

**Research in Kasahara & Kimura Lab.**

**Homogeneous and Heterogeneous  
Multicore / Manycore Processors,  
Parallelizing Compiler  
and Multiplatform API  
for Green Computing**

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**Professor, Dept. of Computer Science & Engineering**

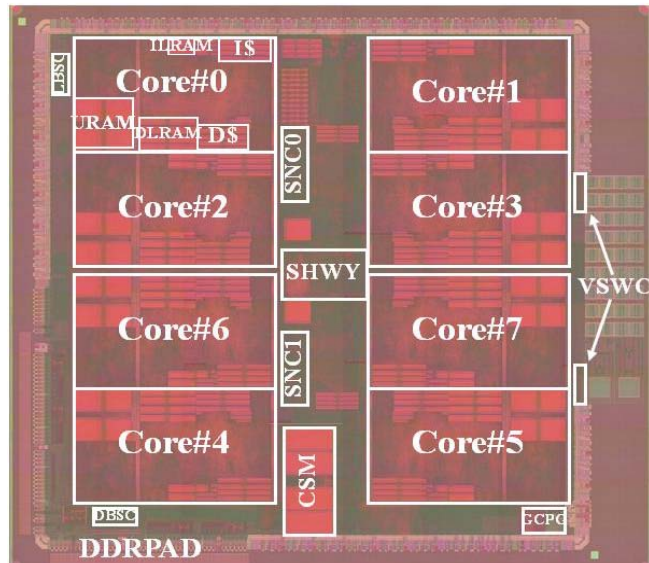
**Director, Advanced Multicore Processor Research Institute**

**Waseda University, Tokyo, Japan**

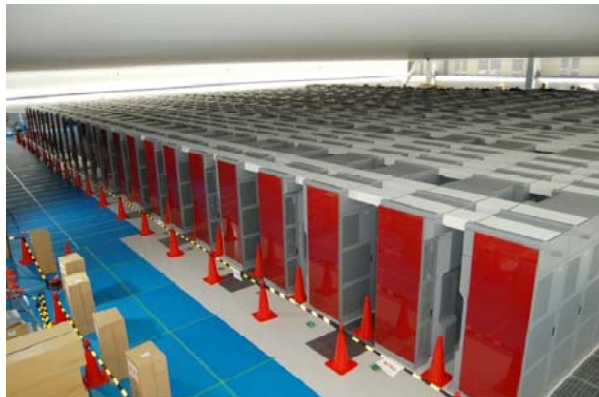
**URL: <http://www.kasahara.cs.waseda.ac.jp/>**

# Multi/Many-core Everywhere

## Multi-core from embedded to supercomputers



OSCAR Type Multi-core Chip by Renesas in METI/NEDO Multicore for Real-time Consumer Electronics Project (Leader: Prof.Kasahara)



The 27th Top 500 (20.6.2011),  
**No.1**, Fujitsu "K" 548,352 cores  
(Current Peak 8.774 PFLOPS)  
LINPACK 8.162 PFLOPS (93.0%)

### ➤ Consumer Electronics (Embedded)

**Mobile Phone, Game, TV, Car Navigation, Camera,**

IBM/ Sony/ Toshiba Cell, Fujitsu FR1000,

Panasonic Uniphier, NEC/ARM MPCore/MP211/NaviEngine,

Renesas 4 core RP1, 8 core RP2, 15core Hetero RP-X,

Plurality HAL 64(Marvell), Tiler Tile64/ -Gx100(->1000cores),

DARPA UHPC (2017: 80GFLOPS/W)

### ➤ PCs, Servers

Intel Quad Xeon, Core 2 Quad, Montvale, Nehalem(8cores),

Larrabee(32cores), SCC(48cores), Night Corner(50 core+:22nm),

AMD Quad Core Opteron (8, 12 cores)

### ➤ WSs, Deskside & Highend Servers

IBM(Power4,5,6,7), Sun (SparcT1,T2), Fujitsu SPARC64fx8

### ➤ Supercomputers

Earth Simulator:**40TFLOPS**, 2002, 5120 vector proc.

BG/Q (A2:16cores) Water Cooled20PFLOPS, 3-4MW (2011-12),

BlueWaters(HPCS) Power7, 10 PFLOP+(2011.07),

Tianhe-1A (4.7PFLOPS,6coreX5670+ Nvidia Tesla M2050),

Godson-3B (1GHz40W 8core128GFLOPS) -T (64 core,192GFLOPS:2011)

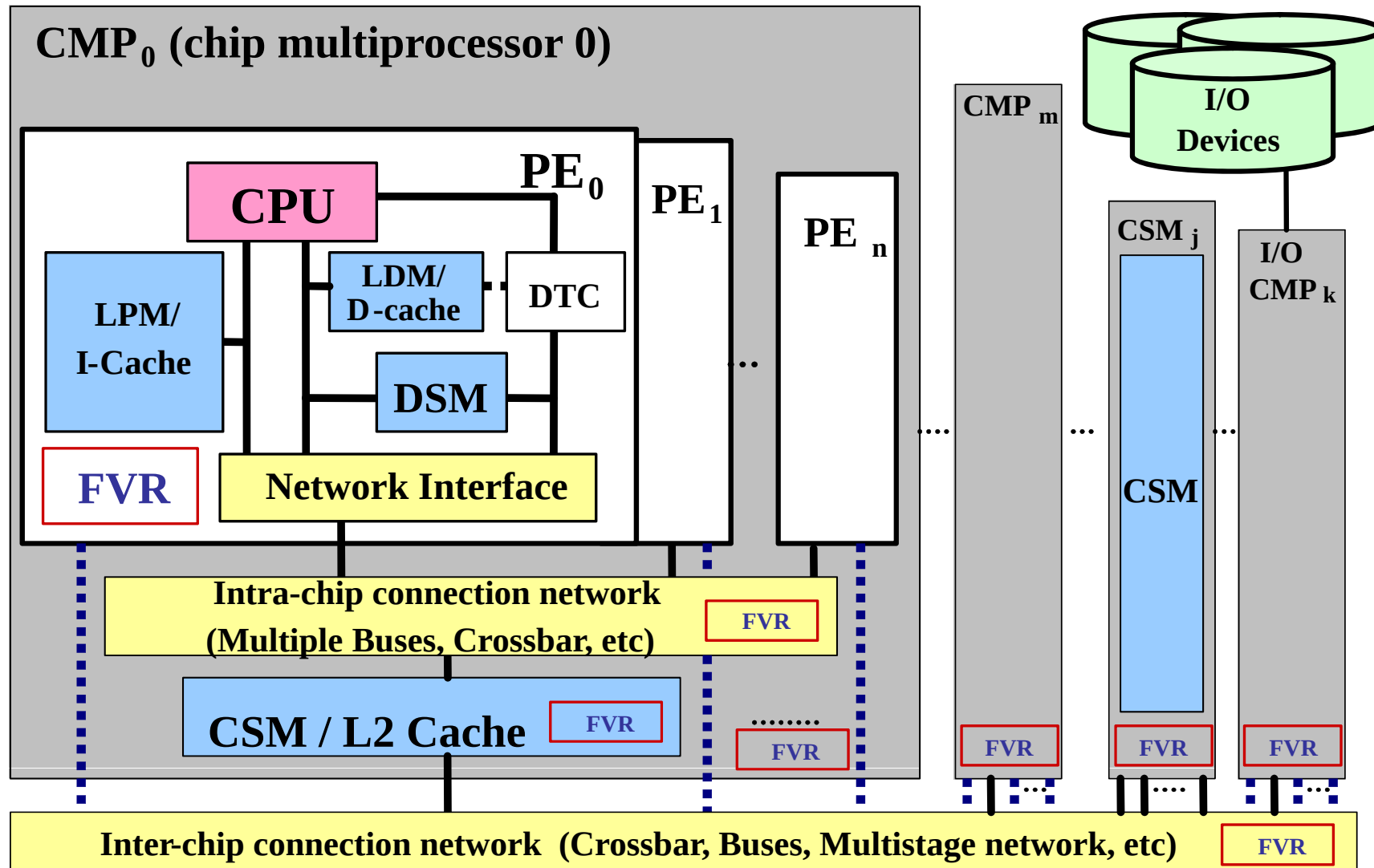
RIKEN Fujitsu "K" 10PFLOPS(8core SPARC64VIlIfx, 128GGFLOPS)

