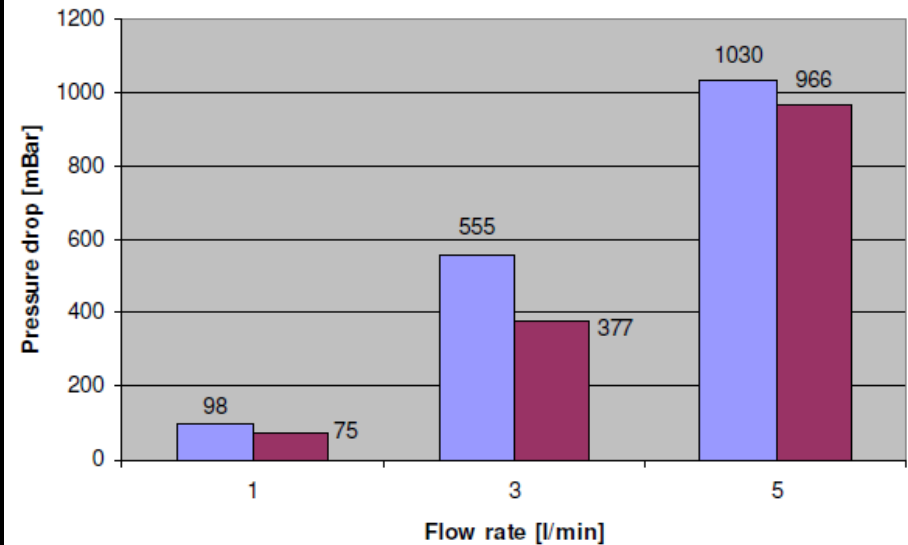


# MDT vs Leading Competitor

Thermal resistance Water 25 °C



Pressure drop Water 25 °C



- MicroCool™
- Leading Competitor

At all 3 flow rates the MicroCool™ coldplate beat out the competition in both thermal resistance and pressure drop.

# CoolIT – Commercial Liquid Cooling Systems

Worlds leading manufacturer of active liquid cooling systems for the consumer server market

- Based in Calgary, Canada
- Manufactures in Shenzhen Province
- Purchased Delphi's liquid cooling div.
- Major Supplier to Apple and Dell
- 10,000 base plates per month
- 100% supplied by MicroCool™ in China
  - Fully Certified ISO 9001 Plant

**CoolIT**  
SYSTEMS™



# CoolIT - MicroCool® Advantage

Design of the copper coldplate and manifold was highly optimized to take advantage of a very dense fin pitch but still provide low pressure drop.

Thermal resistance of 0.05 c/w at a flow rate of only 0.5 l/min



# IBM – Aquasar with MicroCool® inside

## IBM Committed to Zero Emissions Data Center

- Wolverine designed the basic cold plate design with collaboration with Prof. J. Thome, PhD
- Integrated with EPFL and IBM Zurich blade design
- Only cold plate to meet thermal performance
- Lowest cost cold plate option
- First 100 cold plates in test at ETH, Zurich
- Wolverine awarded total cooling loop
- 1,200 cold plate trial pending

