Photonics in computing: use more than a link for getting more than Moore

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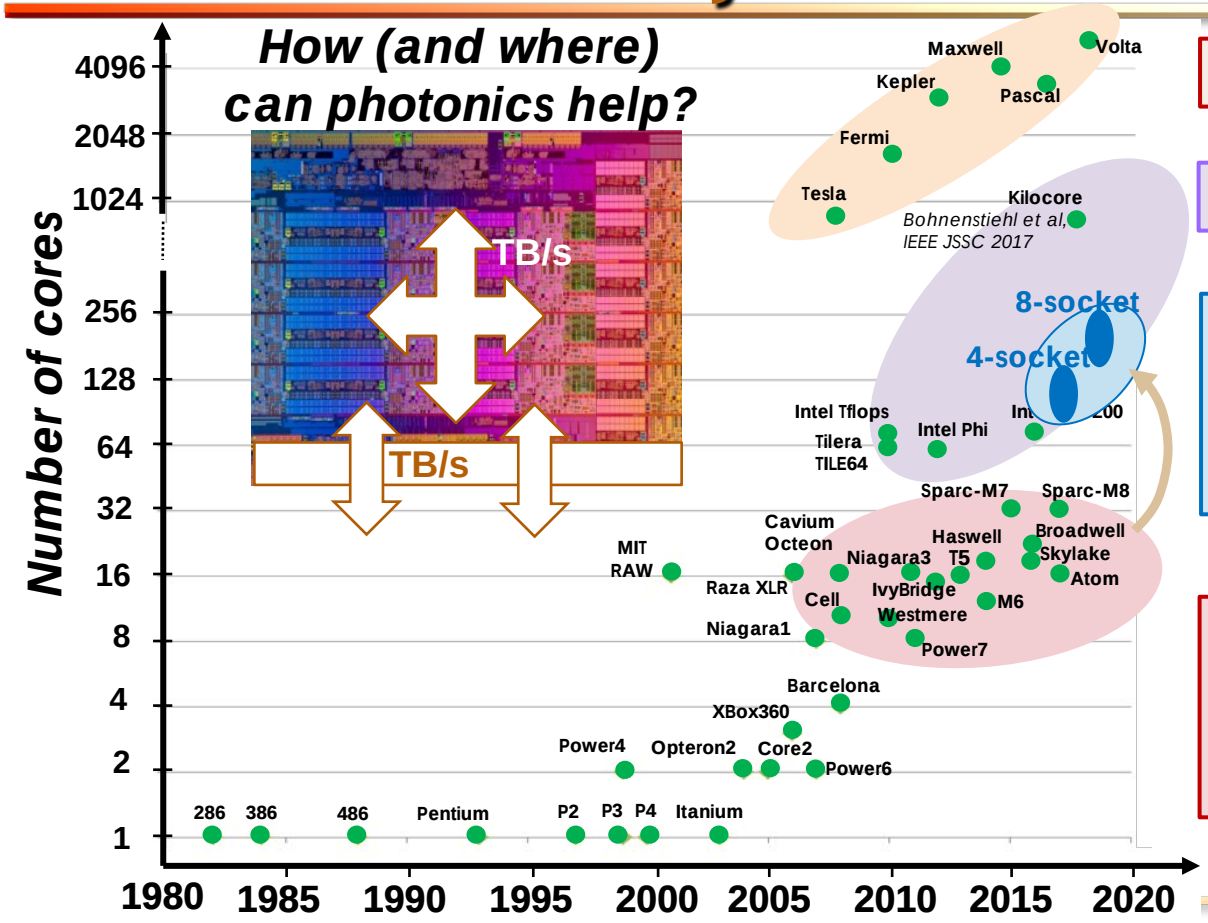
ΚΕΔΕΚ
ΚΕΝΤΡΟ ΔΙΕΠΙΣΤΗΜΟΝΙΚΗΣ ΕΡΕΥΝΑΣ ΚΑΙ ΚΑΙΝΟΤΟΜΙΑΣ ΑΠΘ

PhoS-net Research Group

Multi- and many-core era



NVIDIA Cuda cores, ~2 Gflops/core

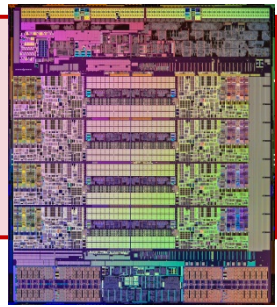
Many-core, up to 3.5 Tflops *(Xeon Phi 7290)*

- ***4S*** *(64-128 cores)*, ***up to 3.6Tflops***
- ***8S*** *(128-256 cores)*, ***up to 7.2Tflops***

