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FNSNF

Two-Phase Microchannel Thermosyphon Cooling System for Blade/2U Servers

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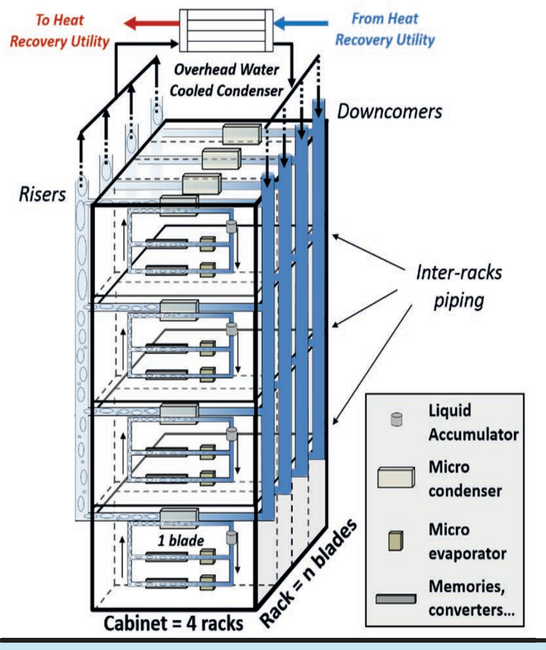
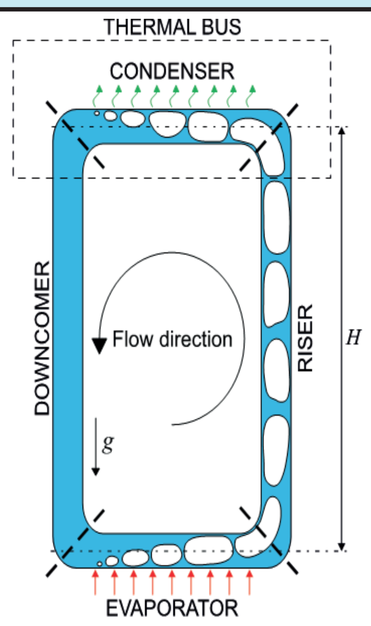
1 - Context/Motivation

a) From air cooling to on-chip two-phase cooling in datacenters:

- Better cooling performance
- Reduce the power consumption
- Allow the reuse of evacuated heat



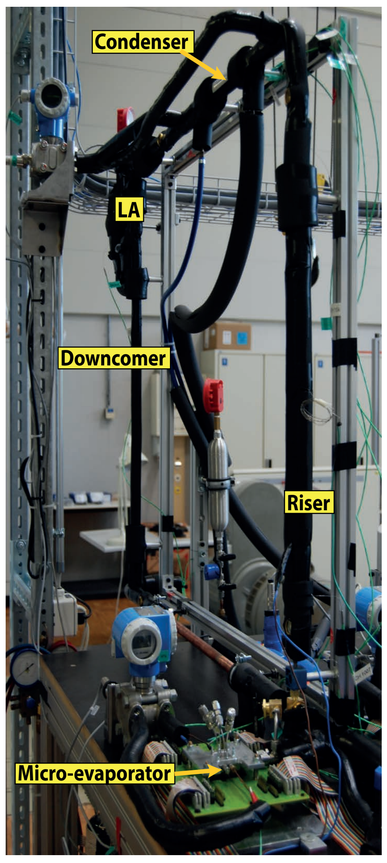


b) From pumped/compressed to thermosyphon on-chip two-phase cooling in datacenters:

- Gravity driven
- No power consumption
- Passive system control

2 - Experimental System

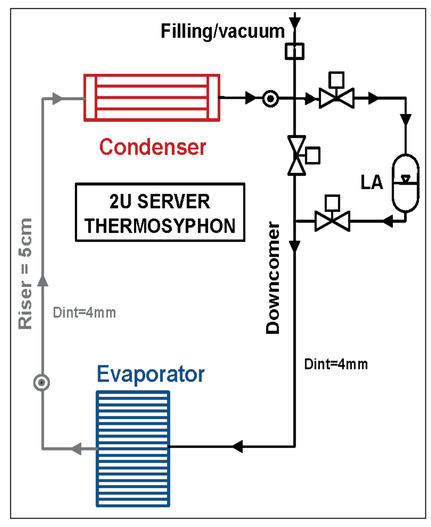
a) Old proof of concept system



Proof test:
20.2 W/cm² (47W) freely removed with a mean chip temperature of 25.0°C and a saturation temperature of 21.3°C (R134a refrigerant). Water inlet and outlet temperatures in the condenser were respectively 10 and 19.2°C.

