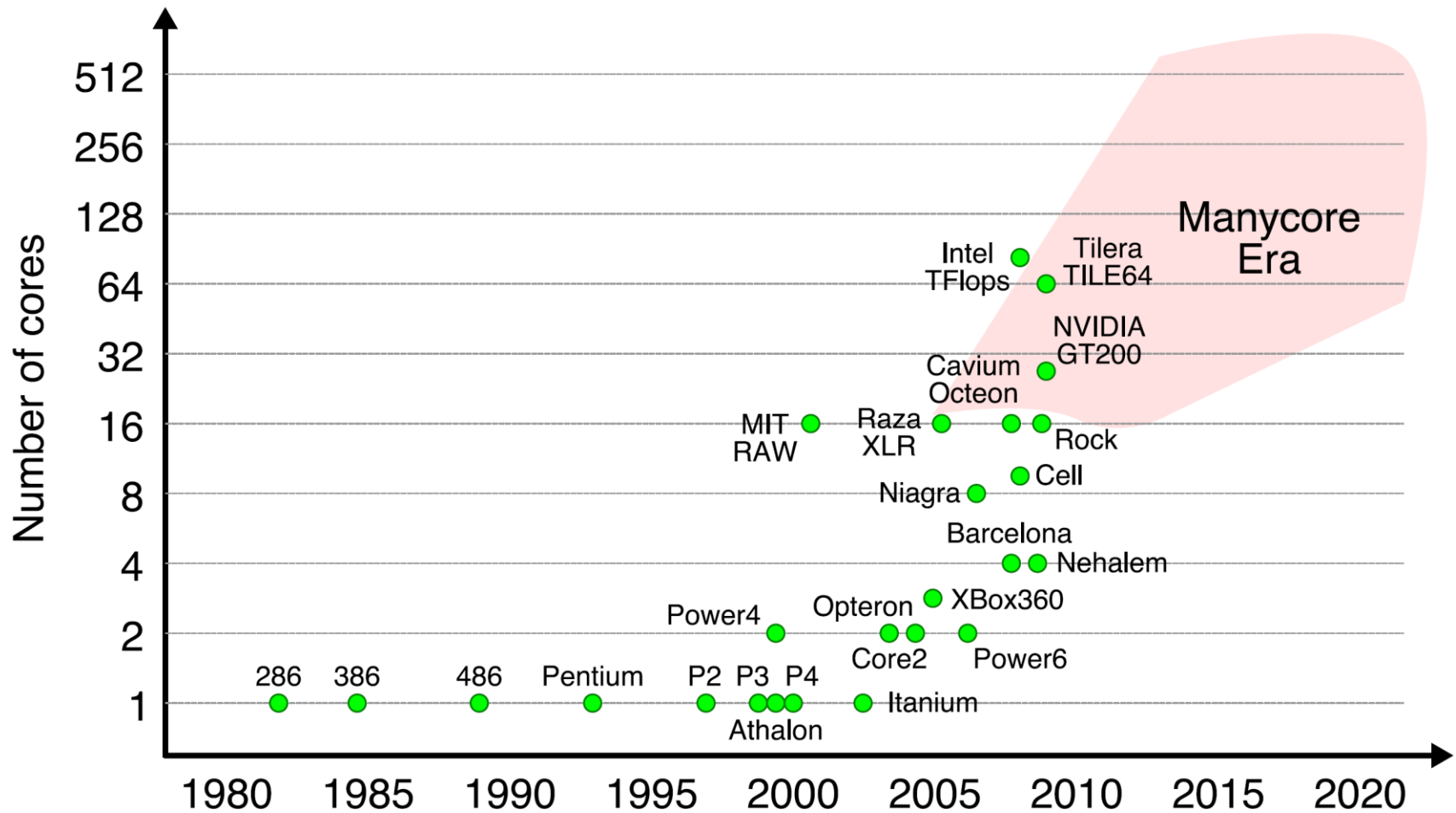


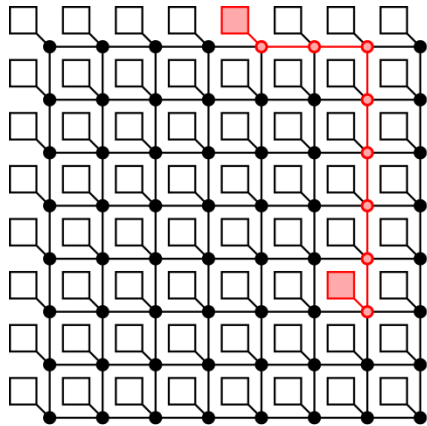
Hybrid Optoelectric On-chip Interconnect Networks