**High quality application software, Productivity, Cost performance, Low power consumption are important**

**Ex, Mobile phones, Games**

**Compiler cooperated multi-core processors are promising to realize the above futures**

# OSCAR Multi-Core Architecture



CSM: central shared mem.

DSM: distributed shared mem.

DTC: Data Transfer Controller

LDM : local data mem.

LPM : local program mem.

FVR: frequency / voltage control register

# Demo of NEDO Multicore for Real Time Consumer Electronics at the Council of Science and Engineering Policy on April 10, 2008

第74回総合科学技術会議【平成20年4月10日】



第74回総合科学技術会議の様子(1)



第74回総合科学技術会議の様子(2)



第74回総合科学技術会議の様子(3)



第74回総合科学技術会議の様子(4)

## CSTP Members

**Prime Minister:**

**Mr. Y. FUKUDA**

**Minister of State for  
Science, Technology  
and Innovation  
Policy:**

**Mr. F. KISHIDA**

**Chief Cabinet  
Secretary:**

**Mr. N. MACHIMURA**

**Minister of Internal  
Affairs and  
Communications :**

**Mr. H. MASUDA**

**Minister of Finance :**

**Mr. F. NUKAGA**

**Minister of  
Education, Culture,  
Sports, Science and  
Technology:**

**Mr. K. TOKAI**

**Minister of  
Economy, Trade and  
Industry:**

**Mr. A. AMARI**

# OSCAR Parallelizing Compiler

To improve **effective performance**, **cost-performance** and **software productivity** and **reduce power**

## Multigrain Parallelization

coarse-grain parallelism among loops and subroutines, near fine grain parallelism among statements in addition to loop parallelism

## Data Localization

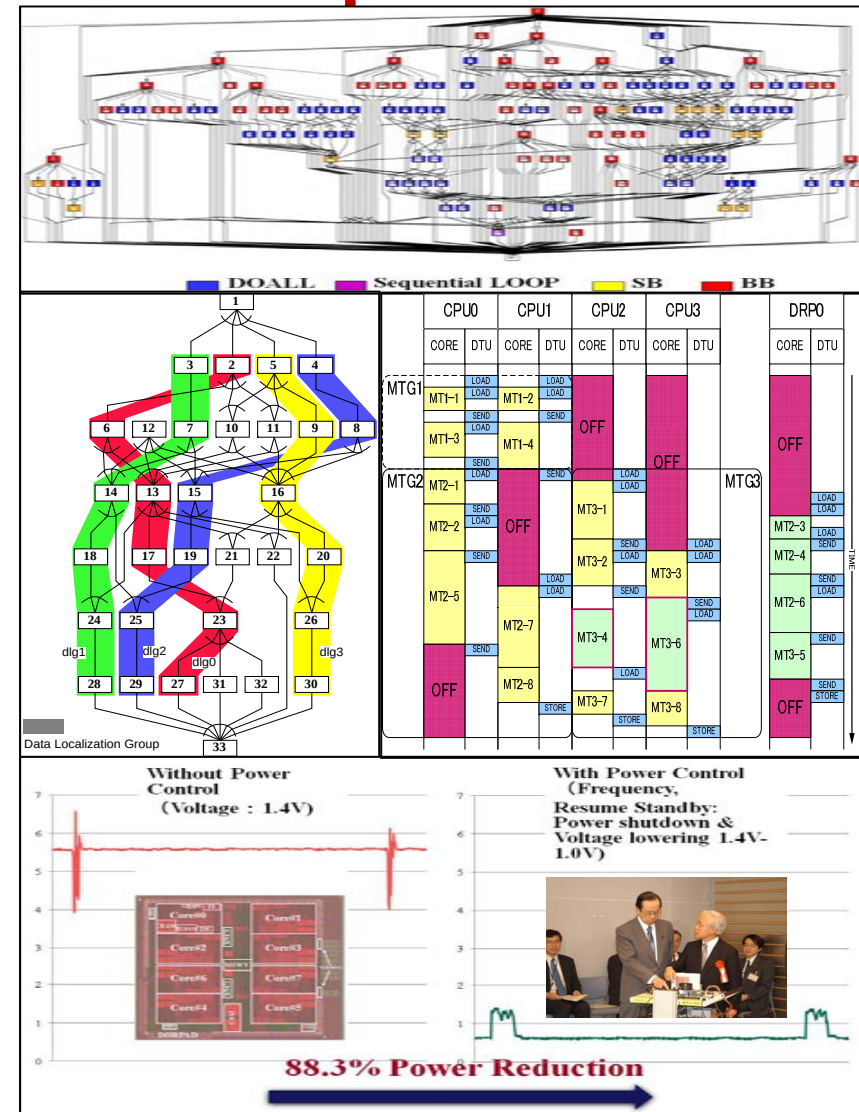
Automatic data management for distributed shared memory, cache and local memory

## Data Transfer Overlapping

Data transfer overlapping using Data Transfer Controllers (DMAs)