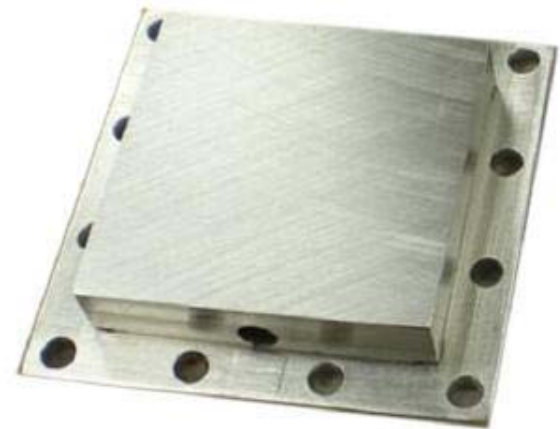
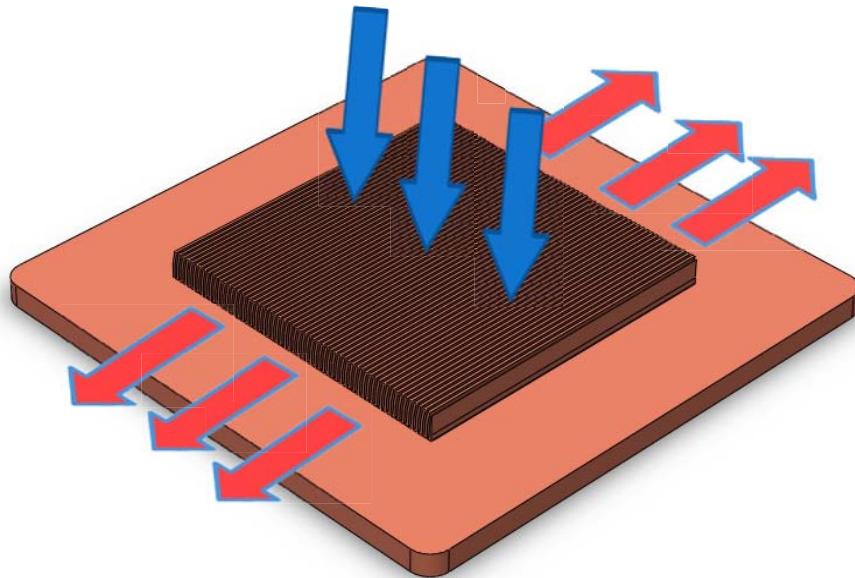


Water-Cooled IBM BladeCenter HS22

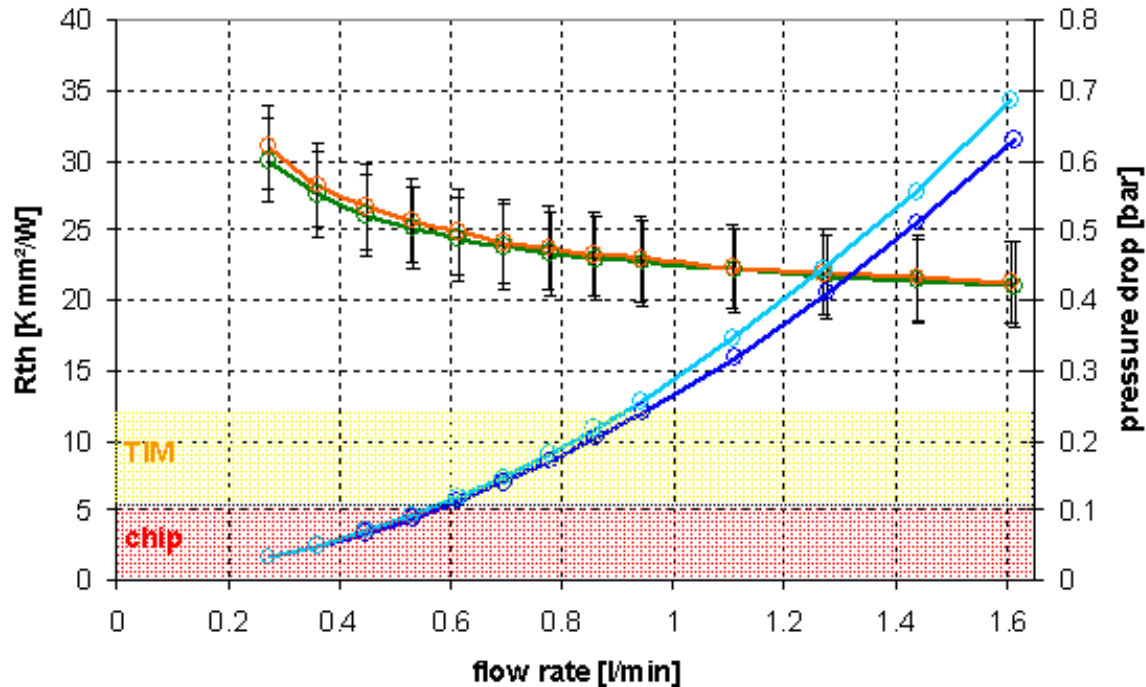
Credit: IBM Research – Zurich

# IBM – Coldplate view

MicroCool™ developed “split flow” manifold based on Prof. John Thome, PhD (EPFL) concept to decrease pressure drop allowing the use of a denser fin array to increase thermal performance.



