PowerCool: Simulation of Integrated Microfluidic Power Generation in Many-Core Servers

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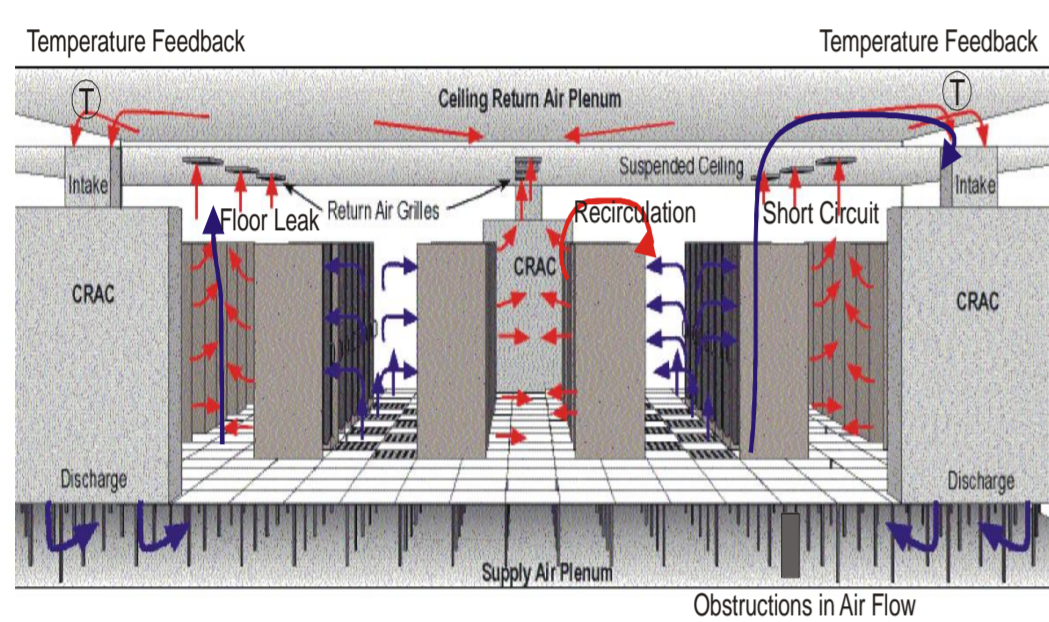
Motivation

High performance and high density computing servers demand high power supply: **cooling** and **power delivery** issues