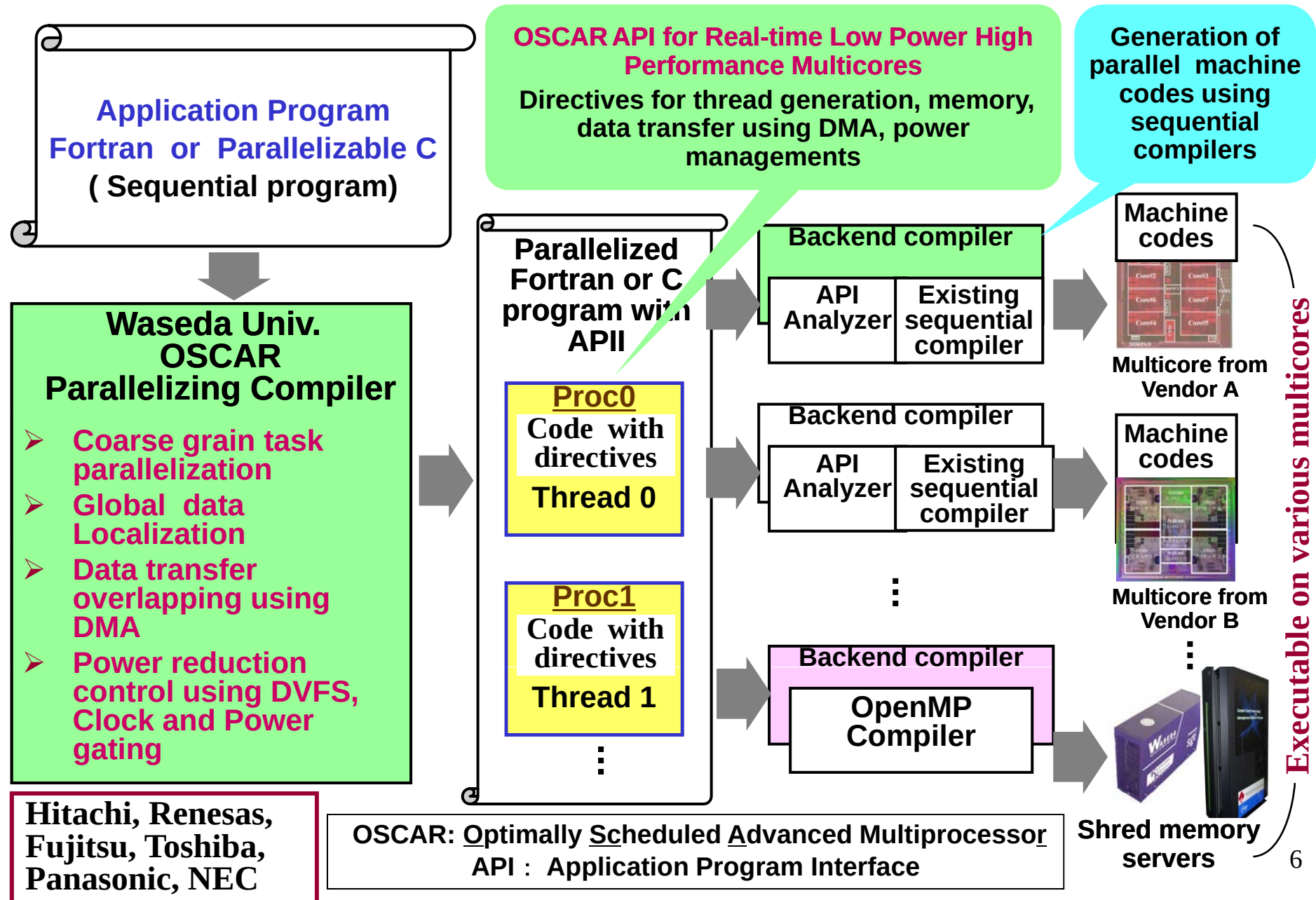
## Power Reduction

Reduction of consumed power by compiler control DVFS and Power gating with hardware supports.

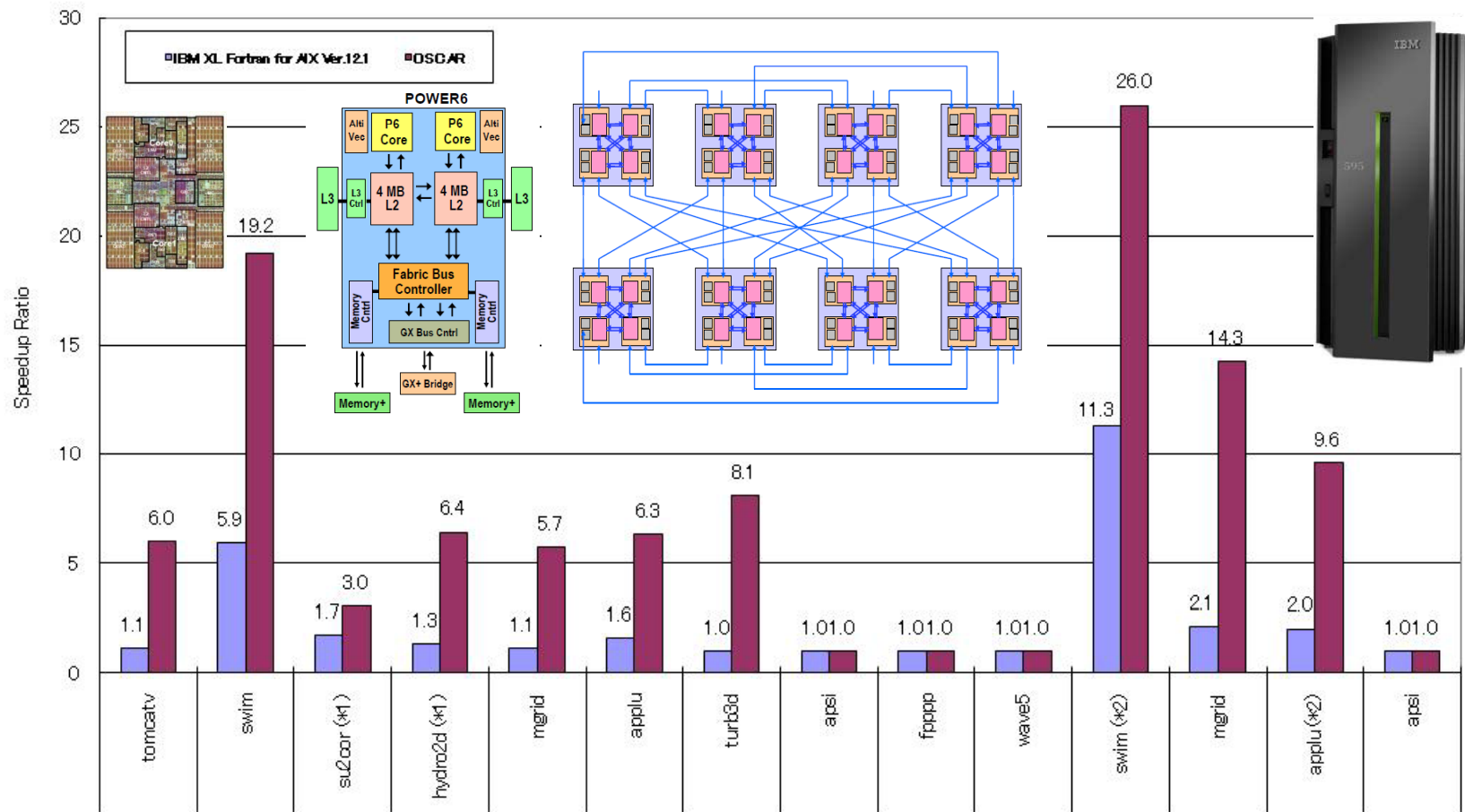




# Compilation Flow Using OSCAR API



# Performance of OSCAR Compiler on IBM p6 595 Power6 (4.2GHz) based 32-core SMP Server



**OpenMP codes generated by OSCAR compiler accelerate IBM XL Fortran for AIX Ver.12.1 about **3.3 times** on the average**