# IBM - Single Phase Split Flow Empirical Data



Above is a plot with the performance of the first two Cold Plates. Shown are the thermal resistance (red and green line) and the pressure drop (blue and cyan line) for flow-rates between 0.25 and 1.6 l/min. The experiment is in reasonable agreement with IBM-modeling for fin-structure: thermal resistance about 10 K mm<sup>2</sup> / W and pressure drop 0.078 bar at a water flow of 0.5 l/min.



# CPU Cold Plate University of Maryland

- University of Maryland – Comparison of two manifolding methods for use with micro-channel cold plates
  - TMHS: Traditional Micro-channel Heat Sink
  - FFMHS: Force Fed Micro-channel Heat Sink
- Optimized fins structures used with a force fed manifold increase the thermal performance over traditional micro-channel
- Performance differential increases as the heat source area grows larger.

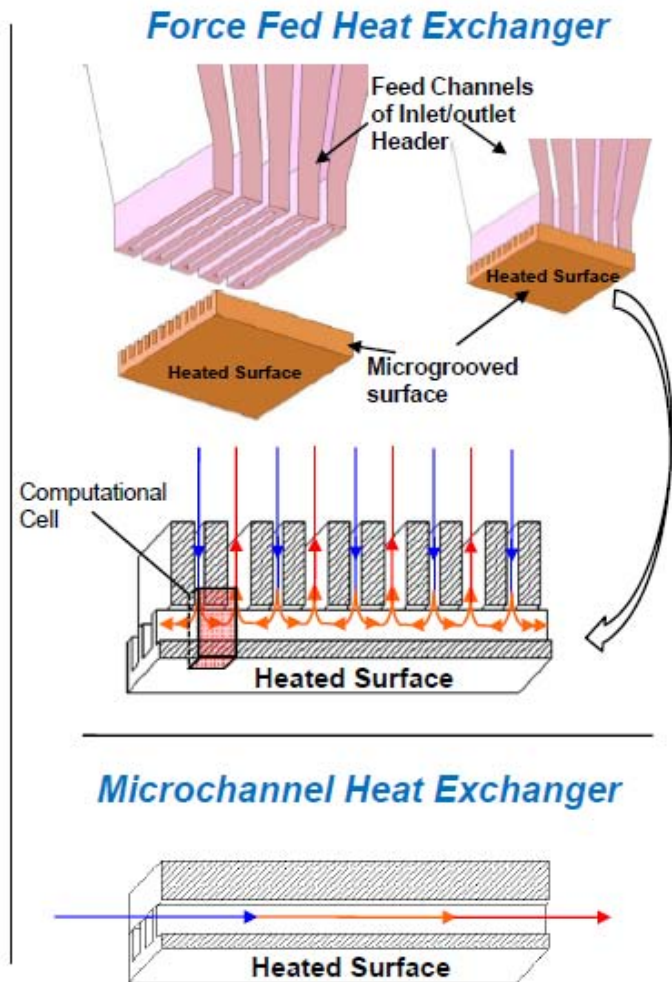


## Single Phase Force Fed Heat Transfer

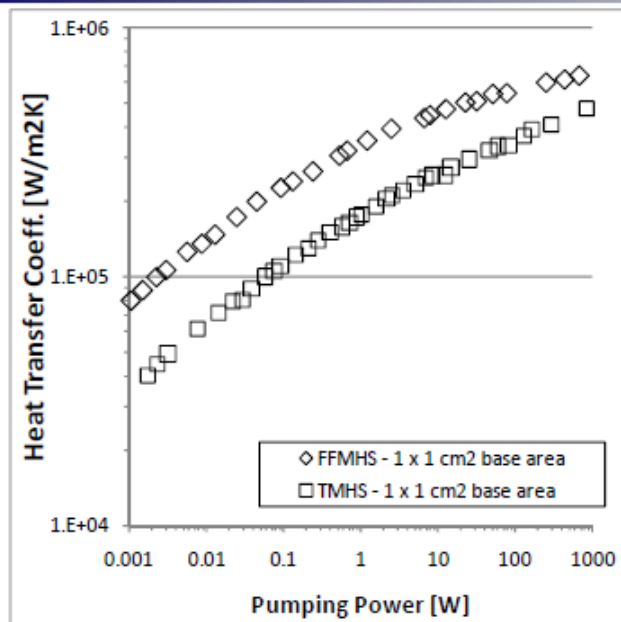
Combination of microgrooved surfaces with developed system of feed channel