Yong-jin Kwon

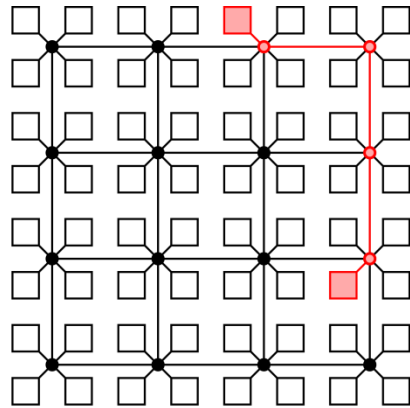
Target Manycore System



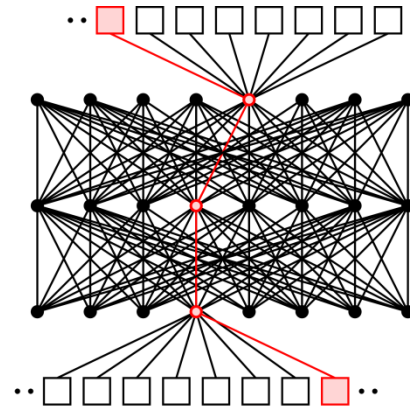
On-chip network topology spectrum



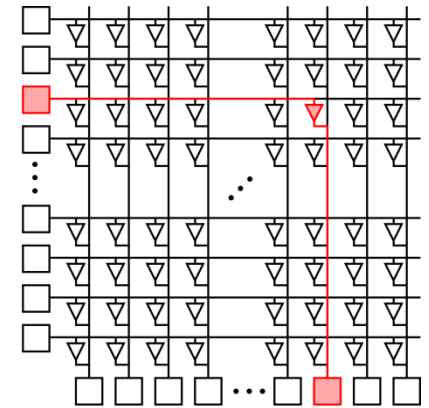
Mesh



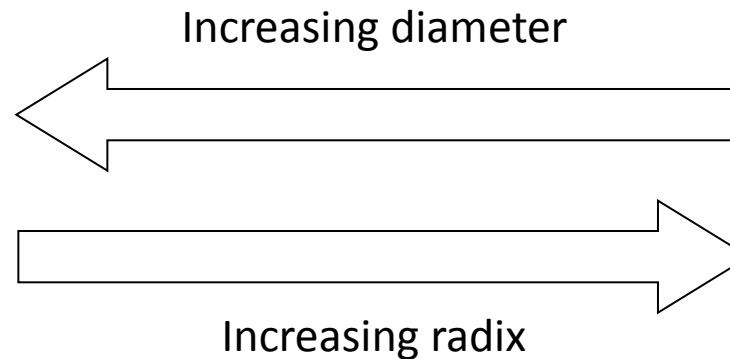
CMesh



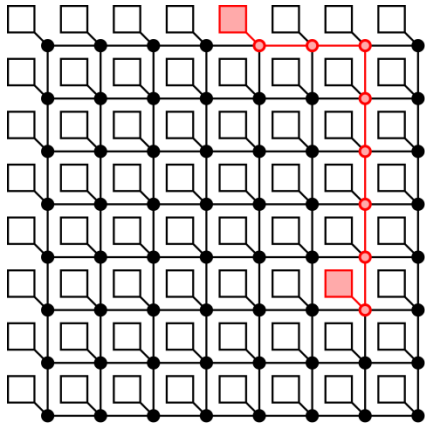
Clos



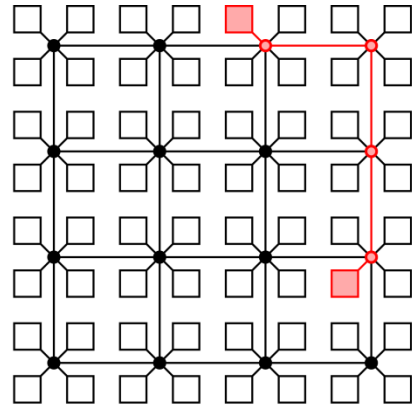