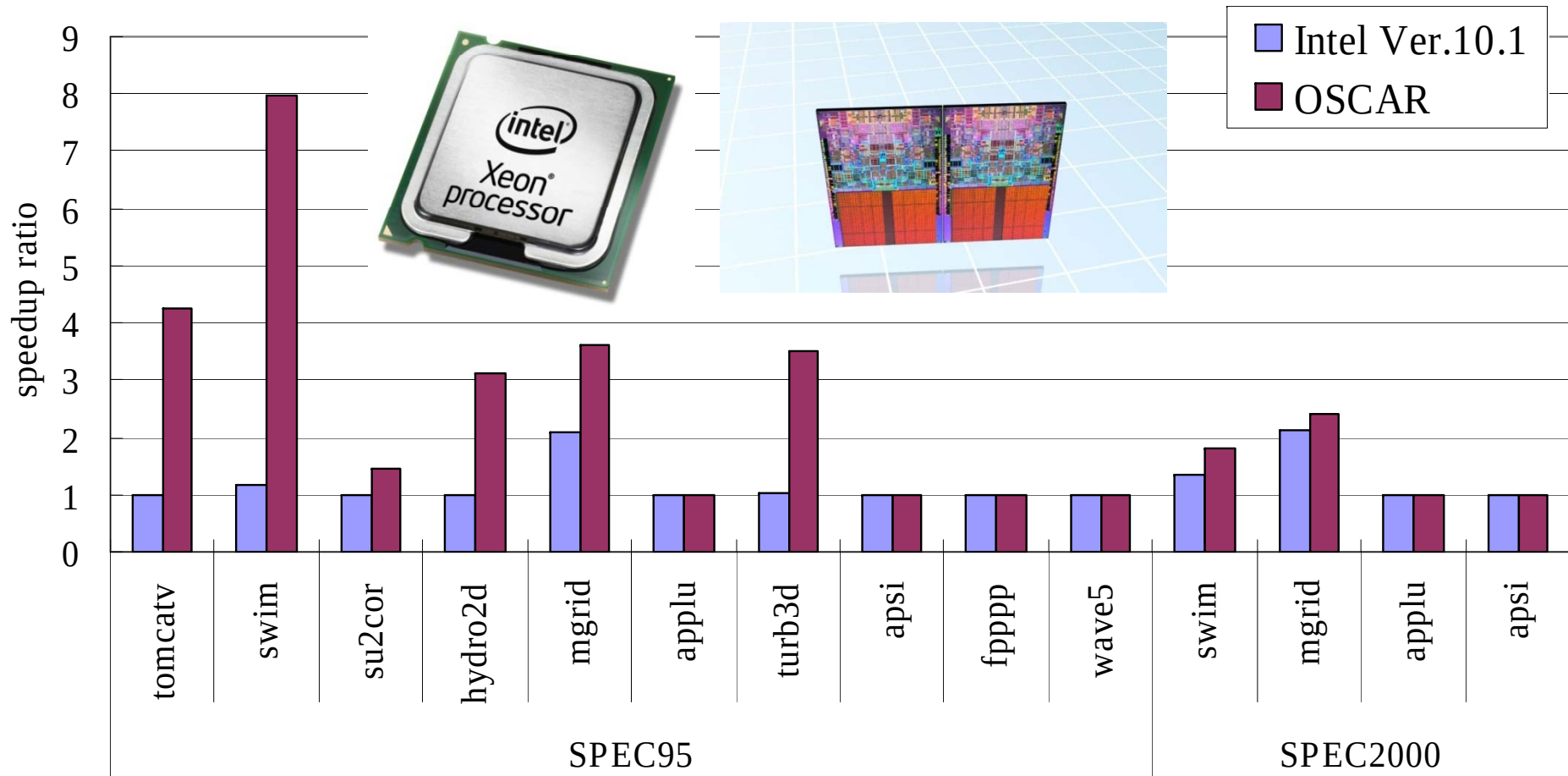
**Compile Option:**

(\*1) Sequential: -O3 -qarch=pwr6, XLF: -O3 -qarch=pwr6 -qsmp=auto, OSCAR: -O3 -qarch=pwr6 -qsmp=noauto

(\*2) Sequential: -O5 -q64 -qarch=pwr6, XLF: -O5 -q64 -qarch=pwr6 -qsmp=auto, OSCAR: -O5 -q64 -qarch=pwr6 -qsmp=noauto

(Others) Sequential: -O5 -qarch=pwr6, XLF: -O5 -qarch=pwr6 -qsmp=auto, OSCAR: -O5 -qarch=pwr6 -qsmp=noauto

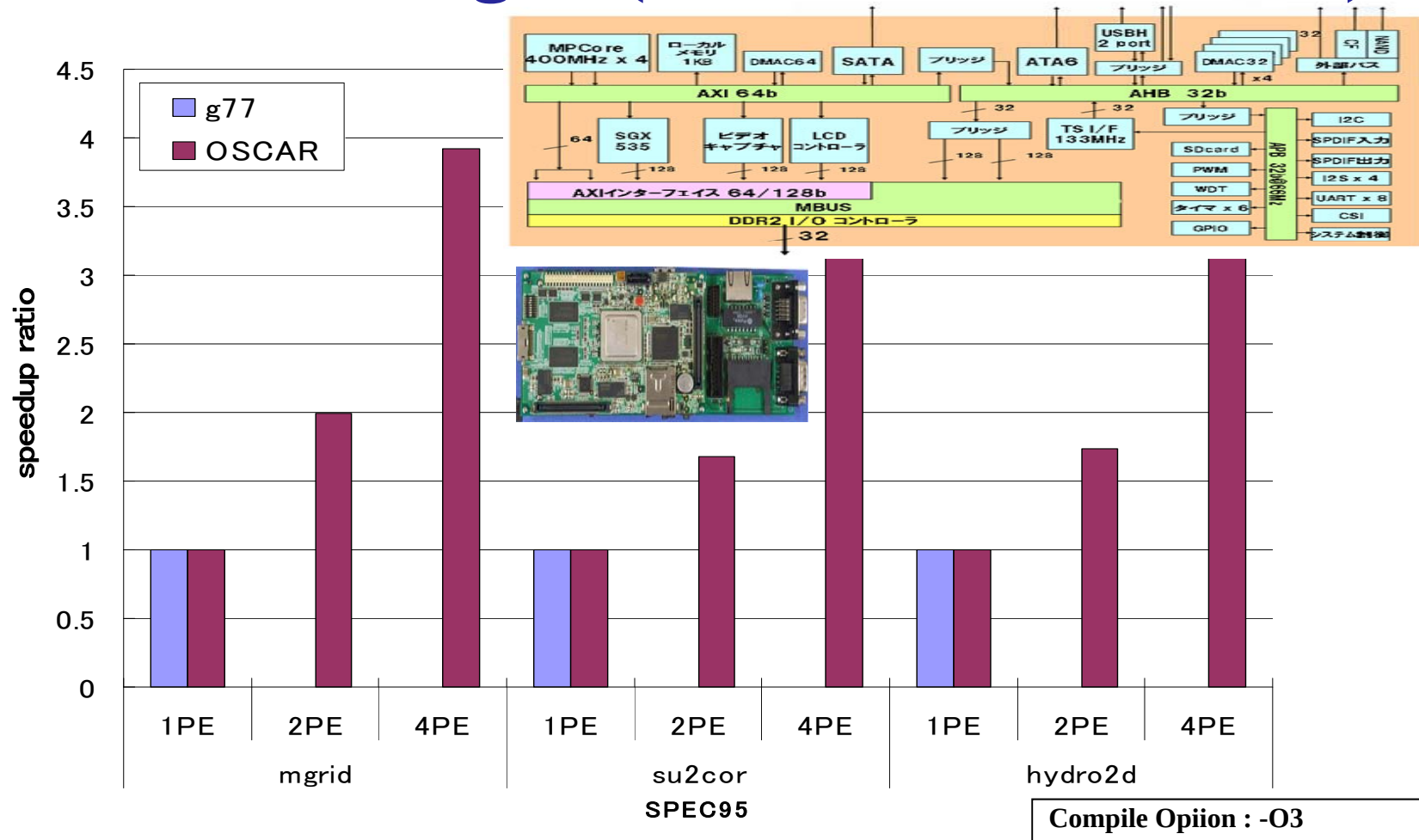
# Performance of OSCAR Compiler Using the Multicore API on Intel Quad-core Xeon