Cooling issues
- High power density of ICs
- Energy efficiency constraints

Modern Air-Cooled Data Centers

Very high energy consumption overhead
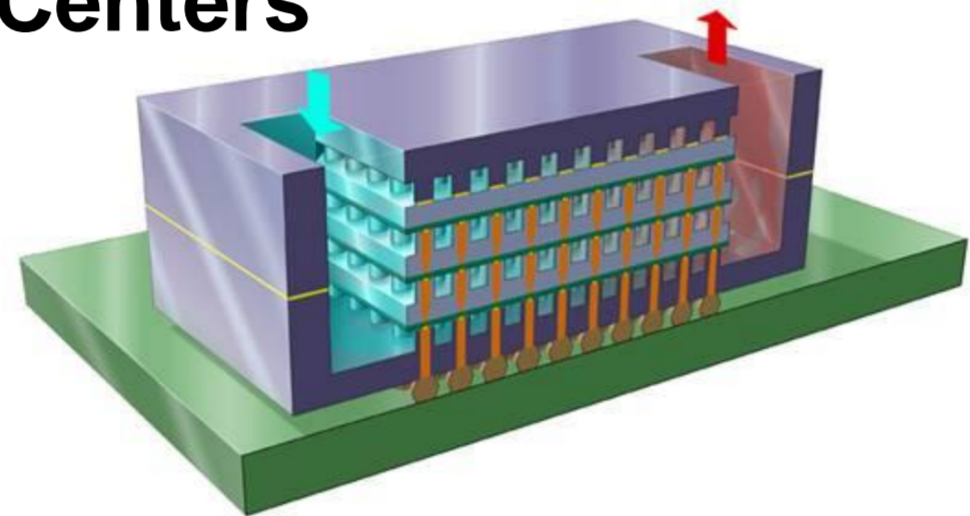

3D-ICE [1] Liquid cooled 3D stacked ICs simulator
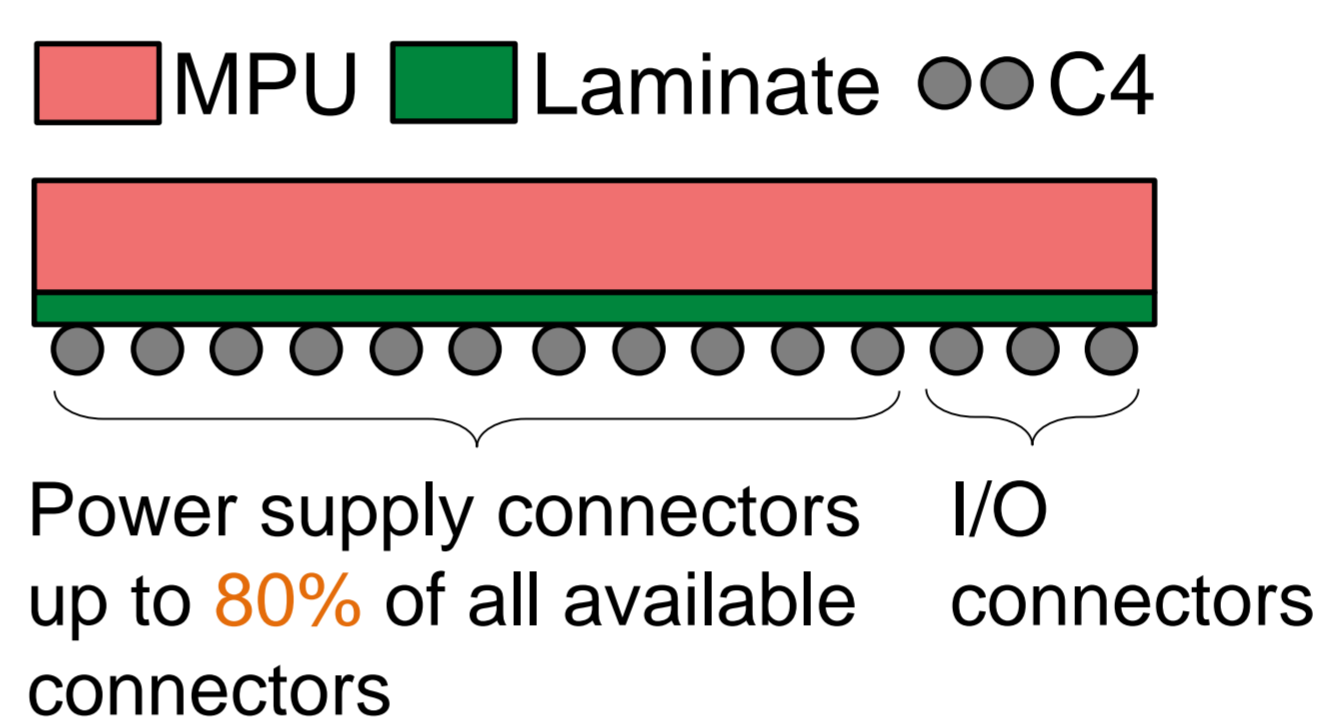
Liquid-cooled ICs
- High cooling capability
- Energy efficient
- 3D scalability