Crossbar



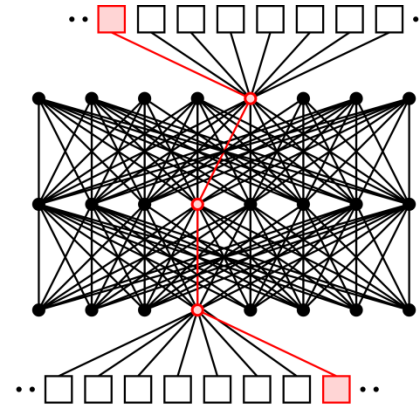
Related Works



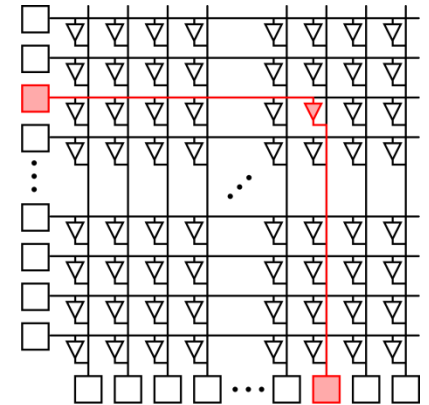
Mesh



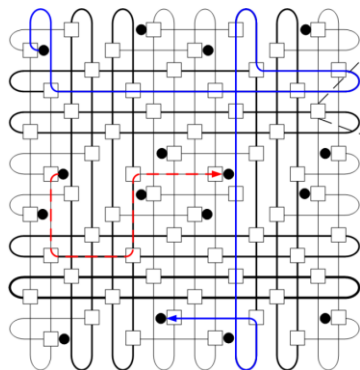
CMesh



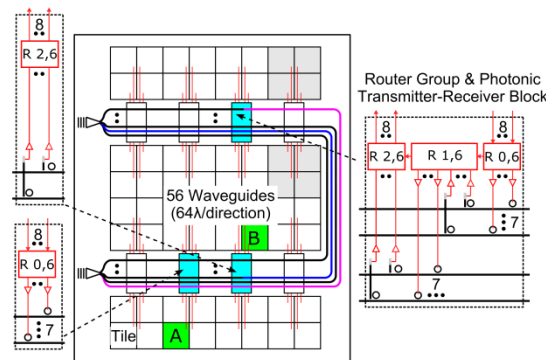
Clos



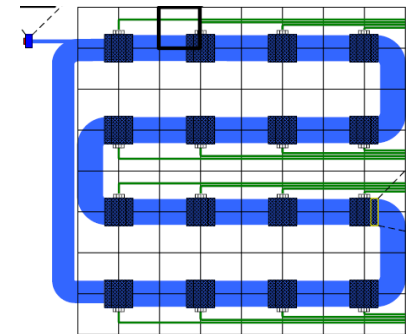
Crossbar



[Shacham'07]
[Petracca'08]



[NOCS'09]
[Pan'09]

