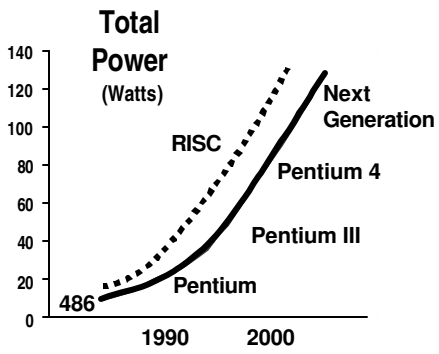
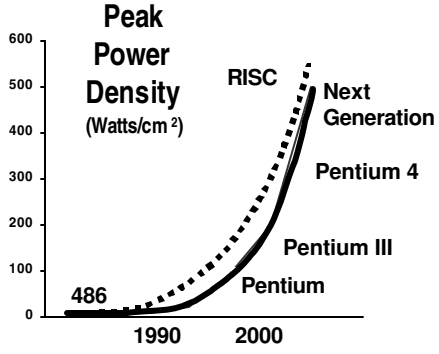
Cooligy

Cooligy

Active Micro-Channel Cooling

The Heat Problem



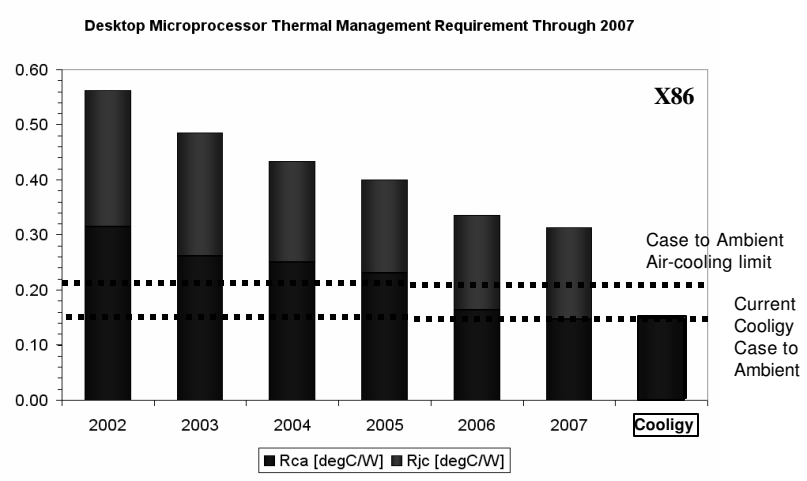


Why Keep CPUs Cool?

- Greater Performance
- Better Reliability

Source: Industry, Cooligy

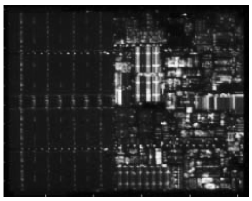
Microprocessor Thermal Requirements



Source:

Microprocessor Thermal Management

- **Microprocessor thermal management challenges**
  - Very high average and peak power densities
    - Q"_average > 150 W/cm^2
    - Q"_peak > 500W/cm^2
  - Thermal management requirement outpaces air-cooling technologies

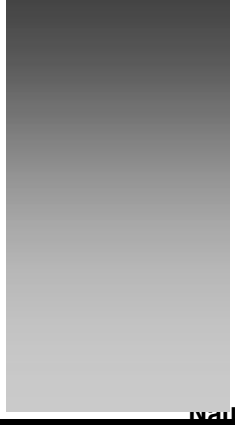


Genossar, D., and Shamir , N., 2003, "Intel® Pentium® M Processor Power Estimation, Budgeting, Optimization, and Validation", Intel Technology Journal, Vol. 7(2), pp. 44-49

- **Electro-kinetic microchannel cooling system advantages**
  - Orders of magnitude higher effective heat transfer coefficient compared with air-cooled heatsinks and liquid-cooled cold-plates
  - Microchannels can be readily implemented for hot-spot cooling
  - Very efficient liquid-air heat exchanger