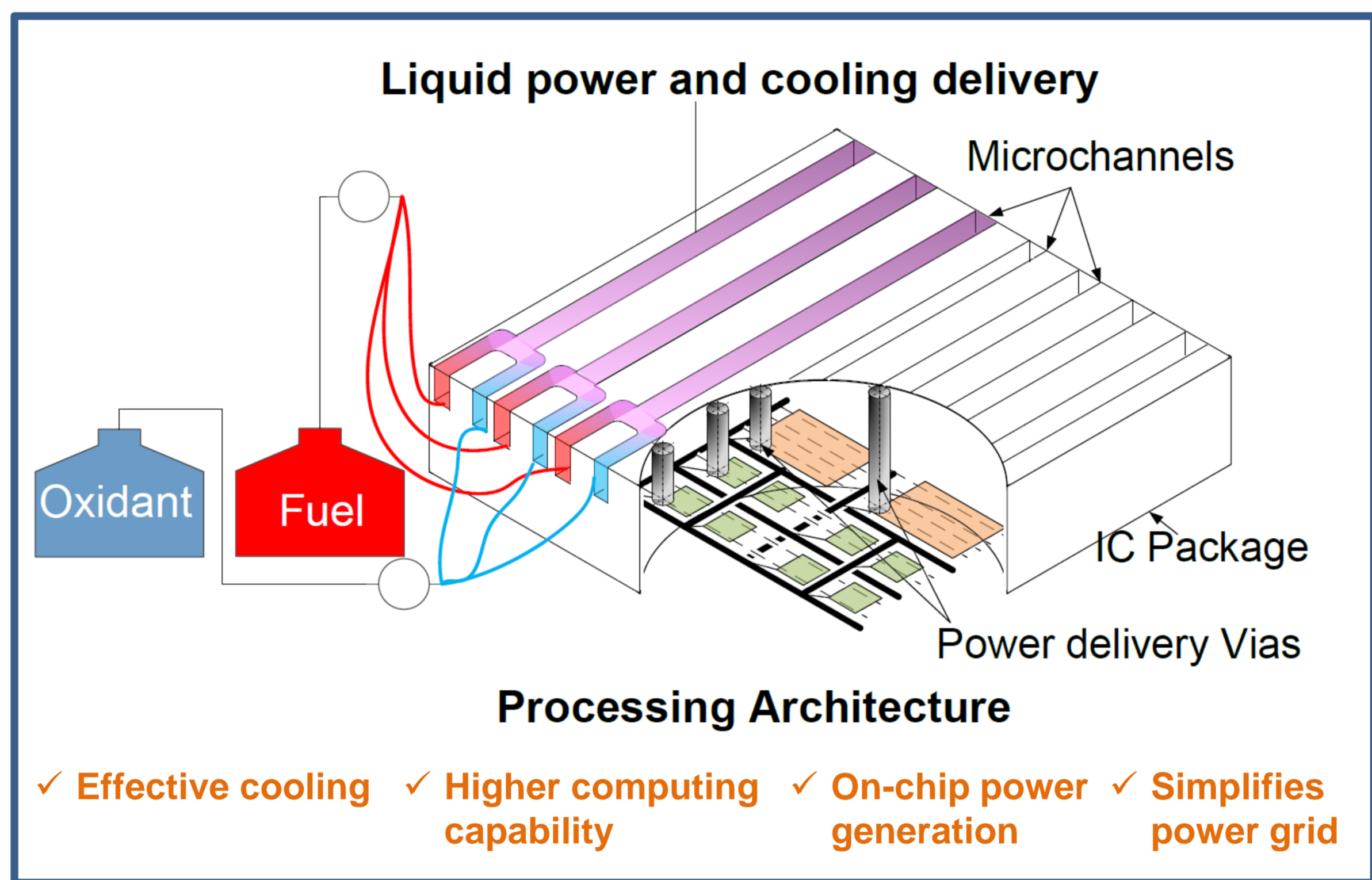**Future Liquid-Cooled Data Centers**

Power delivery issues