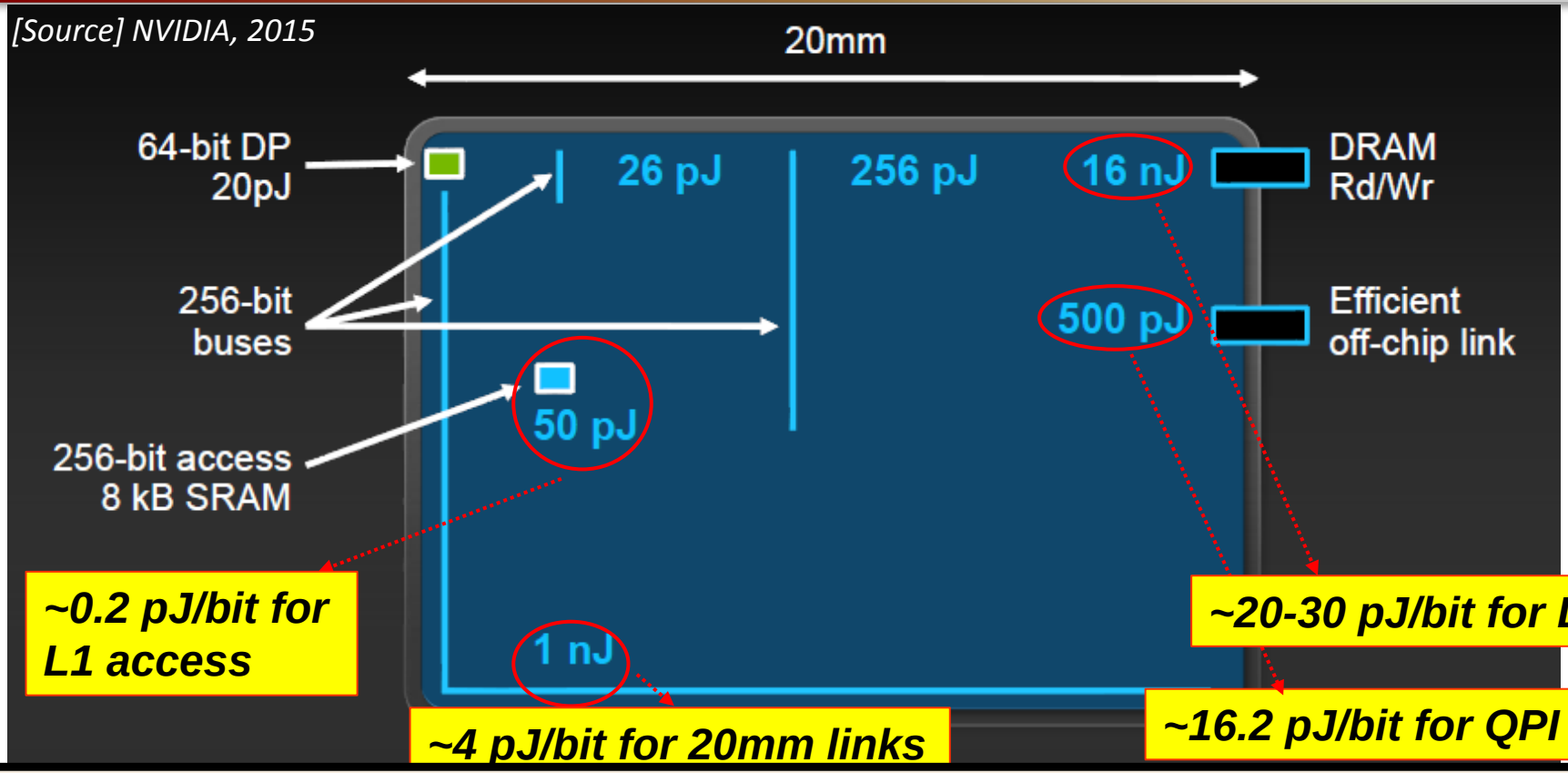
High-perf multicore

up to 0.9Tflops *(E5-2599v4)*

up to 32 cores



Energy

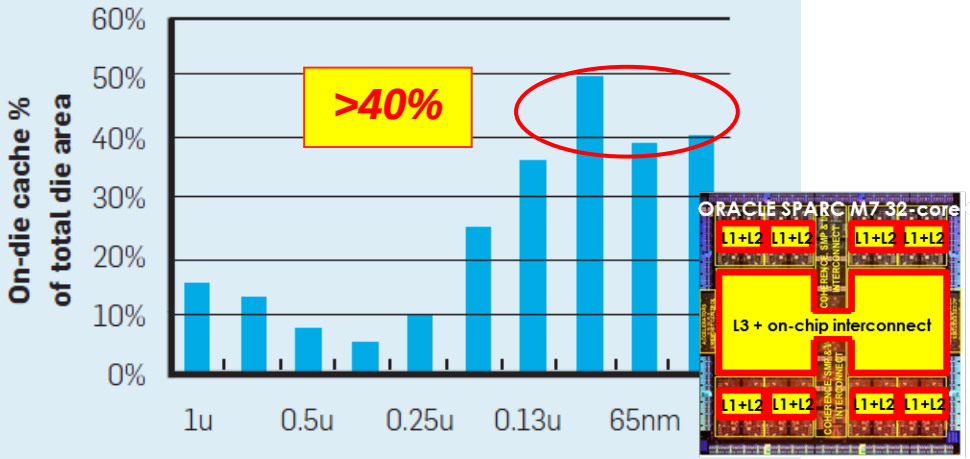


- ***Fetching operands costs more than computing on them!***

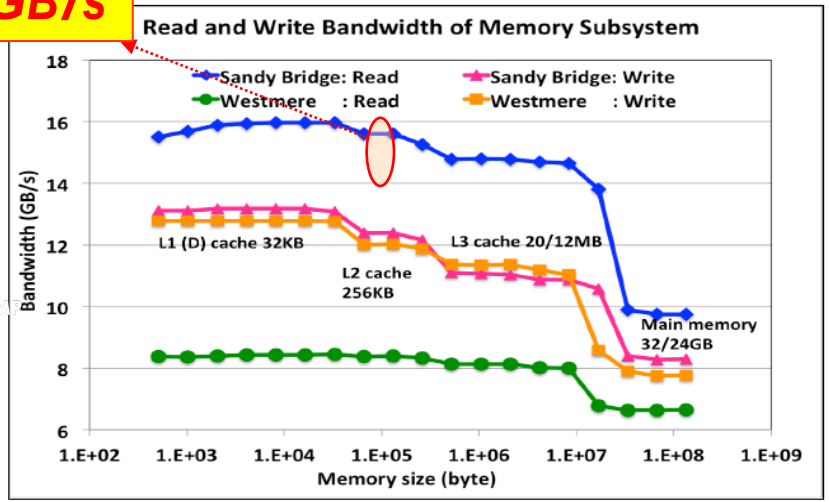
Die Area & Memory BW

Evolution of on-die caches in high-perf CMPs

[Source: S. Borkar and A.A.Chien, Com. ACM, 2011]