Keeping Cool

CPU Power

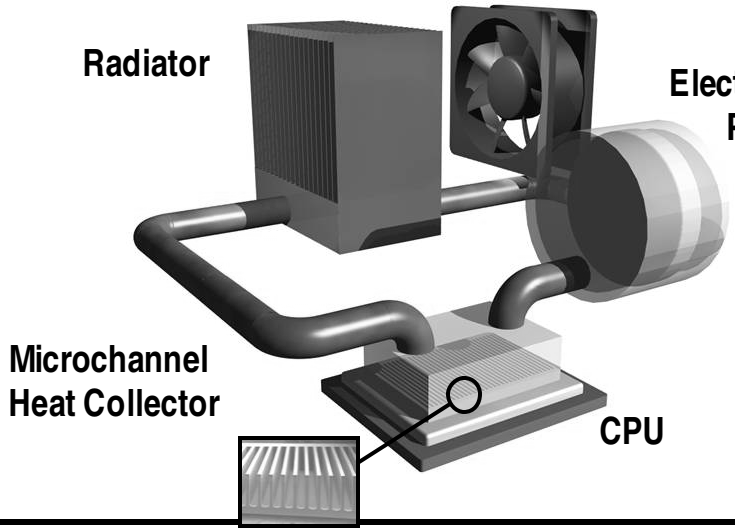


Passive Fluid Heat Pipe

Active Fan Sink

Natural Convection

Microchannel Cooling System



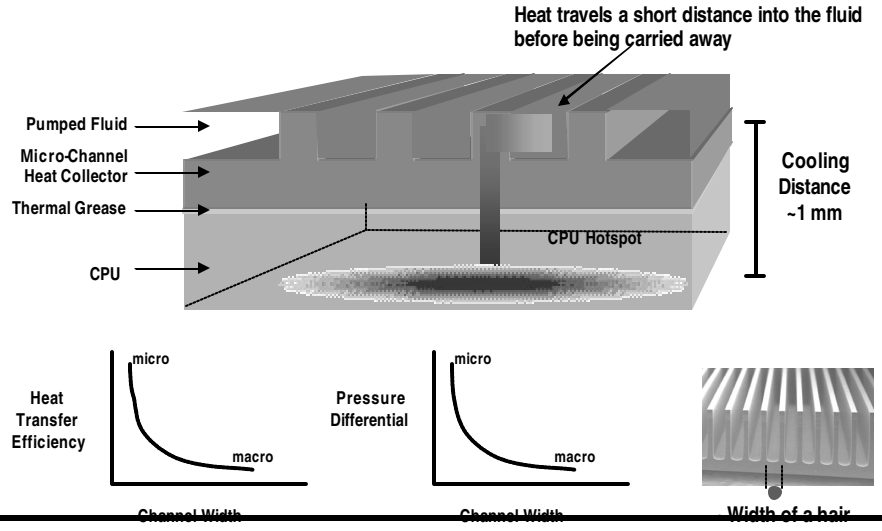
Radiator

Electrokinetic Pump

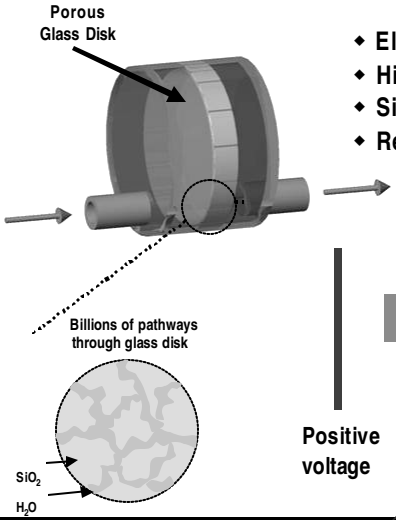
Microchannel Heat Collector

CPU

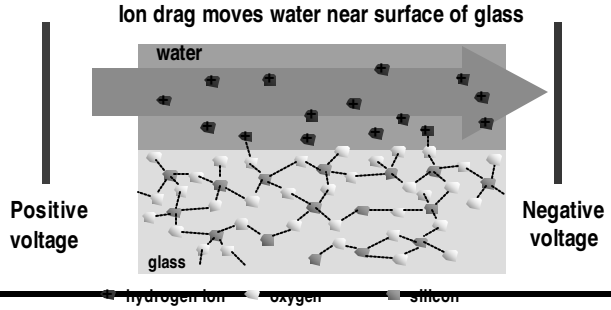
Micro-Channels Provide Highest Performance