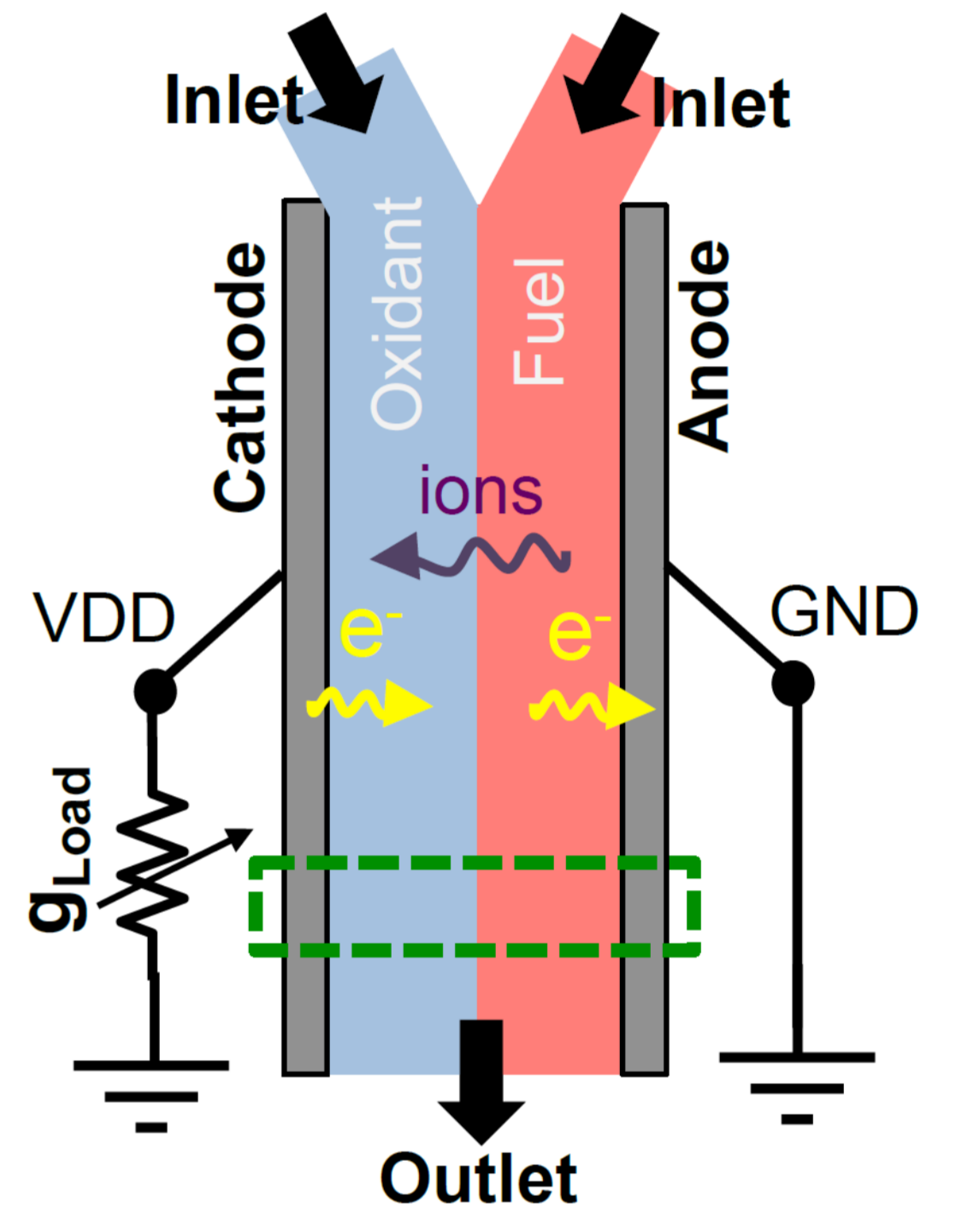- Leakage losses
- Limited number of connection pins
- Complex power distribution network