<20GB/s

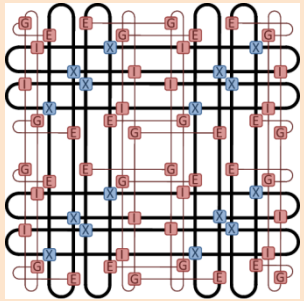


Sandy Bridge vs Westmere

- ✗ ***Up to 40% of die area consumed by NoC & caches – but still <20GB/s L1 bandwidth***
- ✗ ***Small no# of high-perf cores fit in 400mm² area***

The optical NoC escape-way

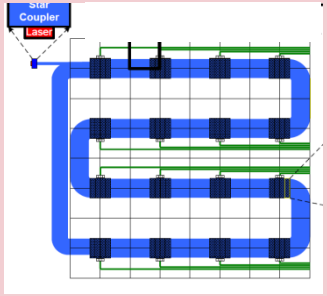
Photonic torus,
(Columbia, A. Shachamet al., 2008)



switch
- 4x4 Si PSE
- 144 in total
- 10mw

TxRx
- 40Gb/s
- 0.2pJ/bit
- 24 λ's

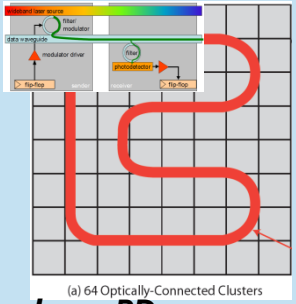
CORONA *(HP, D.Vantrease et al, 2008)*



mod
- Si-ring
- 10Gb/s

PD
- SiGe ring
- 1fF
- no TIA

ATAC 1000-core
(G.Kurian et al, PACT 2010)