Electro-Kinetic Pump – No Moving Parts

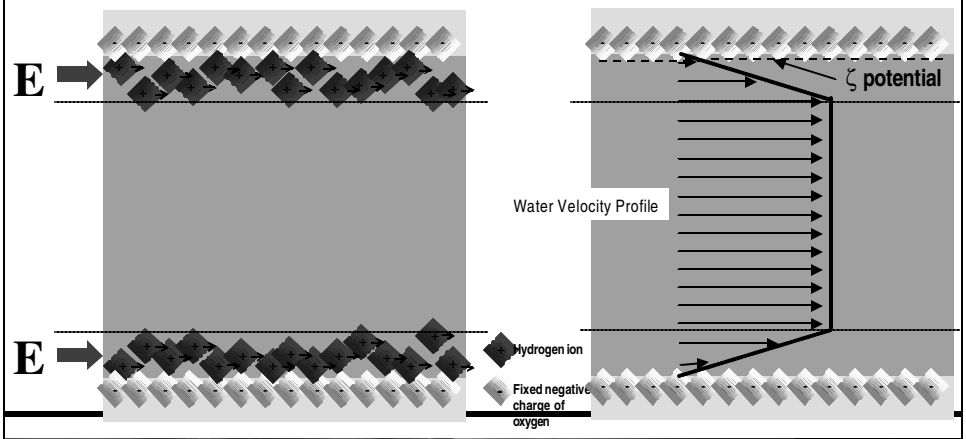


- Electric field drives fluid through porous glass disk
- High pressure, high flow rate
- Silent operation
- Reliable – no moving parts

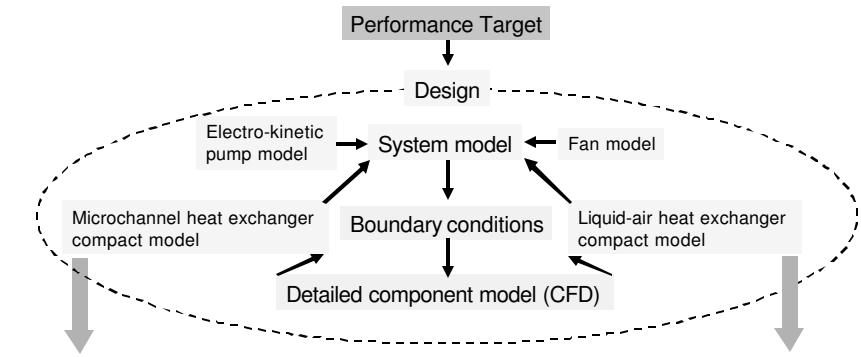


Electrokinetic Fluid Flow

The fixed surface charge creates a diffuse double layer region of net positive charge near the surface. Applied electric field acts on charges and causes fluid to flow.



System Thermal Design

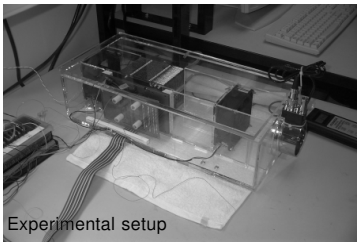


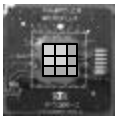
- **Microchannel geometry**
- **Proprietary manifold**

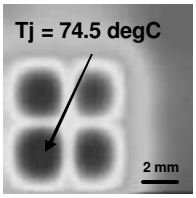
- **Maximize UA on liquid and air passage**
- **Optimized flow arrangement ensures heat transfer efficiency**

Thermal Die Numerical and Experimental Results

	Simulation	Experiment
TDP [W]	150	150
Q"_avg [W/cm^2]	250	250
Q"_peak [W/cm^2]	360	360
Ta [degC]	25	25
V_dot_air [CFM]	50	51
V_dot_l [ml/min]	300	~280
Rja [degC/W]	0.38	0.37


Experimental setup



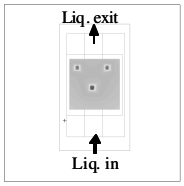


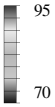
Junction temperature distribution
150W, 360W/cm^2, 300ml/min@25degC water

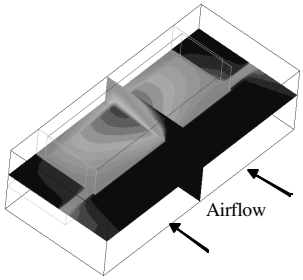
Pentium 4 Model Parameters

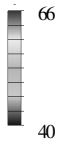
Ambient temperature, C	40
CPU die size, cm^2	1
CPU power, W	**137**
Die thickness, mm	0.75
Spreader size, mm	35 x 35
Integrated heat spreader thickness, mm	1.2
Integrated heat spreader material	Cu
Hot spot size, mm ^{2}	1
Power density at hot spot, W/ cm^2	**500**
No. of hot spots	3
Rejecter size (mm)	160 x 50 x 40
Airflow through rejecter, cfm	28