- **OSCAR Compiler gives us 2.1 times speedup on the average against Intel Compiler ver.10.1**

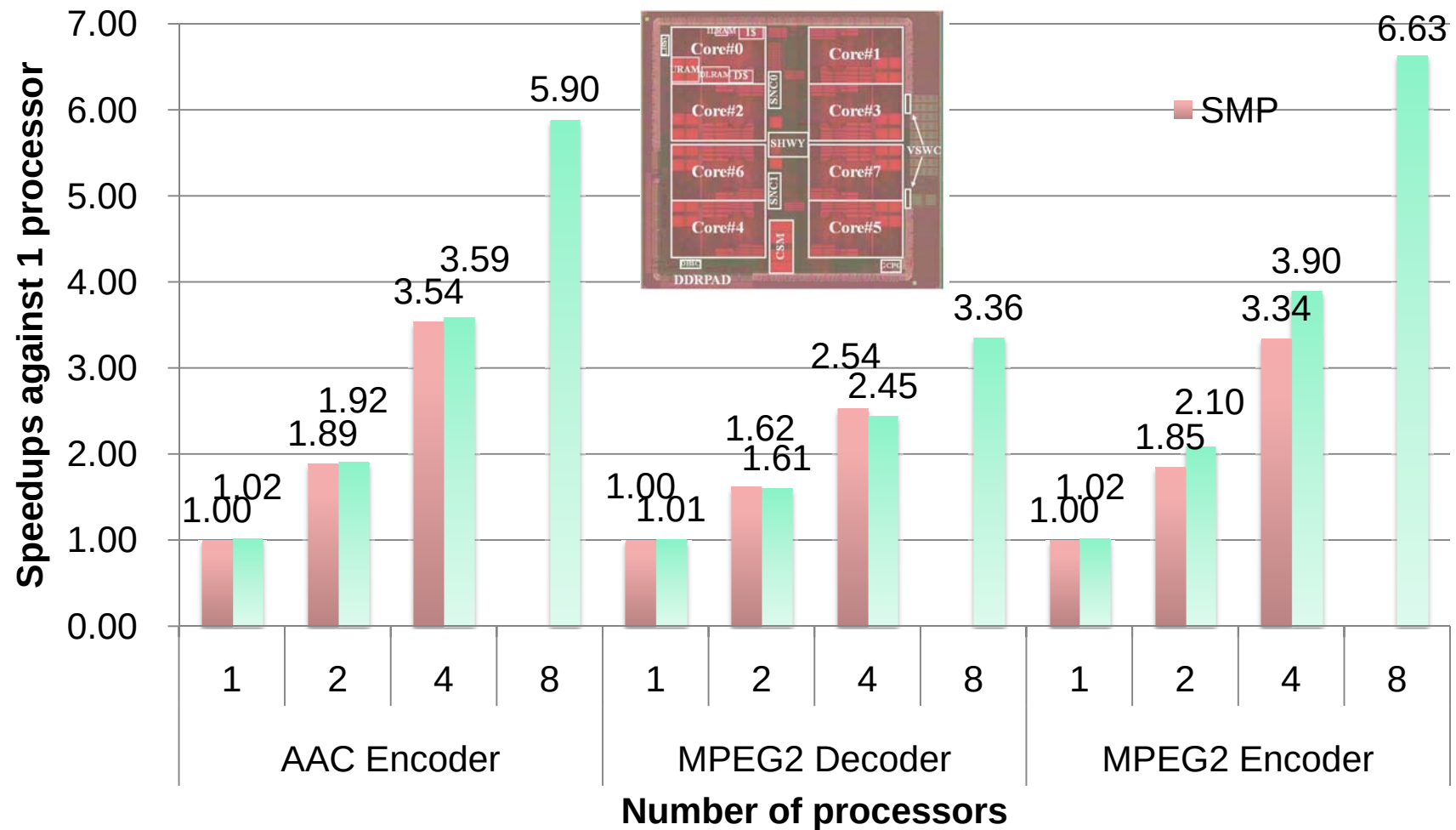


# Performance of OSCAR compiler on NEC NaviEngine(ARM-NEC MPcore)



- OSCAR compiler gave us 3.43 times speedup against 1 core on ARM/NEC MPCore with 4 ARM 400MHz cores

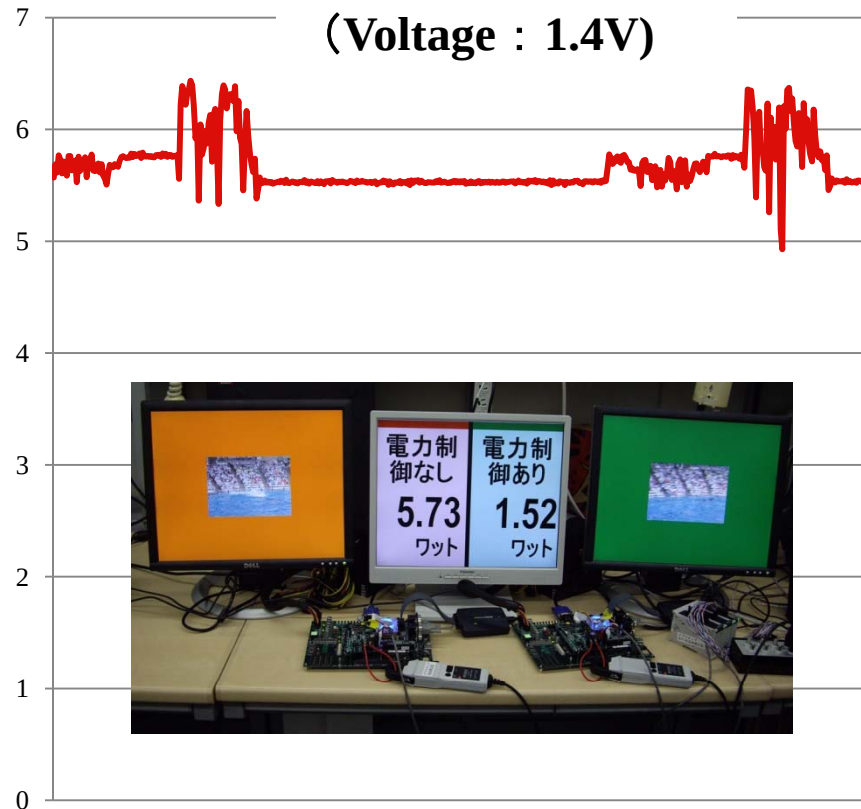
# Software Cache Coherent Control by OSCAR Compiler and API on RP2