mod
- 50um2
- 1Gb/s
- 25fJ/bit

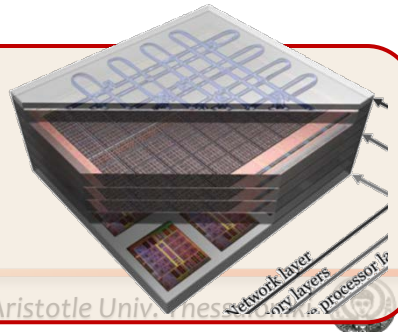
PD
- >1 A/W, 20um2
- 1GHz
- 1fF, no TIA

- ***>1000-core CMPs***
- ***assumed 10-40Gb/s***
- ***20-200 fJ/b OEO***

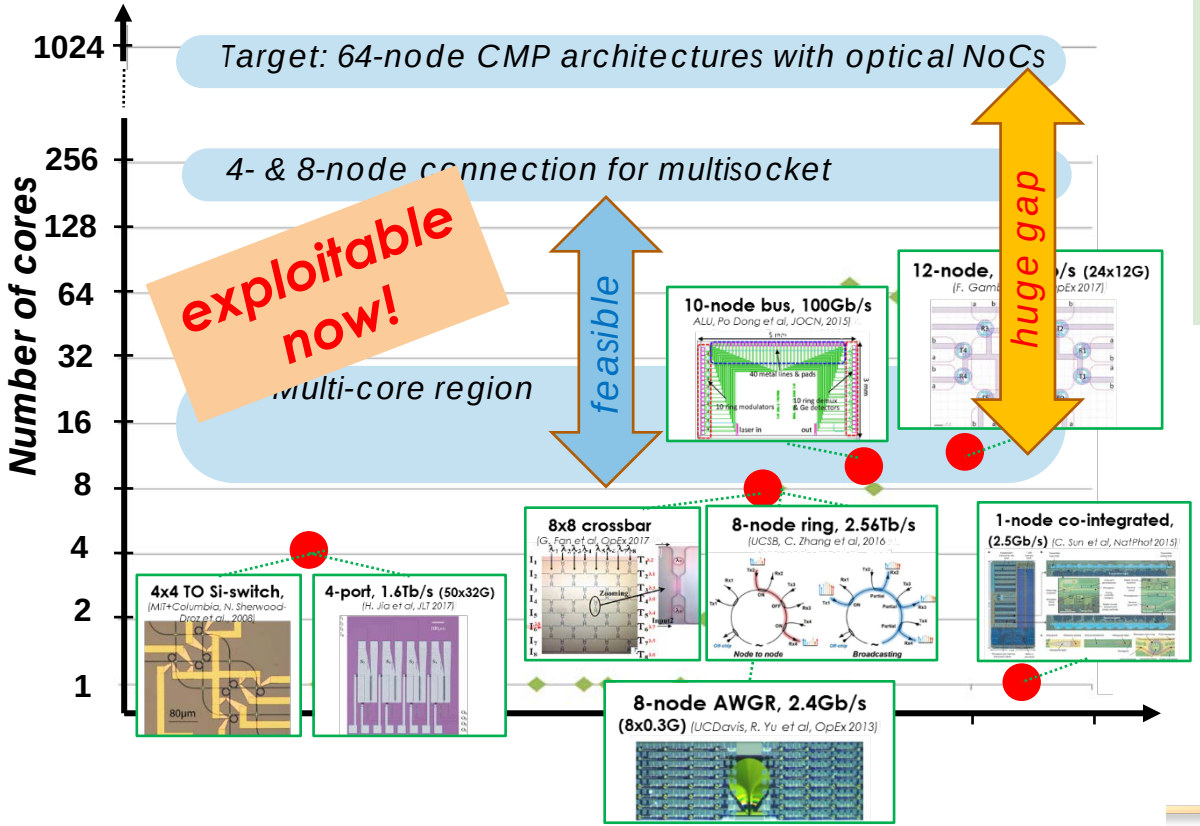
2008 — 2010

Open Problems

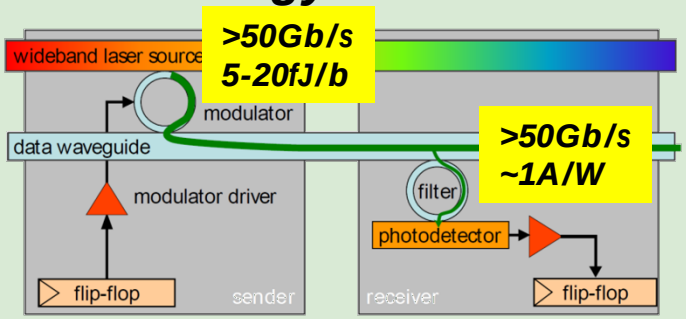
- ***How to co-integrate 1000's of photonic structures!***
- ***3D SiP still far away!***



The optical NoC technologies



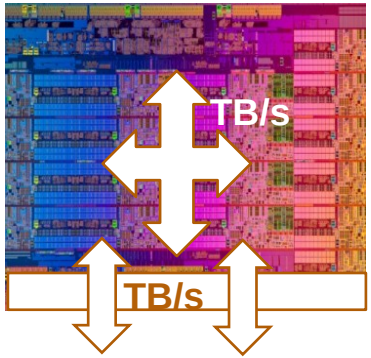
Si-technology is almost here!



BUT, after 10 years

- ***Limited pNoC connectivity***
- ***co-integration only recently realized at 2.5G***

How (and where) can photonics help

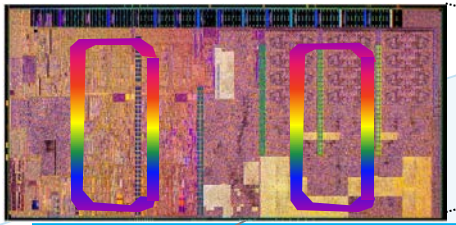


- ✓ NoCs for **high-perf multicores** instead of lower-perf manycores:
  - ✓ focus on easier co-integration technology
  - ✓ Disintegration for overcoming die-area constraints and yield modular and flexible CMPs

- ✓ Adapt the pNoC know-how **in multi-socket interconnects** for scaling into high-perf manycore setups:
  - ✓ at a much lower energy than electronics
  - ✓ and an increased number of sockets!

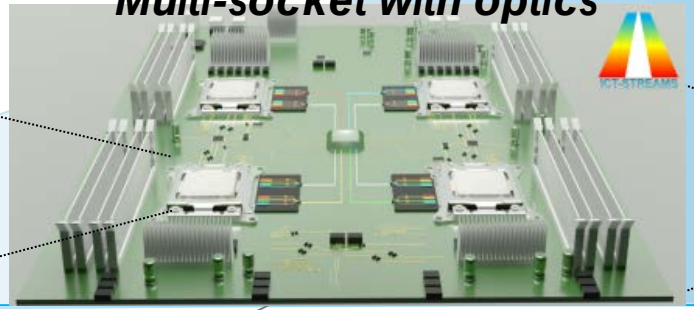
Our work @PhosNET

Chip-scale

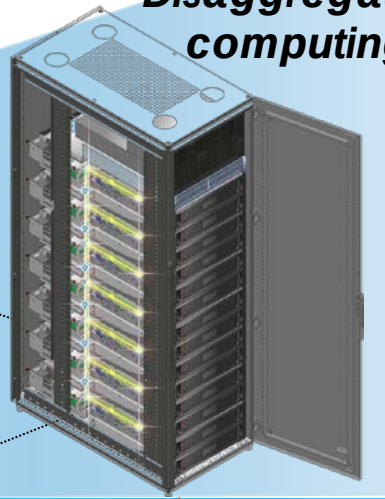


hierarchy

Multi-socket with optics



Disaggregated computing

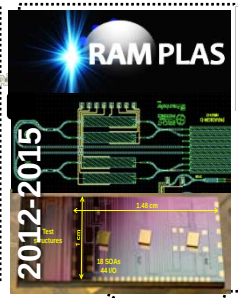


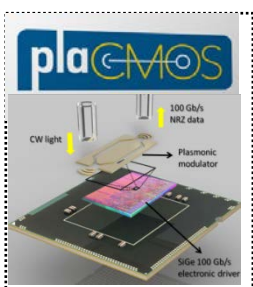
- ✓ ***CMOS plasmonics:*** *easier co-integration of Tx/Rx interfaces*
- ✓ *Deploy* ***ultra-fast optical cache memories***
- ✓ ***Disintegrate:*** *macro-chips!*

- ✓ ***Use Silicon photonics*** *for:*
  - ✓ *scaling to 16 sockets*
  - ✓ *lower by 75% the QPI pJ/b*
  - ✓ *Improve 5x the QPI BW*

- ✓ ***Use silicon photonics*** *for low-latency high-port switching: Hipoλaos*
- ✓ ***Deployed OptoHPC*** *simulator*