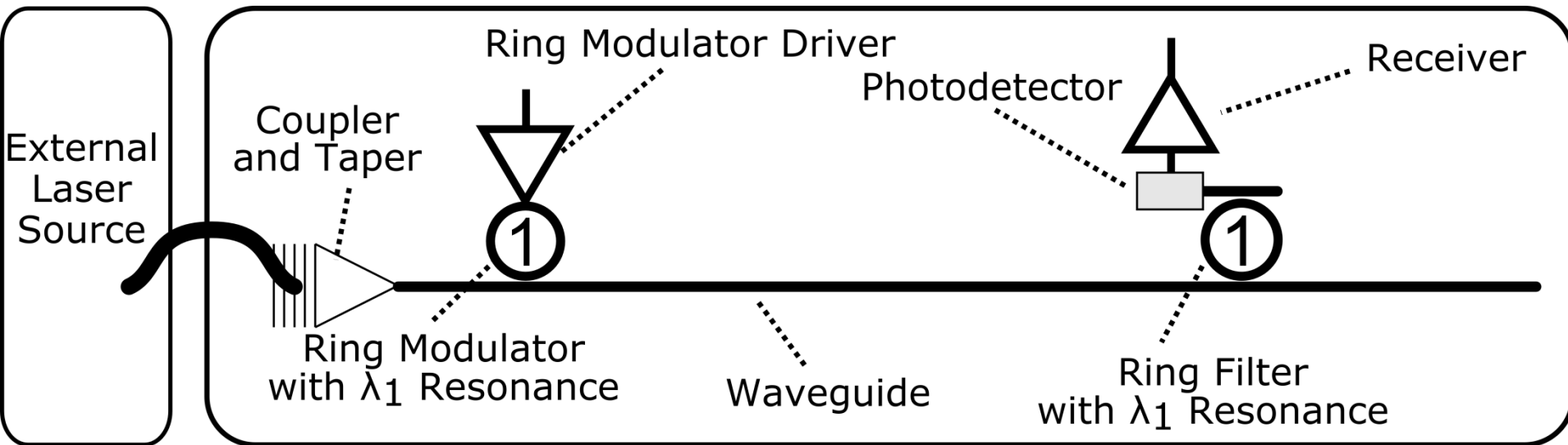


[Vantrease'08]
[Psota'07]
[Kirman'06]