# Power Reduction by OSCAR Parallelizing Compiler for MPEG2 Decoding

MPEG2 Decoding with 8 CPU cores

Without Power Control  
(Voltage : 1.4V)



Avg. Power  
5.73 [W]

With Power Control  
(DVFS, Clock & Power Gating:  
600/300/150/75/0 MHz, 1.4/1.2/1.0V)



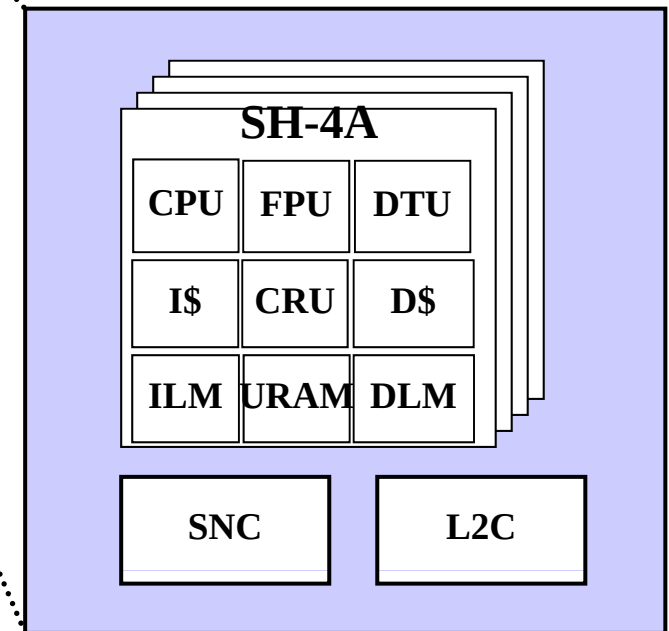
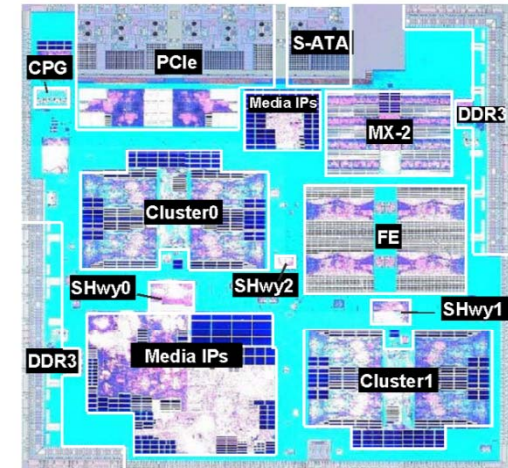
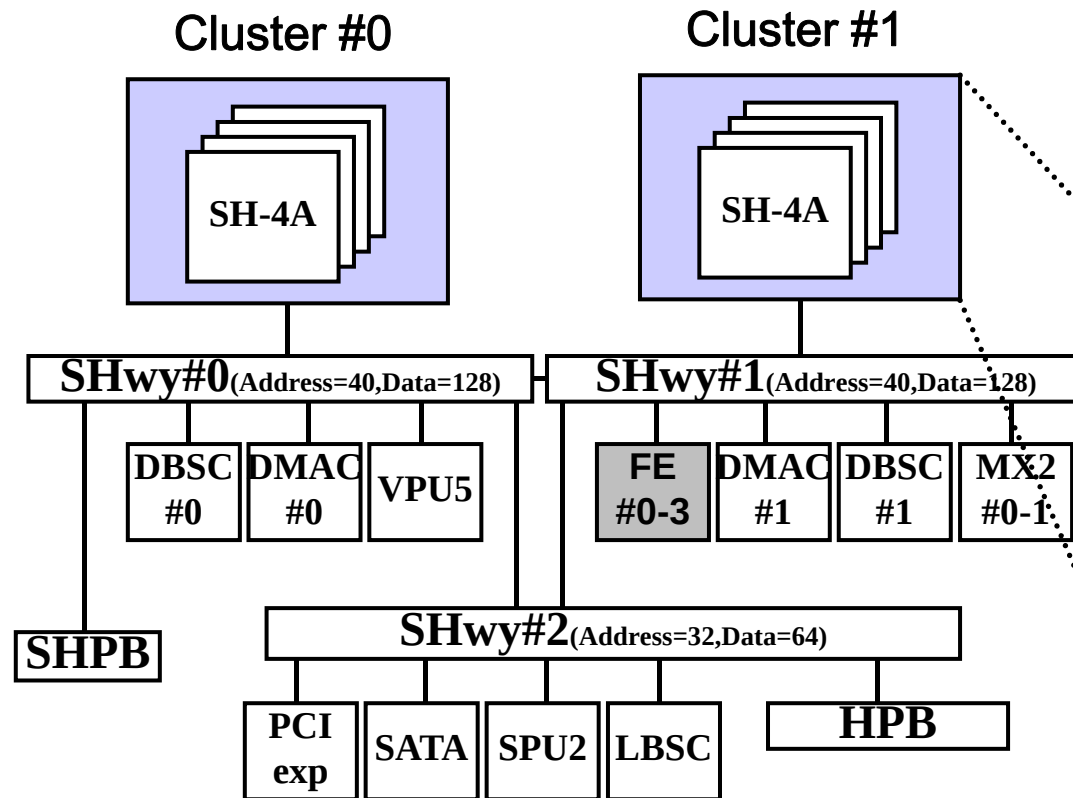
Avg. Power  
1.52 [W]