Benefits of single phase Force Fed Heat transfer:

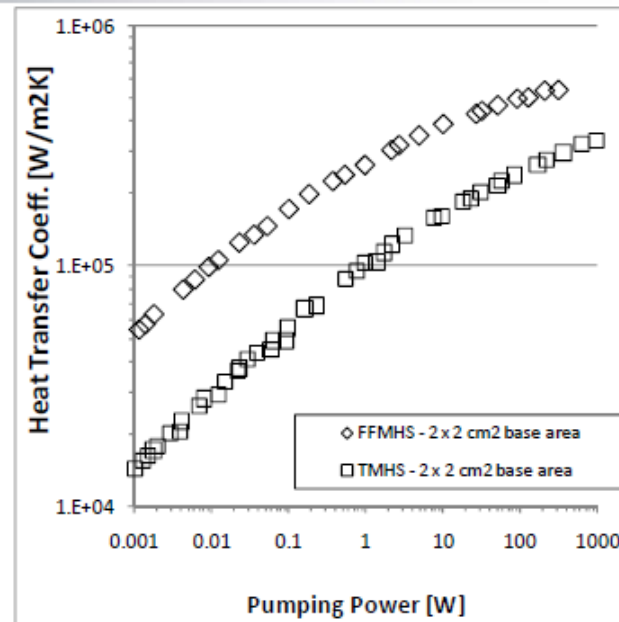
- Decreases pressure drop substantially by creating many arrays of microchannels working in parallel
- Benefits from thermal entrance effects
- Suitable for large area cooling, excellent surface temperature uniformity
- Inlet and outlets perpendicular to the microgrooved surface can create secondary flows that enhance heat transfer



## Technology Comparison



	Pumping Power at 100 000 w/m2k	Heat Tr. Coeff. at 1 W Pumping Power
FFMHS	0.002315	335249
TMHS	0.056784	175118



	Pumping Power at 100 000 w/m2k	Heat Tr. Coeff. at 1 W Pumping Power
FFMHS	0.009263	263390
TMHS	0.982047	104811

0.9%

- For 1x1 cm<sup>2</sup> heat sink, the FFMHS can perform almost twice better in heat transfer and use just 4% pumping power compare to microchannels.
- The advantages of FFMHS significantly increase for the larger cooling areas



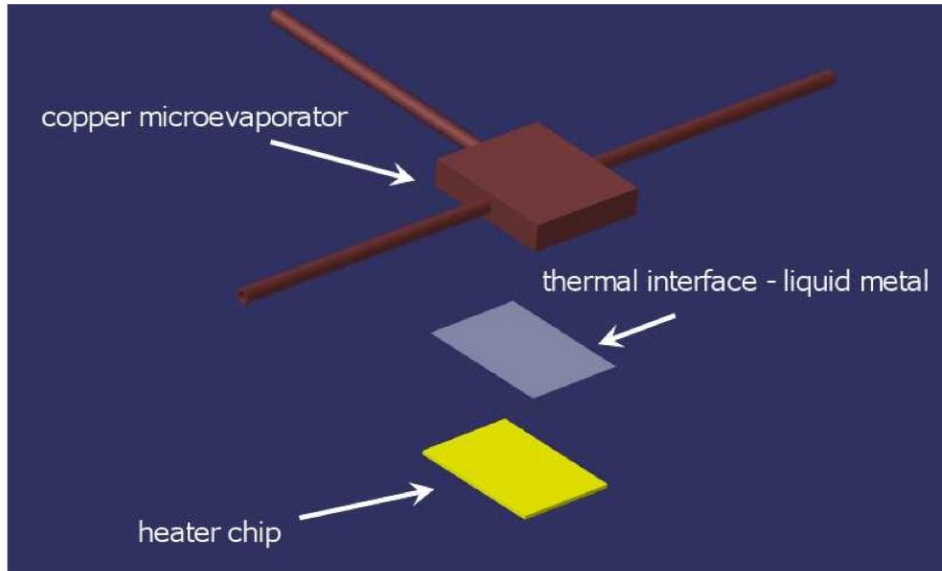
# Two Phase Cooling Applications

## Multi-microchannels heat spreaders for cooling of CPUs

Cooling CPUs dissipating heat fluxes higher than  $300 \text{ W/cm}^2$  while operating at  $85^\circ\text{C}$  maximum.