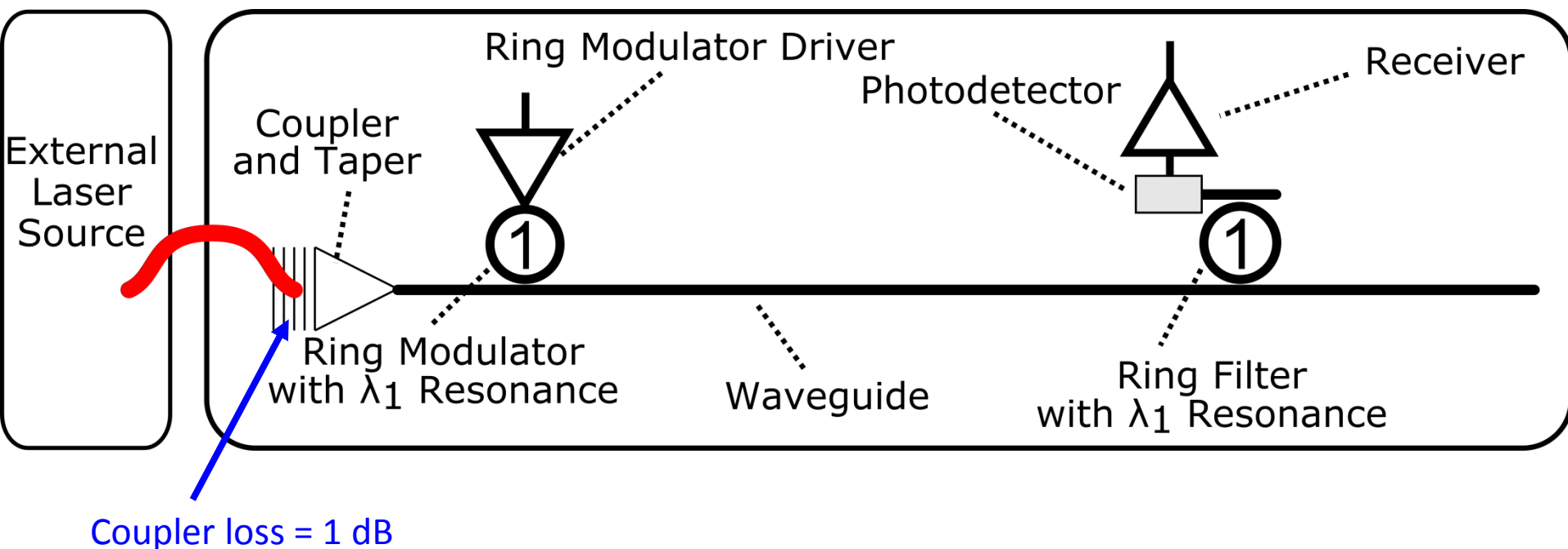
Outline

- Technology Background
- Previous Studies and Motivation
- Performance Analysis
- Power Analysis
- Conclusion