73.5% Power Reduction



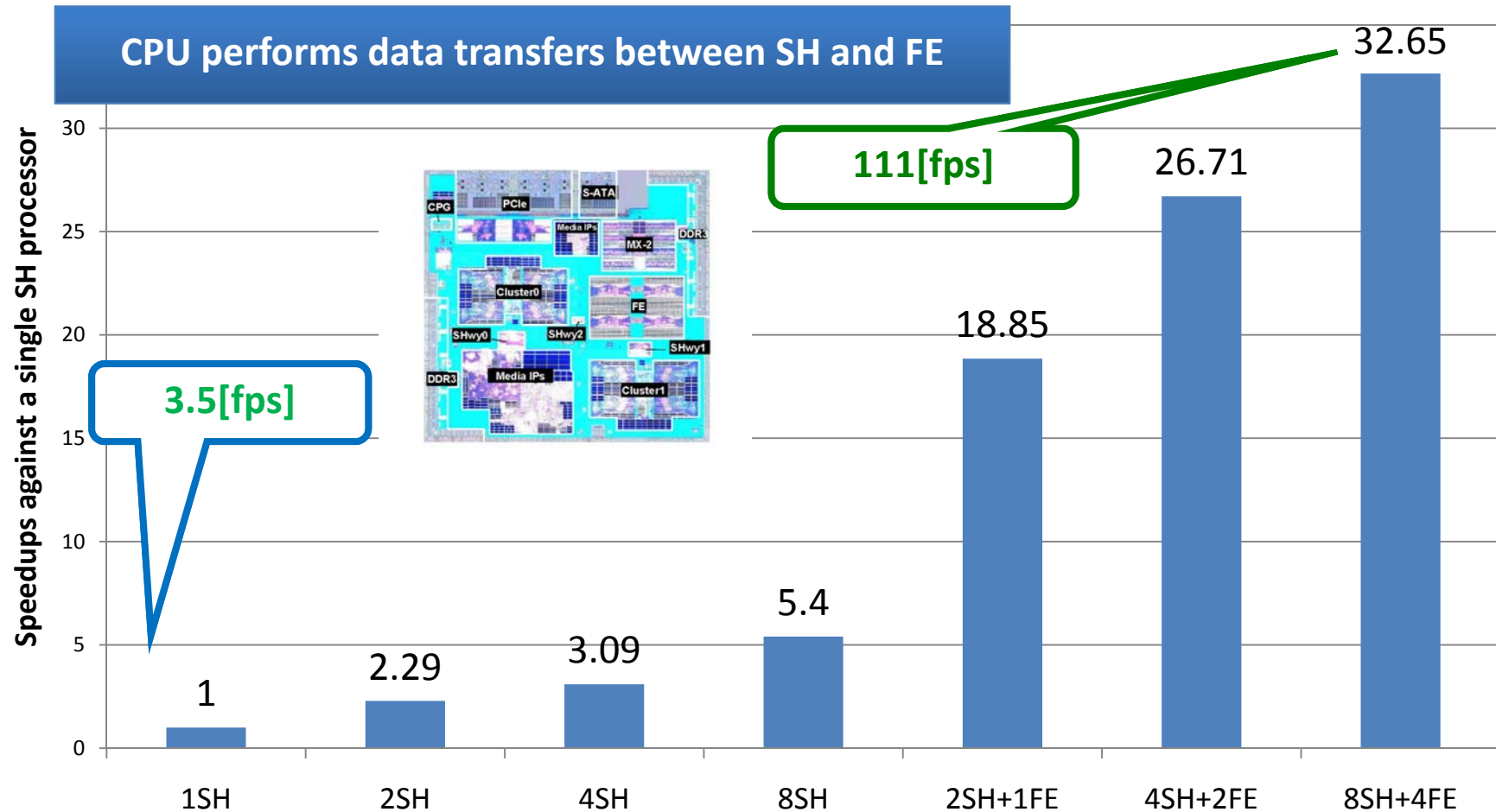
# Heterogeneous Multicore RP-X

presented in SSCC2010 Processors Session on Feb. 8, 2010



Renesas, Hitachi, Tokyo Inst. Of Tech. & Waseda Univ.

# Parallel Processing Performance Using OSCAR Compiler and OSCAR API on RP-X(Optical Flow with a hand-tuned library)



# Power Reduction in a real-time execution controlled by OSCAR Compiler and OSCAR API on RP-X (Optical Flow with a hand-tuned library)

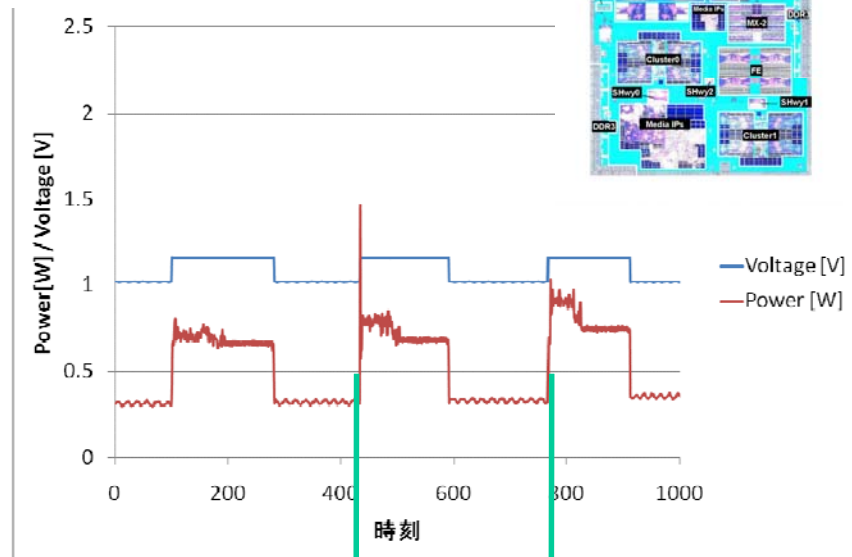
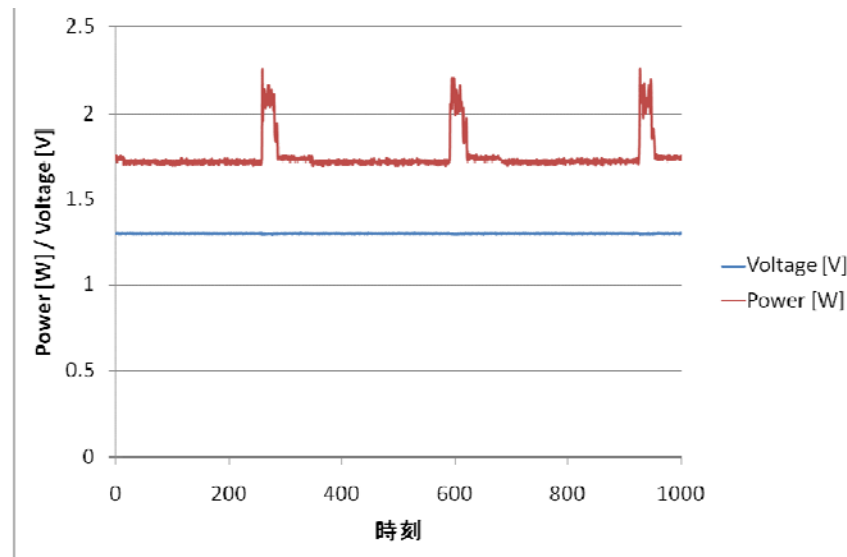
**Without Power Reduction**

**With Power Reduction  
by OSCAR Compiler**

**70% of power reduction**

**Average: 1.76[W]**

**Average: 0.54[W]**



**1cycle : 33[ms]  
→30[fps]**



# Green Computing Systems R&D Center

## Waseda University

Supported by METI (Mar. 2011 Completion)

### <R & D Target>

Hardware, Software, Application  
for Super Low-Power Manycore  
Processors

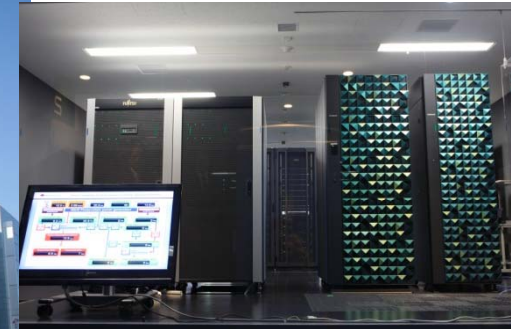
- More than 64 cores
- Natural air cooling (No fan)  
Cool, Compact, Clear, Quiet
- Operational by Solar Panel