MPU   Laminate   C4

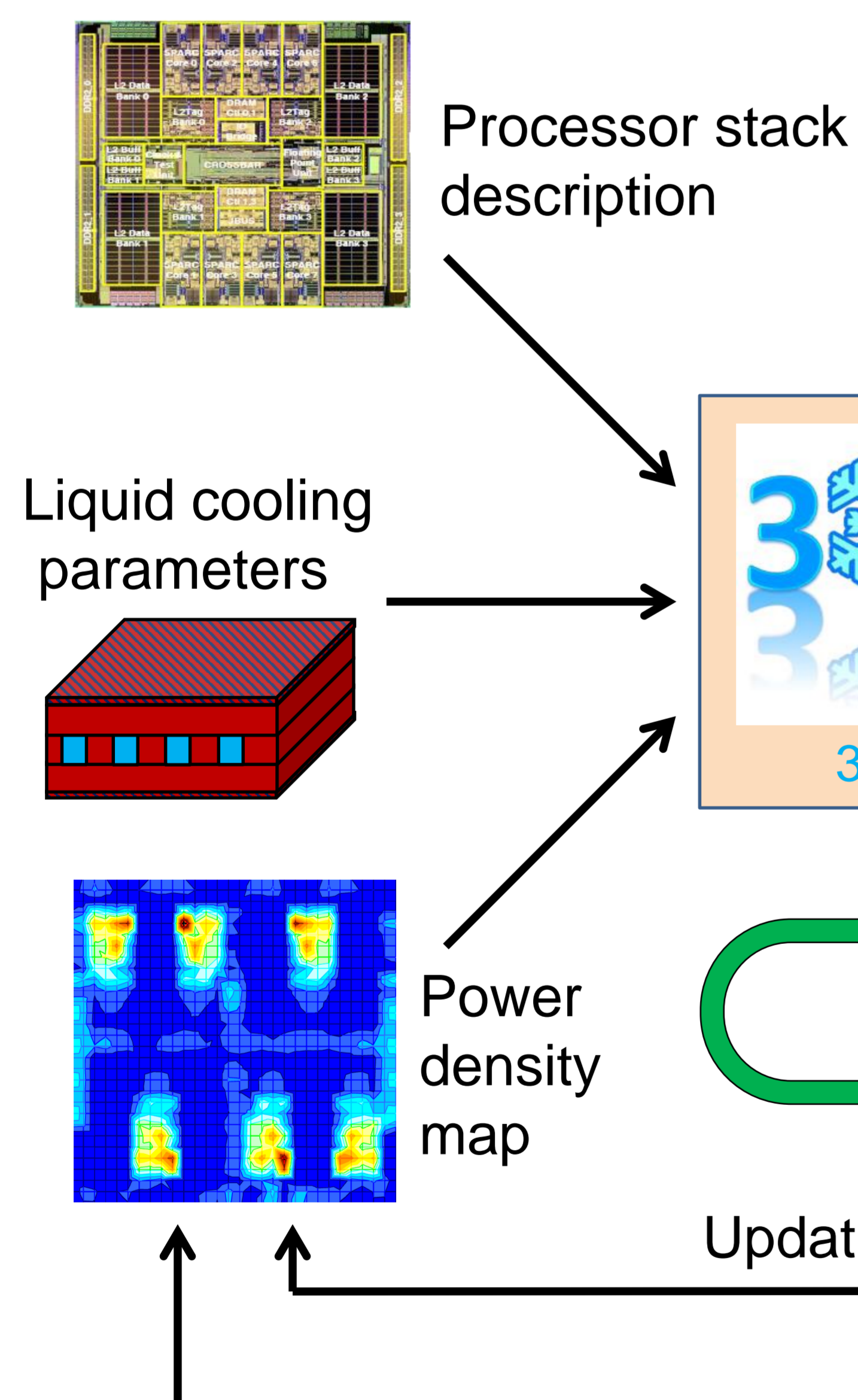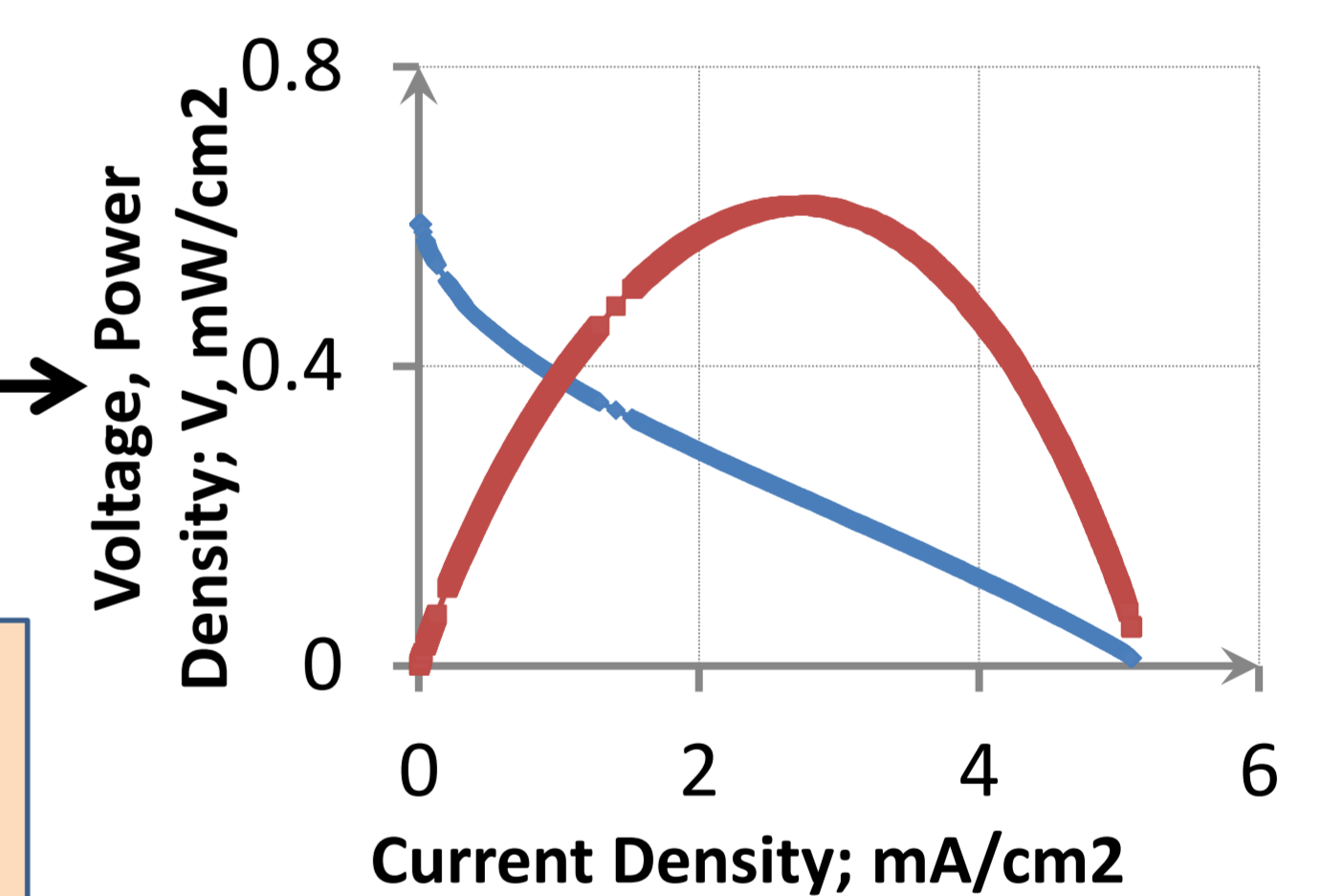Power supply connectors up to 80% of all available connectors