Our work @PhosNET



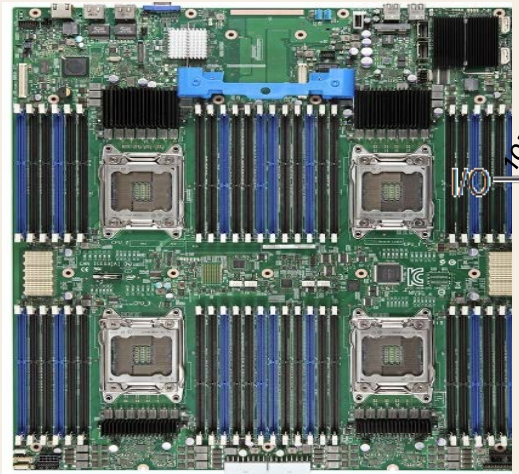


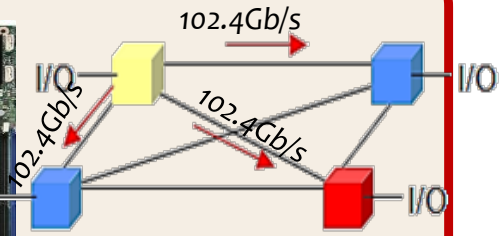
2010 2012 2016 2018

- ✓ *First concepts for plasmonics in NoCs*
- ✓ *Ultra-fast Optical RAMs and caches*
- ✓ *16-socket compute with 12.8Tb/s*
- ✓ *OptoHPC simulator software*
- ✓ *Hipoλaos 1024-port switch for disaggregation*
- ✓ *to CMOS plasmonics*
- ✓ *To 200G CMOS plasmonic mod*

Multisocket processors…"glueless"

4-Socket



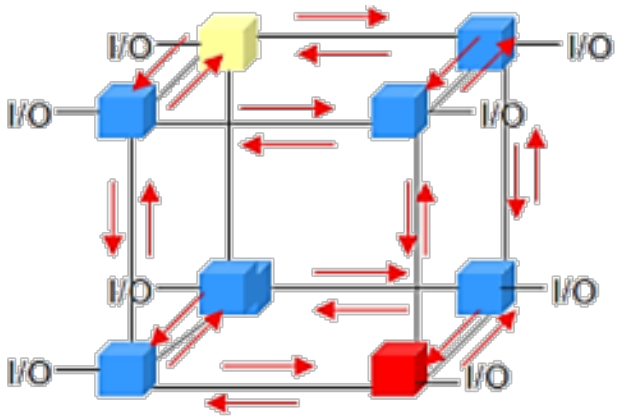


Intel® QuickPath Interconnect

- ✓ *4 sockets P2P*
- ✓ *9.6 Gb/s*
- ✓ *38.4 GB/s BW (307.2 Gb/s) or 102.4 Gb/s /direction*
- ✓ *60ns-240ns Latency*
- ✓ *16 pJ/bit link*

- ✓ ***120 high-perf processors directly connected !***
- ✓ ***Low-latency, low-power***

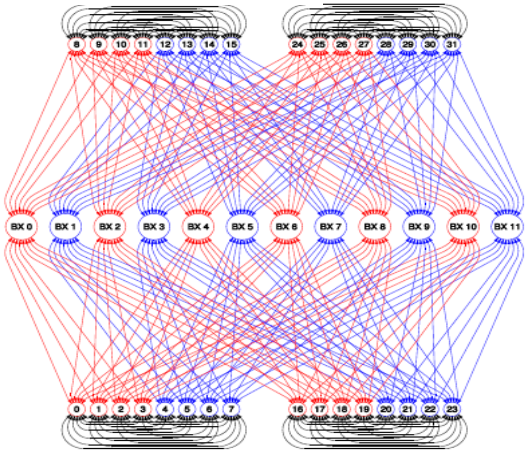
8-Socket



- ✓ ***240 high-perf processors!***
- ✗ ***up to 2-hop***
- ✗ ***Increased latency***

Going beyond 8 sockets?

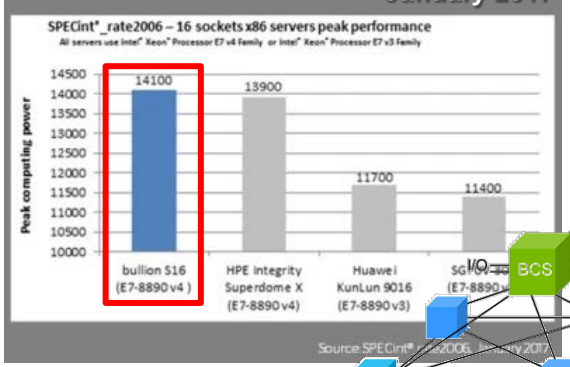
ORACLE



Bixby (BX) switches

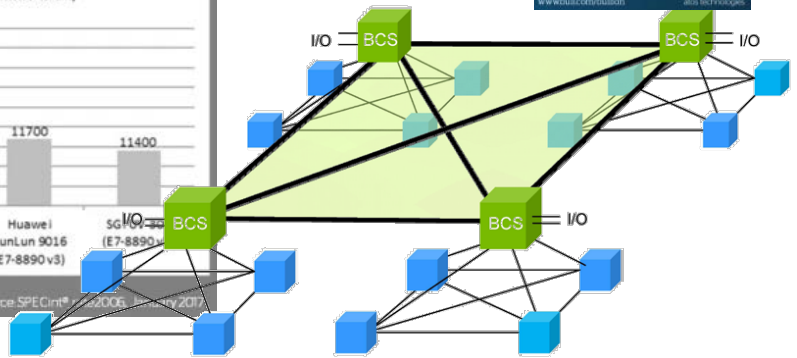
bullion™ high-end server beats worldwide records