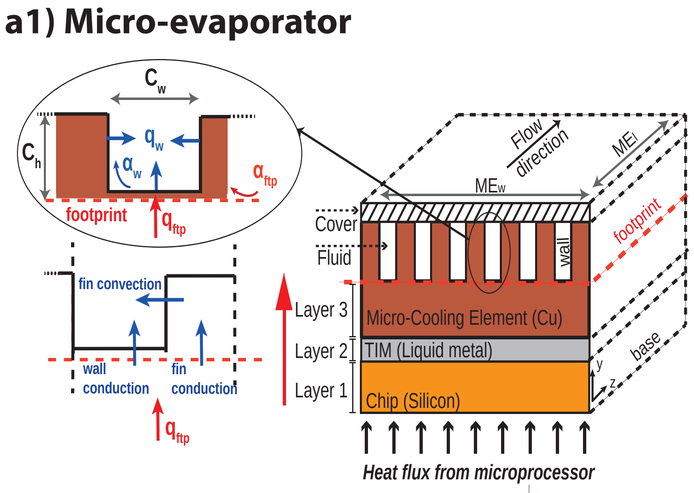
b) New 2U server thermosyphon demonstrator

- Demonstrator-like system
- About **80W** of heat load
- Max height of **5cm**
- Copper multi-microchannel evaporator
- Tube-in-tube water cooled condenser
- Piping of 6mm external diameter
- Also test with condenser on the downcomer

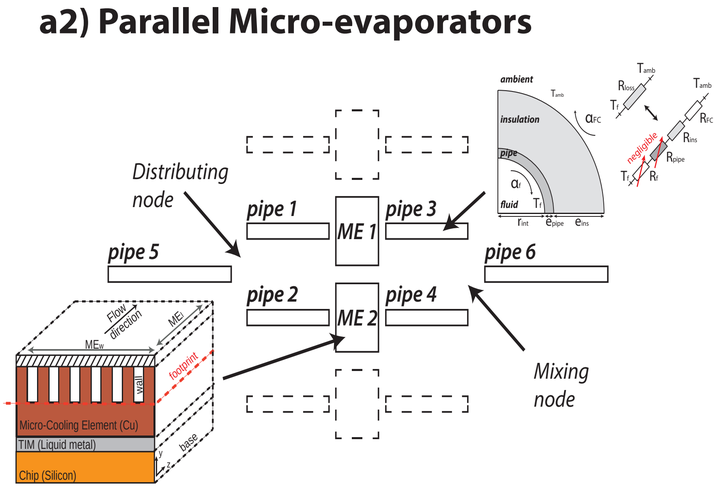


3 - Dynamic modeling

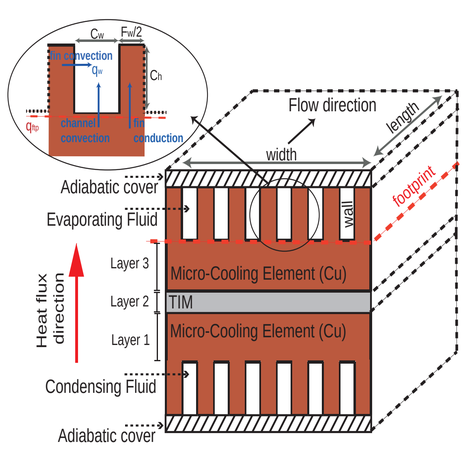
a1) Micro-evaporator



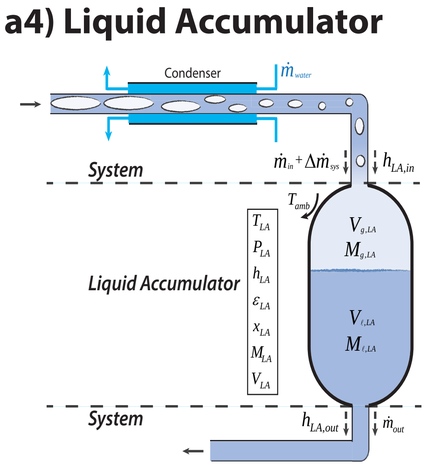
a2) Parallel Micro-evaporators



a3) Micro-condenser / Tube-in-tube condenser



a4) Liquid Accumulator



b1) Two-phase flow model

- One dimensional flow
- Thermodynamic equilibrium
- Homogeneous model

$$\varepsilon = \frac{x\rho_l}{(1-x)\rho_v + x\rho_l}$$

$$\rho_h = \rho_v\varepsilon + (1-\rho_l)\varepsilon$$

$$u_l = u_v = u = \frac{\dot{m}_{tot}}{\rho_h A}$$

b2) Old to New set of differential equations

- ***Mass***

$$\frac{\partial \rho_h u}{\partial z} = 0$$

- ***Momentum***

$$\frac{\partial P}{\partial z} = -\frac{\partial \rho_h u^2}{\partial z} - \left(\frac{\partial P}{\partial z}\right)_{fr} - g\rho_h \sin\theta$$

- ***Energy***

$$\frac{\partial \rho_h h}{\partial t} = -\frac{\partial \rho_h u h}{\partial z} + \frac{P_{heat}\dot{q}_{ftp}}{A}$$

Constant spatial mass flow rate obtained by balanced of static heigtht and friction force