I/O connectors

On-chip flow cell
- Significantly reduces losses
- Simplifies power distribution
- Saves pins for I/O
- 3D scalability

Electrochemical flow cell

Inlet   Inlet

Cathode   Oxidant   Fuel   Anode

ions

VDD e^- e^- GND

g_{Load}

Outlet

Liquid power and cooling delivery

Microchannels

Oxidant   Fuel

IC Package

Power delivery Vias

Processing Architecture

✓ Effective cooling   ✓ Higher computing capability   ✓ On-chip power generation   ✓ Simplifies power grid

Processor stack description

Liquid cooling parameters

Power density map

3D-ICE

Updated leakage power

Thermal map

ions e^- e^-
Electrochemical parameters

PowerCool [2] flow-cell array simulator

PowerCool

Flow-cell array power supply

Current state

EDA-compatible tool flow

Only 8% error with respect to experimental data
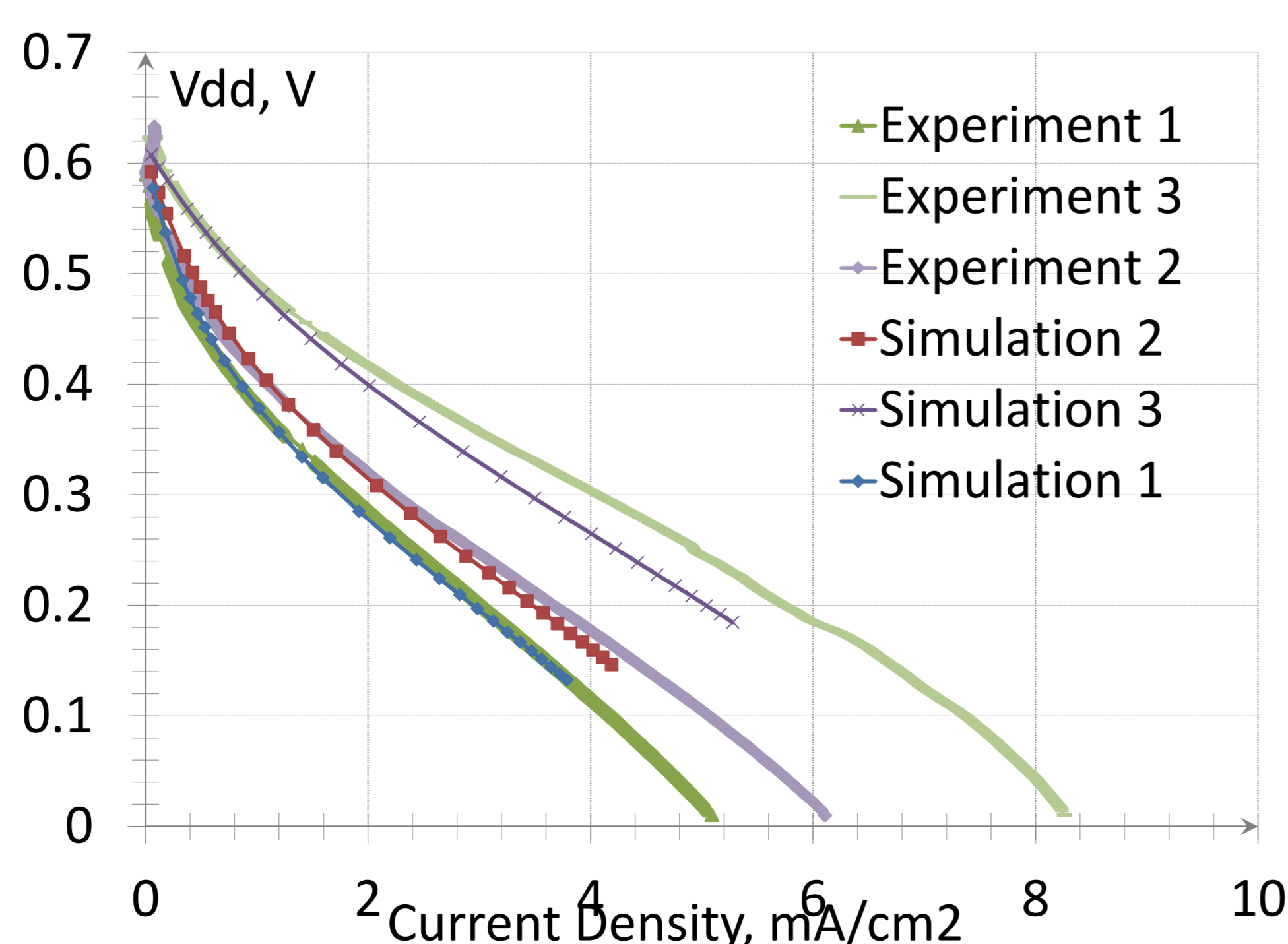
Future
- Floorplan-aware design
- Transient analysis
- Cooling and power supply optimization

References

[1] A. Sridhar, A. Vincenzi, D. Atienza Alonso and T. Brunschwiler. *3D-ICE: a Compact Thermal Model for Early-Stage Design of Liquid-Cooled ICs,* in IEEE Transactions on Computers, vol. 63, num. 10, p. 2576-2589, 2014.
[2] A. Sridhar, M. M. Sabry, P. Ruch, D. Atienza Alonso and B. Michel. *PowerCool: Simulation of Integrated Microfluidic Power Generation in Bright Silicon MPSoCs.* Proc. of IEEE/ACM ICCAD 2014.