January 2017



Bull

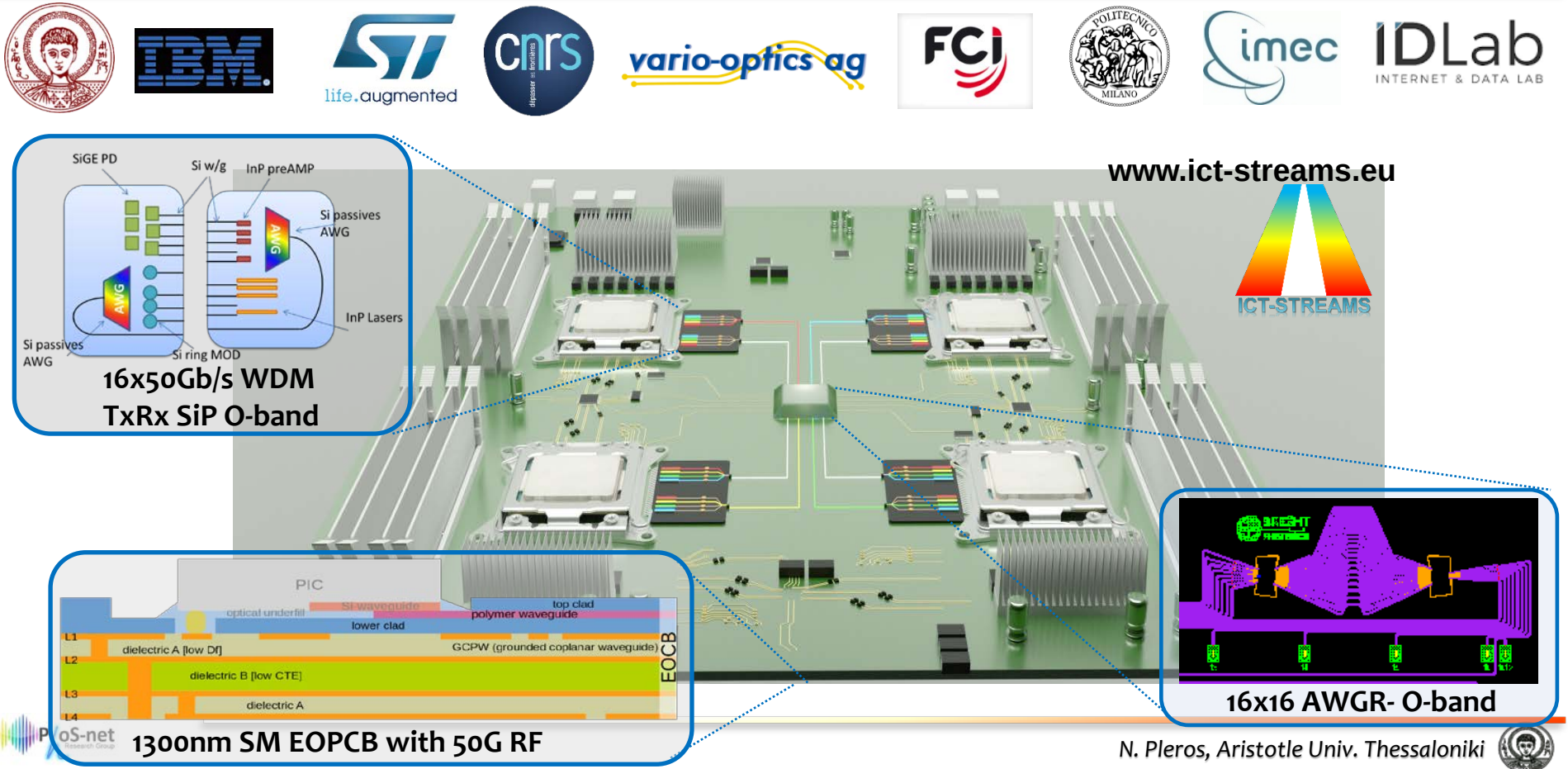
bullion



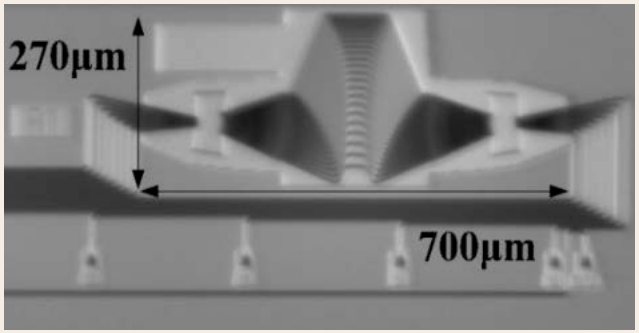
enormous compute power: >14TFlops

- ✓ *only through extra switch stage*
- ✓ *...but latency increases dramatically*
- ✓ *65% of QPI BW wasted for cache coherency updates*

The ICT-STREAMS multisocket interconnect



Si-based 8x8 AWGR & RM technology

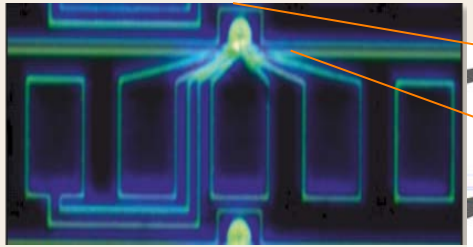


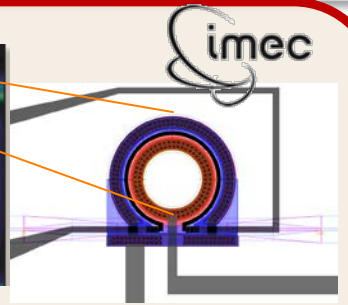
- ***8x8 AWGR O-band***
- ***10nm channel spacing***