- Although liquid cooling is the preferred near-term solution, cooling of computer chips through flow boiling of refrigerants seems to be a more long-term solution.
- Taking advantage of the latent heat liberated during boiling of refrigerants allows to work at lower mass flow rates and thus reduces pumping power, resulting in a more energy efficient system.
- Two-phase flow boiling is also interesting in terms of thermal interface durability as the phase change occurs at a constant temperature. Temperature uniformity is also suited for CPUs since too large gradient could damage them.

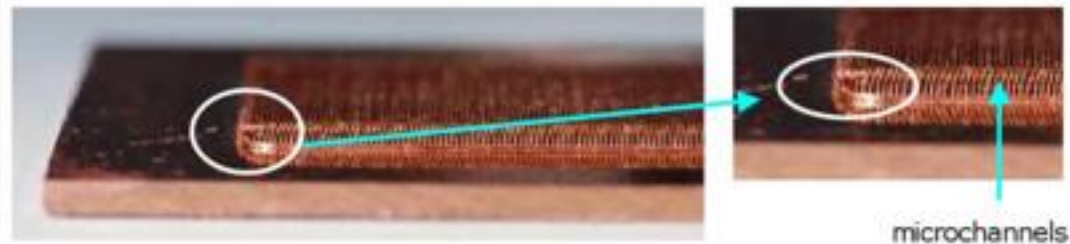
# Two phase cooling: EPFL & IBM Zurich Research Laboratory



WOLVERINE  
**MICROCOOL™**

Multi-microchannel heat sink

100 parallel channels  
100  $\mu\text{m}$  wide  
680  $\mu\text{m}$  high  
15 mm long  
72  $\mu\text{m}$  gap between fins