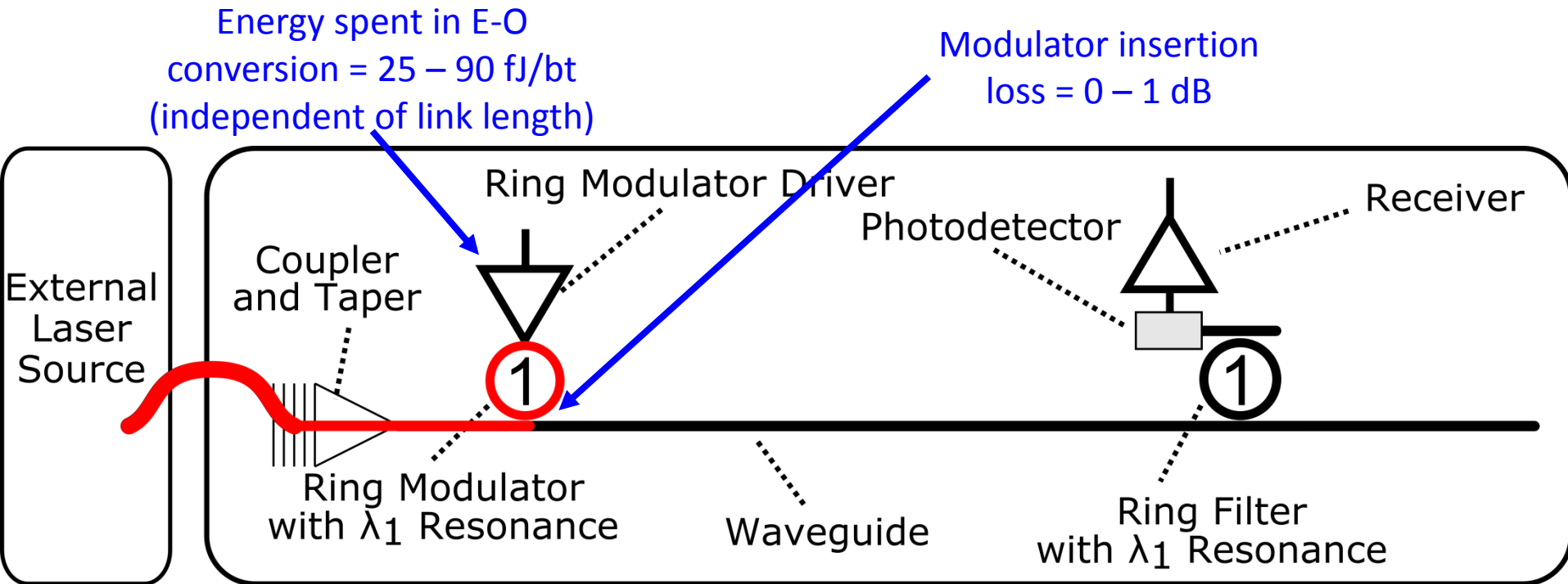
Photonic technology – photonic link



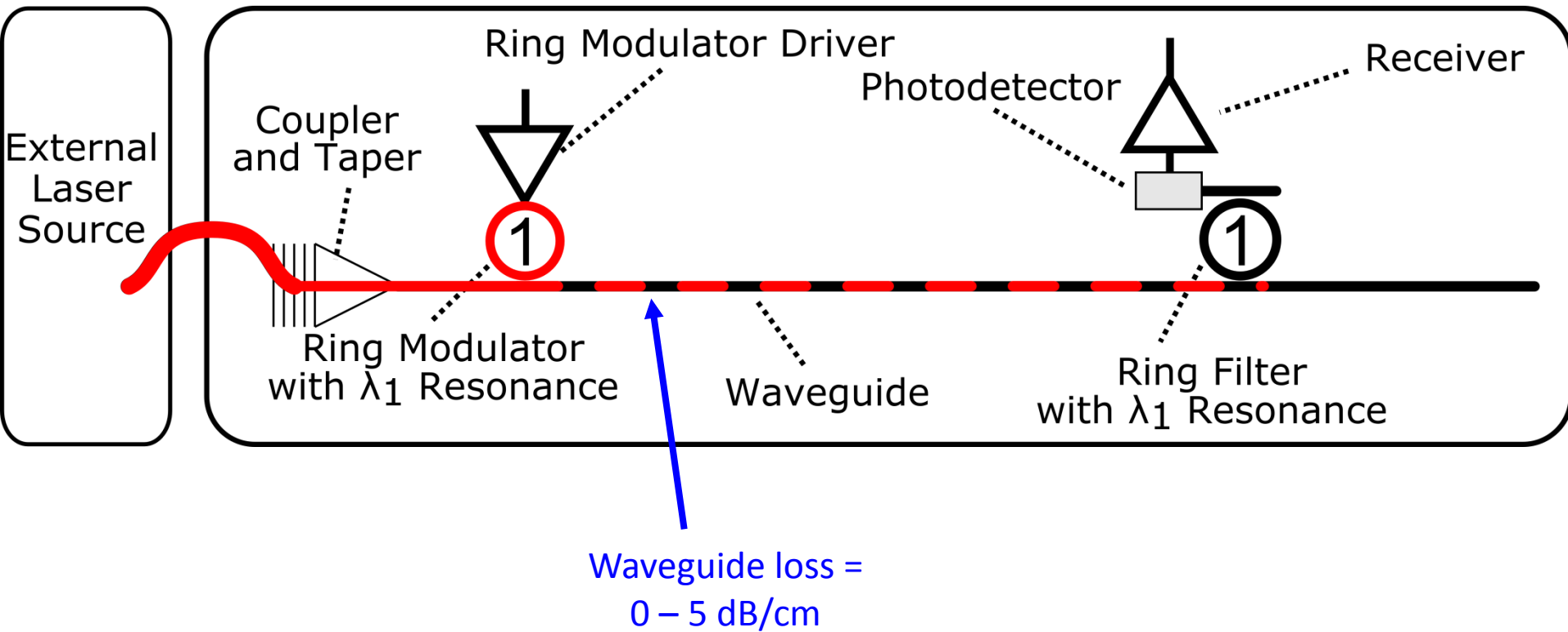