- ***Mass***

$$\frac{\partial \rho_h}{\partial t} = -\frac{\partial \rho_h u}{\partial z}$$

- ***Momentum***

$$\frac{\partial \rho_h u}{\partial t} = -\frac{\partial \rho_h u^2}{\partial z} - \frac{\partial P}{\partial z} - \left(\frac{\partial P}{\partial z}\right)_{fr} - g\rho_h \sin\theta$$

- ***Energy***

$$\frac{\partial \rho_h h}{\partial t} - \frac{\partial P}{\partial t} = -\frac{\partial \rho_h u h}{\partial z} + u\left(\frac{\partial P}{\partial z}\right)_{fr} + \frac{P_{heat}\dot{q}_{ftp}}{A}$$

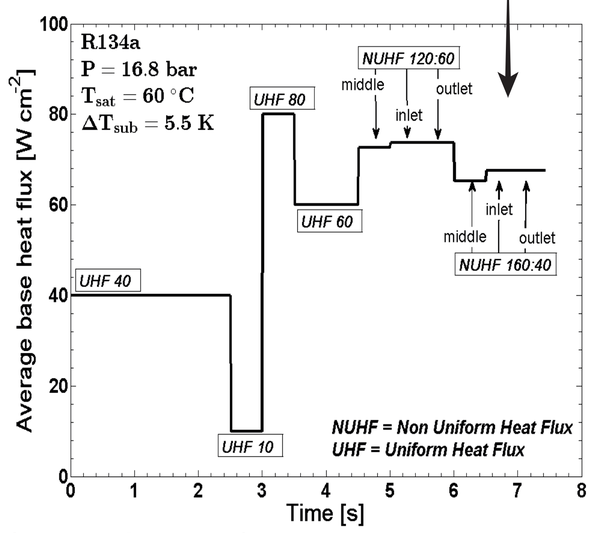
Spatial mass flow rate obtained by solving mass and momentum balance equations

c) Best microchannel two-phase flow methods

- ***Condensation/Evaporation Pressure Drop***
  - Homogeneous model
  - Muller-Steinhagen and Heck (1986)
- ***Evaporation Heat Transfer Coefficient***
  - Bertsch et al. (2009)
  - Costa-Patry and Thome (2013)
- ***Condensation Heat Transfer Coefficient***
  - Koyama et al. (20003)
  - Cavallini et al. (2006)
  - Cioncolini and Thome (2011)

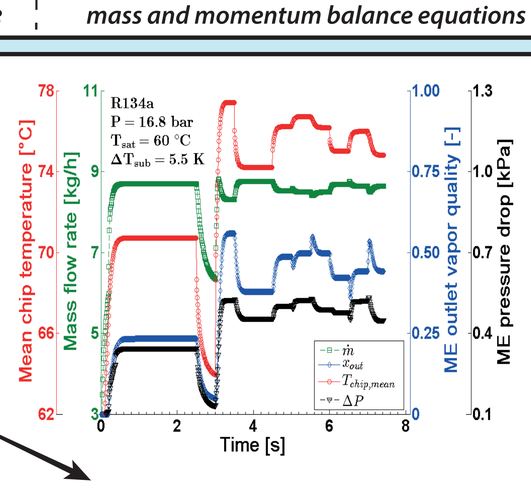
4 - Preliminary simulation results

- Silicon / TIM / Copper evaporator
- nz=100 and ny=30 in each layer
- Transient UHF and NUHF tested

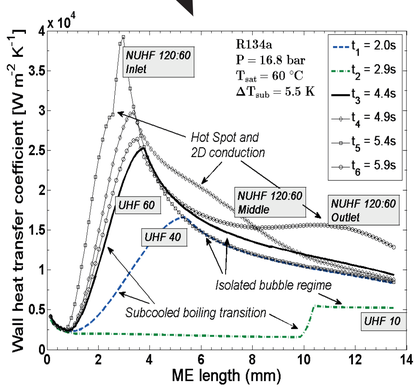


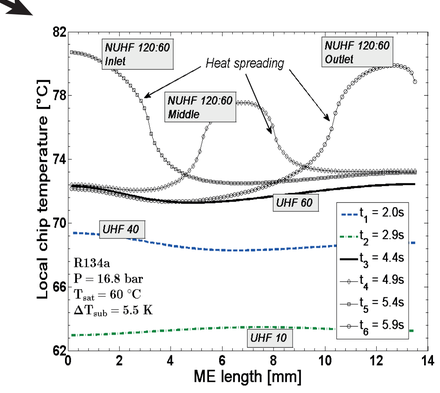
(in ITHERM2014)

$T_{chip,mean}$, mass flow rate, x_{out} and ΔP temporal variations



HTC and chip temperature profiles variations





5 - Current work/Perspectives

- Installation of the **experimental setup of the 2U server thermosyphon cooling** demonstrator
- Design of a **rack scale prototype** with multiple 2U thermosyphons
- Implementation of the **new set of differential equations** for more accurate dynamic modeling
- Refinement of a double-thermosyphon system financial analysis in a datacenter (**worst payback period obtained of 15 months**, see «*Passive Thermosyphon Cooling System For High Heat Flux Servers», in InterPACKICNMM2015)*

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