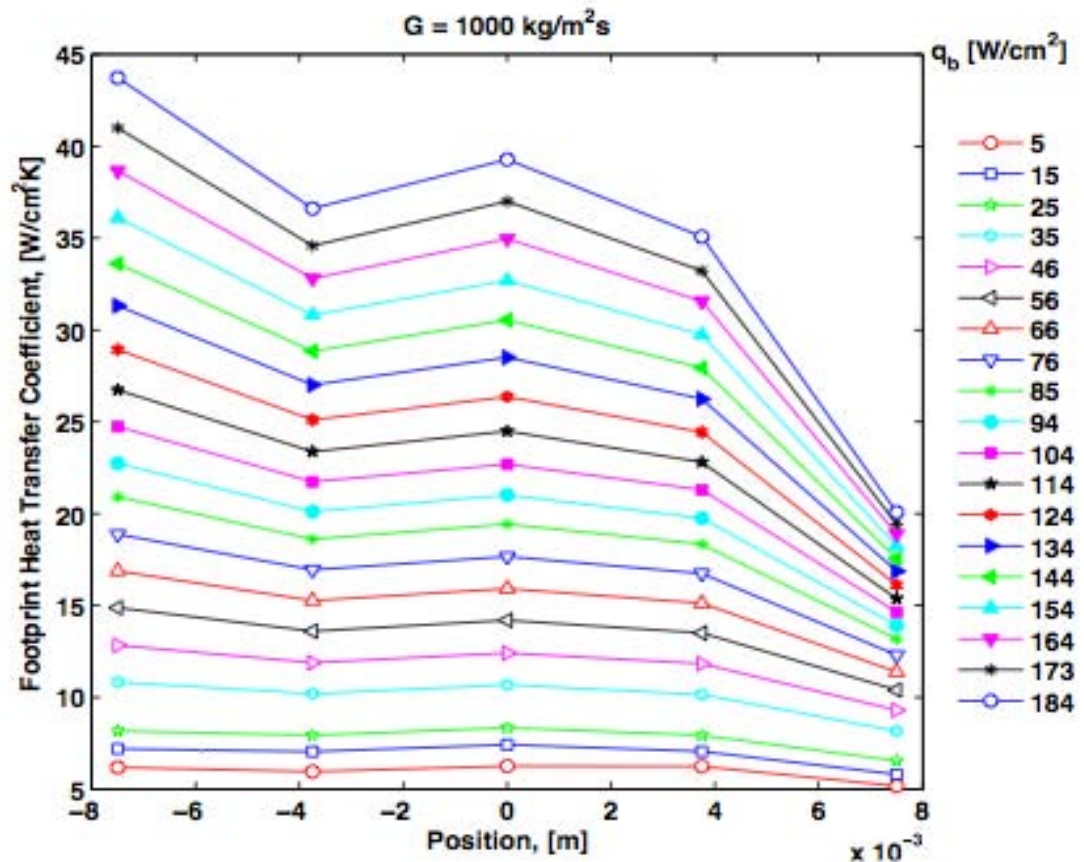


# Thermal Performances of the MicroCool Evaporator

## EPFL & IBM Zurich testing results

Very high heat transfer coefficient for increasing base heat fluxes.

Heat transfer coefficients as high as 40 W/cm<sup>2</sup> K can be reached with flow boiling of refrigerant R134a in the MicroCool Evaporator



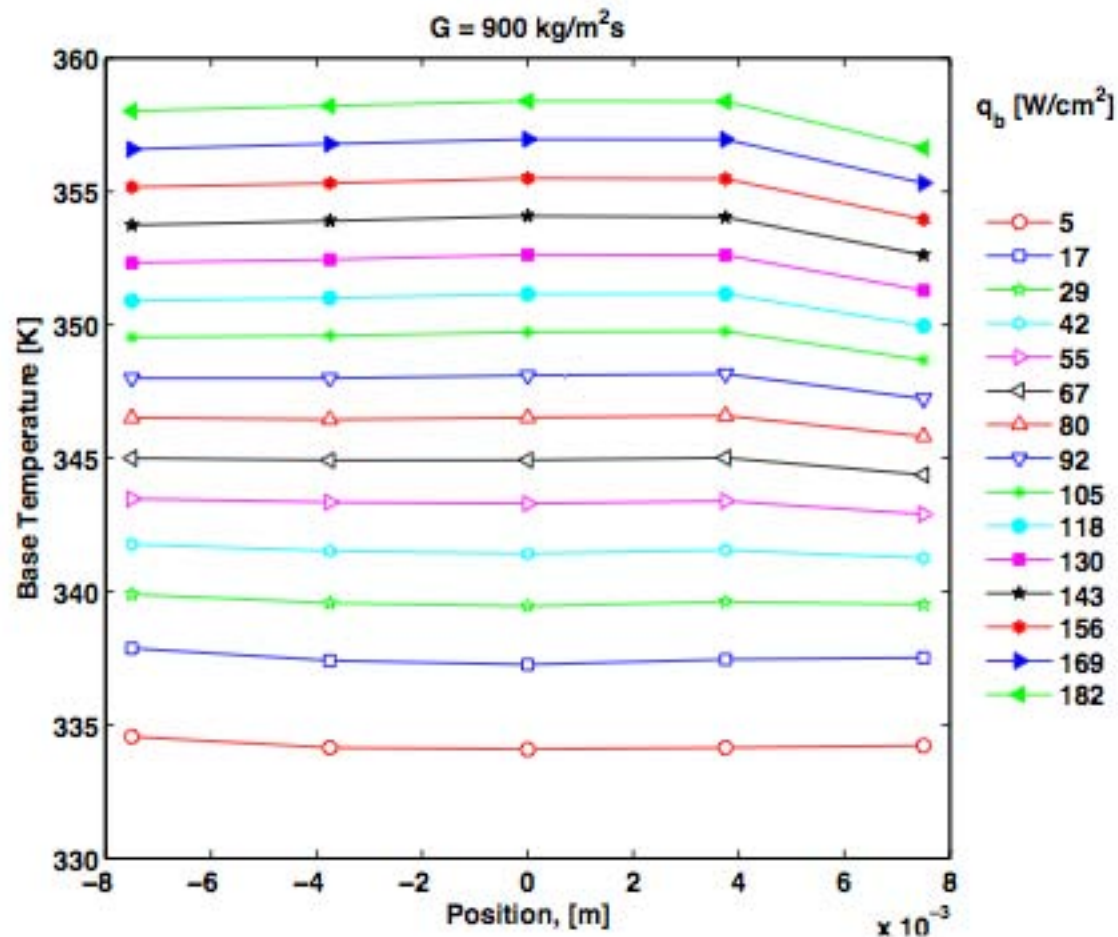
# Thermal Performances of the MicroCool Evaporator