Simulation Results







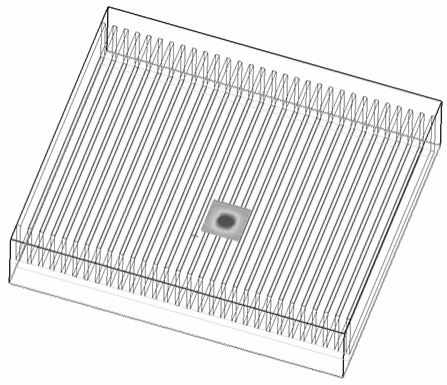


Component	Resistance C/W
Silicon Die	0.07
TIM1	0.05
TIM2	0.07
Micro channel case-fluid-rejecter-ambient	0.21
Total Resistance, R_{j-a}	0.4

Passive Cooling: Fan Heat Sink

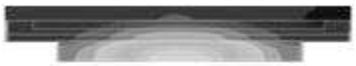
- Average power cooling
- Heat must spread up to reach cooling air
- Fan heat sink is many times larger than the CPU

120 Watt CPU
Hot spot in center



Active Micro-Channel Cooling

- Efficiently cools hot spot
- Active microchannel cooling area is 7-10 times the area of the die
- Cooling fluid brought directly to hottest areas on die



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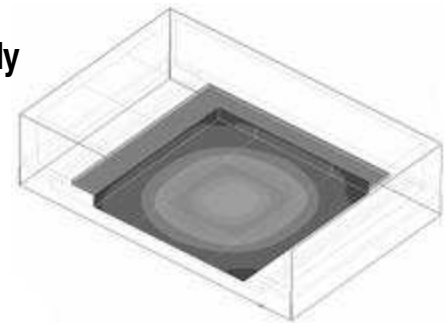
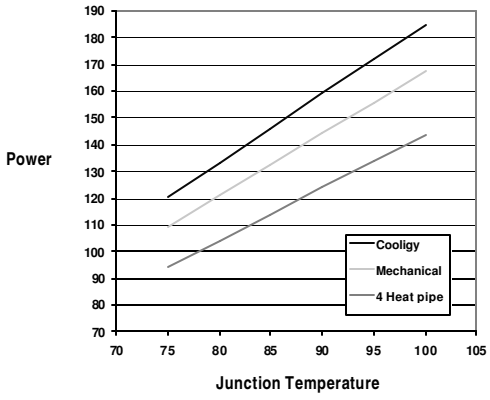


Example: RISC Workstation Power Scaling

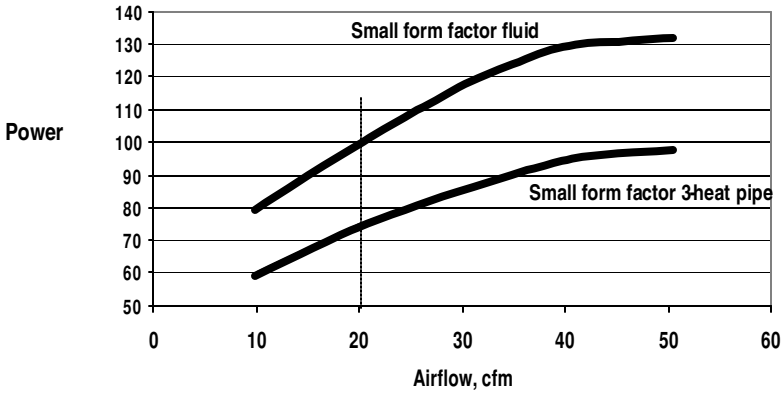


	Cooligy	Mechanical	4-Heat pipe
Rejecter size	120x90x90	120x90x90	120x90x90
Liquid flow rate ml/m	300	1800	
Airflow per CPU, cfm	43	43	43
Hot spot Flux, W/cm²	500	500	500

Fluid Cooling

- Higher total power per CPU
- Lower fan speed

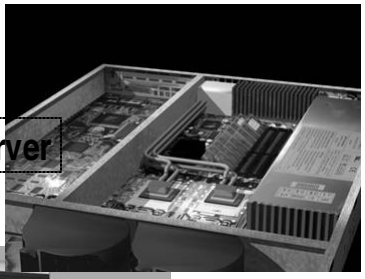
Active Fluid Air Flow Advantage



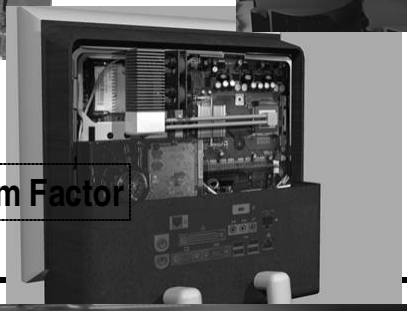
Small form factor radiator
Ambient temperature = 38C

Target Applications

Workstation



1U Server



Small Form Factor