### <Industry, Government, Academia>

Hitachi, Fujitsu, NEC, Renesas, Olympus,  
Toyota, Denso, Mitsubishi, Toshiba, etc

### <Ripple Effect>

- Low CO<sub>2</sub> (Carbon Dioxide) Emissions
- Creation Value Added Products
  - Consumer Electronics, Automobiles,  
Servers



Hitachi SR16000:

Power7 128coreSMP

Fujitsu M9000

SPARC VII 256 core SMP



Beside Subway Waseda Station,  
Near Waseda Univ. Main Campus

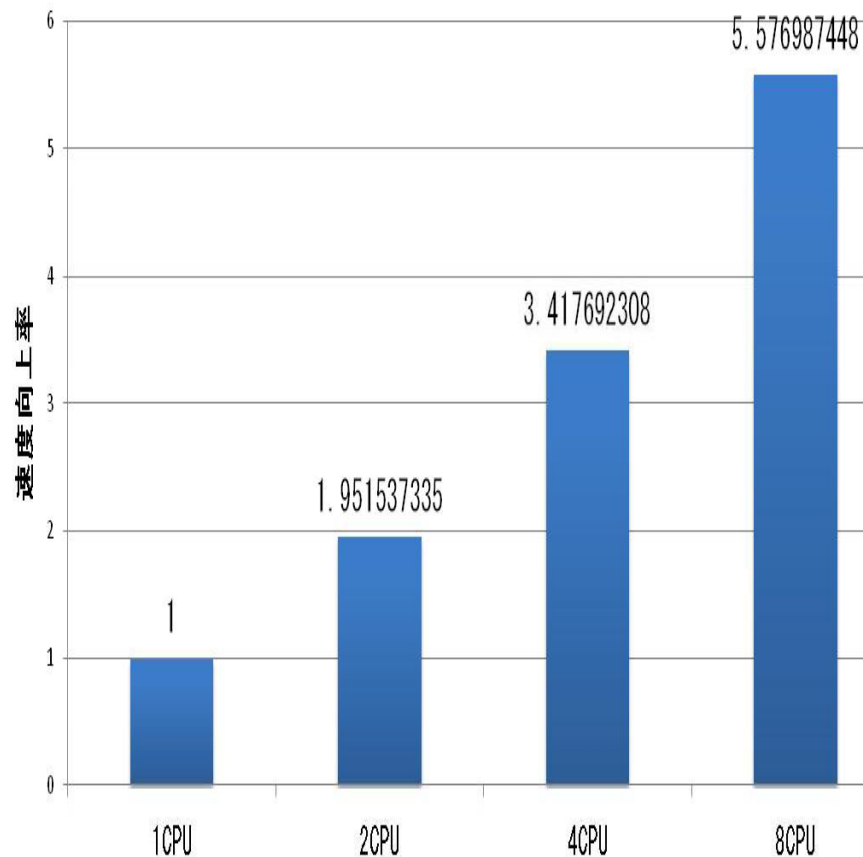
Research, development and practical utilization through industry-government-academia partnerships (spillover effect)

## Environment



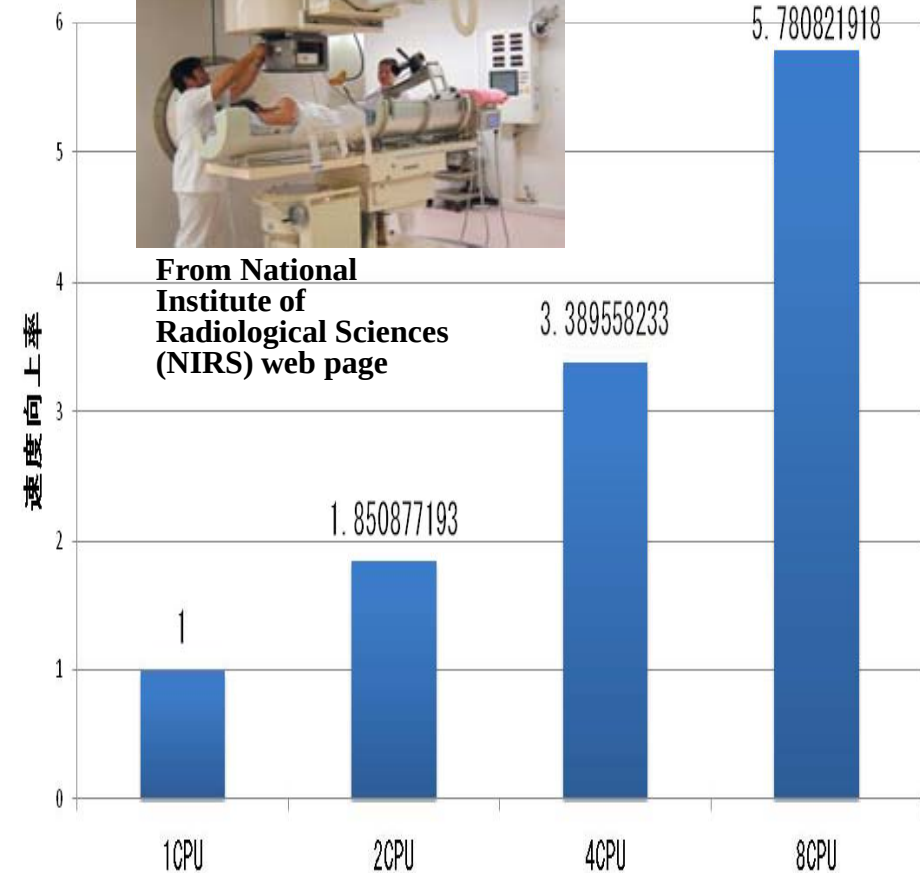
# Cancer Treatment

## Carbon Ion Radiotherapy



5.58 times speedup by 8 processors

**Intel Quadcore Xeon 8 core SMP**



5.78 times speedup by 8 processors

**IBM Power 7 8 core SMP  
(Hitachi SR16000)**

# Conclusions

- **OSCAR compiler cooperative real-time low power multicore with high effective performance, short software development period** will be important in wide range of IT systems from consumer electronics to automobiles, medical systems, disaster super-realtime simulator (Tsunami), and EX-FLOPS machines.
- **For industry**
  - A few minutes of compilation of C program using OSCAR Compiler and API without months of programming allows us**
    - **Several times speedups on market available SMP servers.**
    - **Scalable speedup on various multicores like 8 core homogeneous RP2 (8SH4A) , 15 core heterogeneous RPX (8SH4A, 4FEGA, 2MX2 & 1VPU), MPCore, FR1000 and so on.**
    - **70% power reduction on RP2 and RPX for realtime media processing .**
- **OSCAR green compiler, API, multicores and manycores will be continuously developed for saving lives from natural disasters and sickness like cancer in addition to the current activities.**