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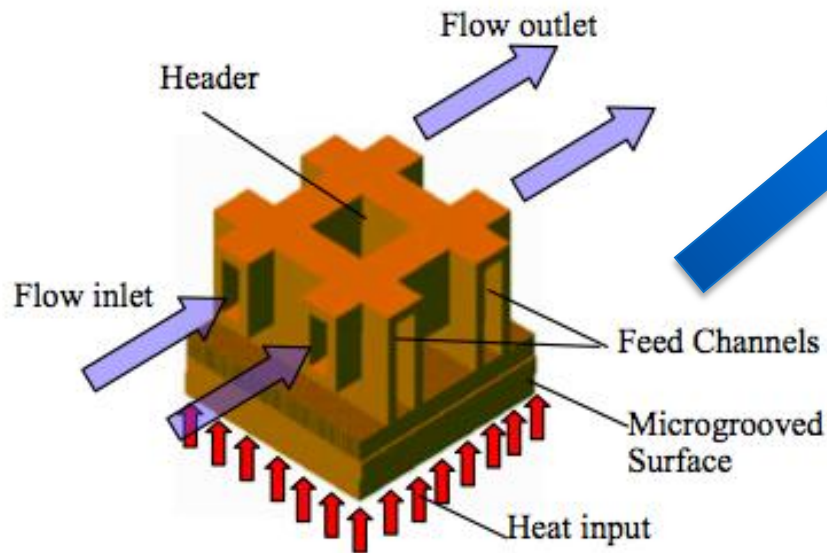
Base temperatures along micro-channel for increasing heat fluxes

Two phase cooling insures a very temperature uniformity along the flow path

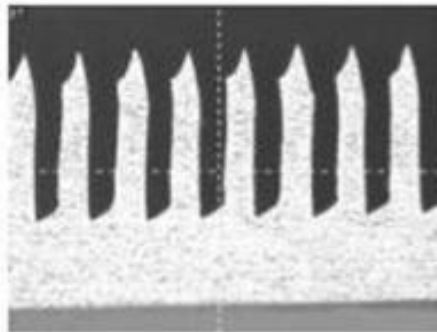
Maximum temp. gradient was  $0.3^{\circ}\text{C}/\text{mm}$  at  $188 \text{ W}/\text{m}^2$



# Forced-Fed Micro Channel Boiling – Univ. of MD



(a)



(b)

- Combination of Microchannels with developed system of feed channel

- Heat transfer coefficient over  $300 \text{ kW/m}^2\text{K}$
- Successfully tested for cooling  $925 \text{ W/cm}^2$
- Decrease pressure drop by creating many arrays of microchannels working in parallel



# Conclusions - MicroChannel Base Plates

- Liquid Cooling is penetrating the high end desk top server market; retail, OEM and System Integrator
- Single phase liquid cooling with micro-channel base plate
  - Improved thermal performance
  - Lower cost and more consistent quality micro-channel base plates
  - Low tooling cost for rapid product design change
- Micro-Channel key to liquid cooling of the blade server
  - Fin density with manifold construction
  - Energy savings pays for the cooling loop: 12-18 mo
  - Small size, weight and profile
- Two phase cooling continues in development and test



# Thank You

WOLVERINE  
**MICROCOOL**<sup>TM</sup>  
ENGINEERING THERMAL INNOVATION