OFC2018

S.Pitris et al, Th.2.A.1 Poster Ses., OFC18

S. Pitris et. al., to appear at OpEx

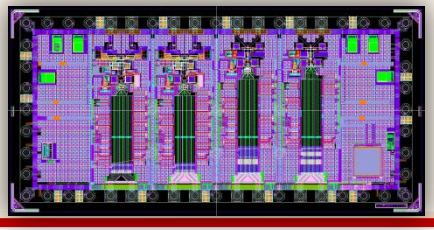




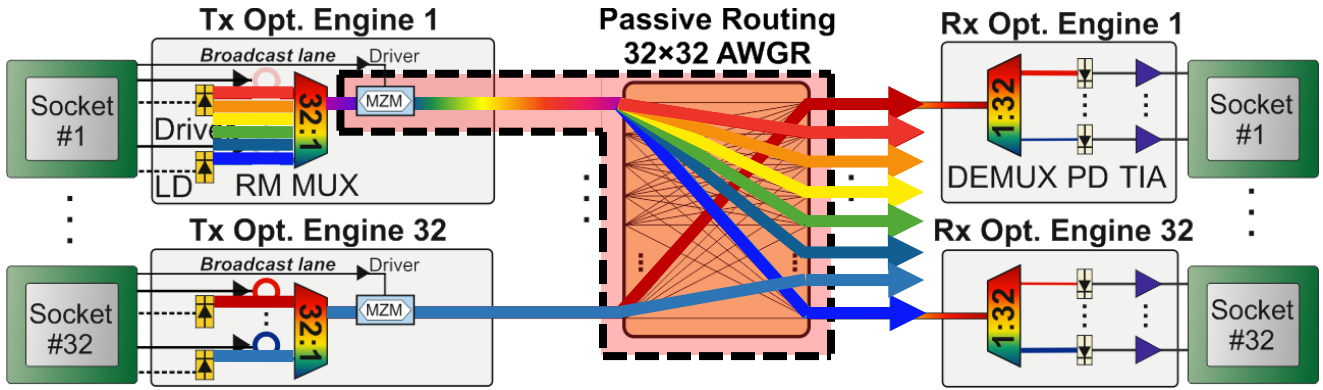
~20 fF 2.3V Vpp @25 Gb/s

- ***26.5 fJ/bit @ 25Gbps***
- ***2.4pj/b expected when driven by IC driver (in fab)***

ST 55 nm SiGe BiCMOS

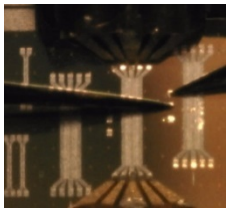


Improving energy in cache coherency updates



S.Pitris et al, Th.1.G.5, OFC2018

Si-pho Mach-Zehnder Modulator



D. Perez-Galacho et al, Opt. Express 25 (10), 2017

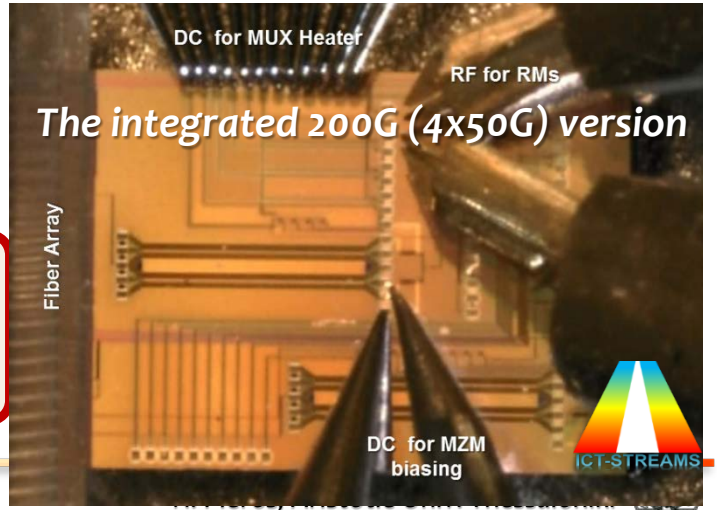
Unicasting — *Enable ➔ 1 LD + 1 RM + 1 PD/TIAs*

Broadcasting — *Enable ➔ 32 LDs + 32 ~~RMs~~ + 32 PD/TIAs*

1 MZM

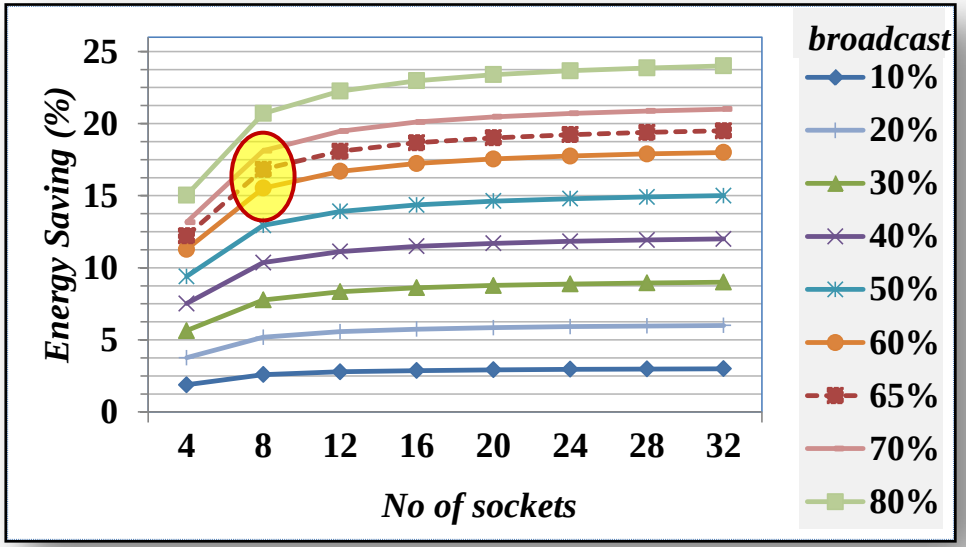
Broadcast-friendly topology:

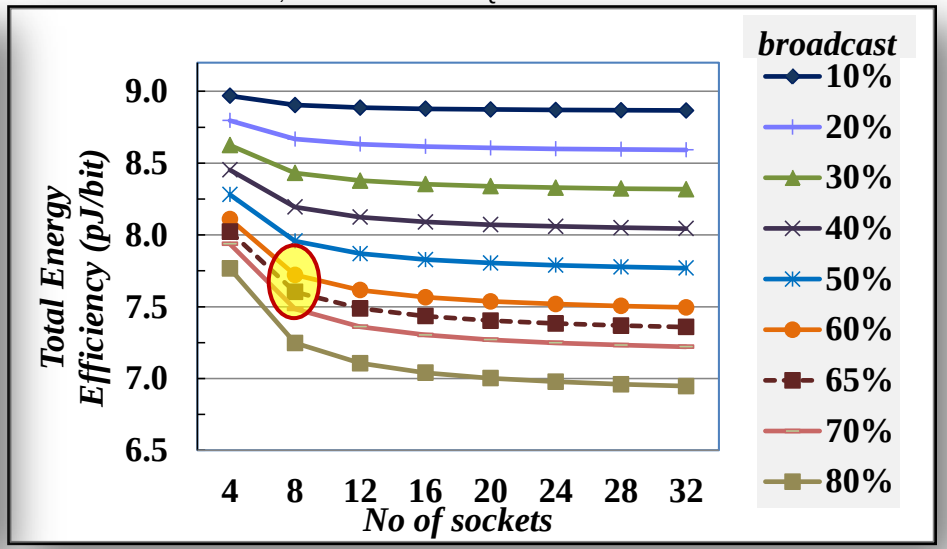
- *Use MZM for simultaneous modulation*
- *RMs in transparency mode*



The energy gain

C. Mitsolidou et al, submitted at JSTQE





✓ ***>15% energy gain*** *for >8-sockets & 65% broadcasted traffic*

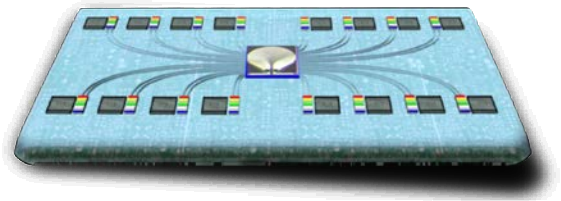
*…**solely** through the broadcast-friendly architecture*

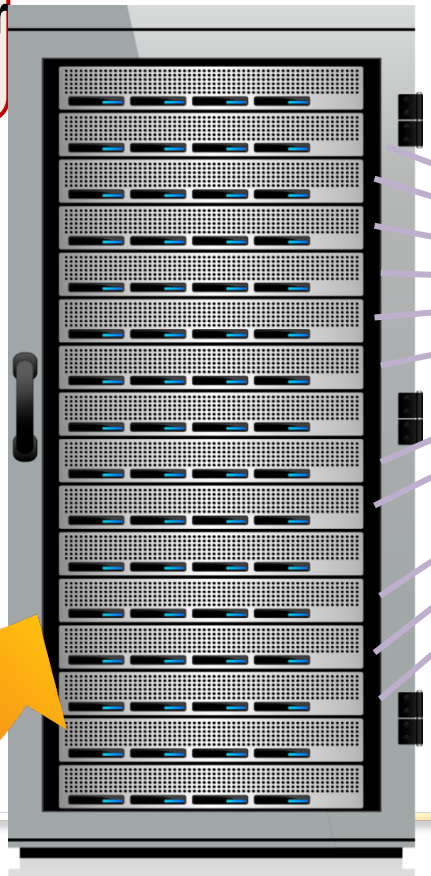
✓ ***~7.5pJ/bit*** *for >8-sockets & 65% broadcasted traffic (25G)*

✓ ***>50% energy savings compared to QPI***

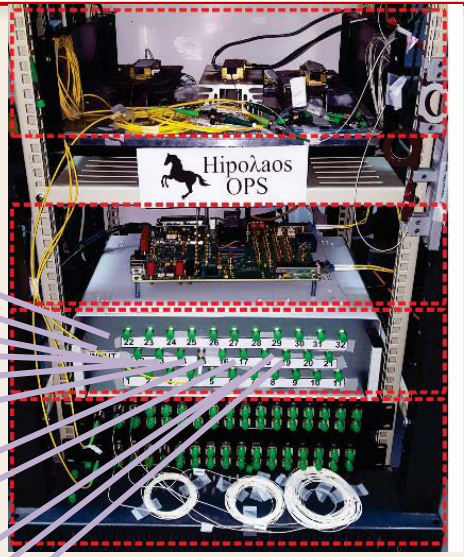
Disaggregate powerful multisocket boards

Release a powerful setup for disaggregated computing





Scaling up to Rack-level



- ***Hipολaos OPS: 256x256 up to 1024x1024 ports***
- ***sub-μsec latency***

N. Terzenidis et al, to appear at OpEx

Conclusions

- ✓ *Connectivity and 3D co-integration the limits for Si-Pho pNoCs in manycore… but not for multicore!*
- ✓ *Form powerful manycore setups through:*
  - ✓ *Si-Pho for >16-socket compute nodes (~480 cores)*
    - ✓ *directly linked, with 12.8T*
    - ✓ *<50% energy over QPI*
    - ✓ *adapting to cache coherency-induced broadcasting*
  - ✓ *Disintegrated macro-chip layouts via off-chip optical cache memories*
- ✓ *Disaggregated computing through powerful Si-Pho multi-socket boards connected over a low-latency 256x256 Hipoλaos OPS*

Acknowledgements

PHOTONICS PUBLIC PRIVATE PARTNERSHIP

ICT-STREAMS

www.ict-streams.eu

L3MATRIX
LARGE, LOW POWER AND LOW COST DATA CENTRES

http://l3matrix.eu

PLASMO

www.plasmofab.eu

Acknowledgements

Greek colleagues and PhD students who stayed in Greece despite the financial crisis, “guarding Thermopylae” (φυλάττω Θερμοπύλες)

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THANK YOU !

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