Silicon photonic link – Coupler



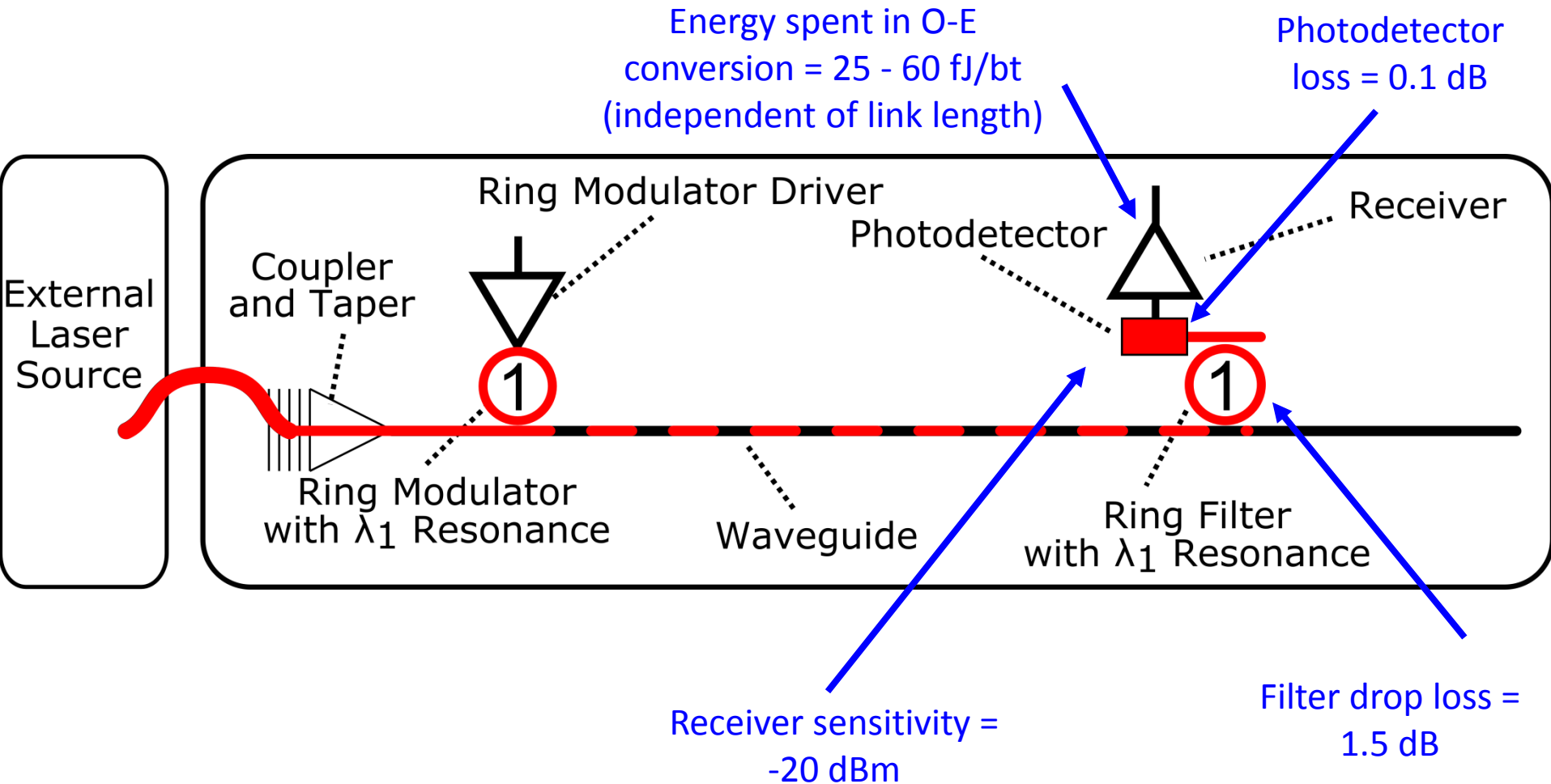
Silicon photonic link – Ring modulator



Silicon photonic link – Waveguide

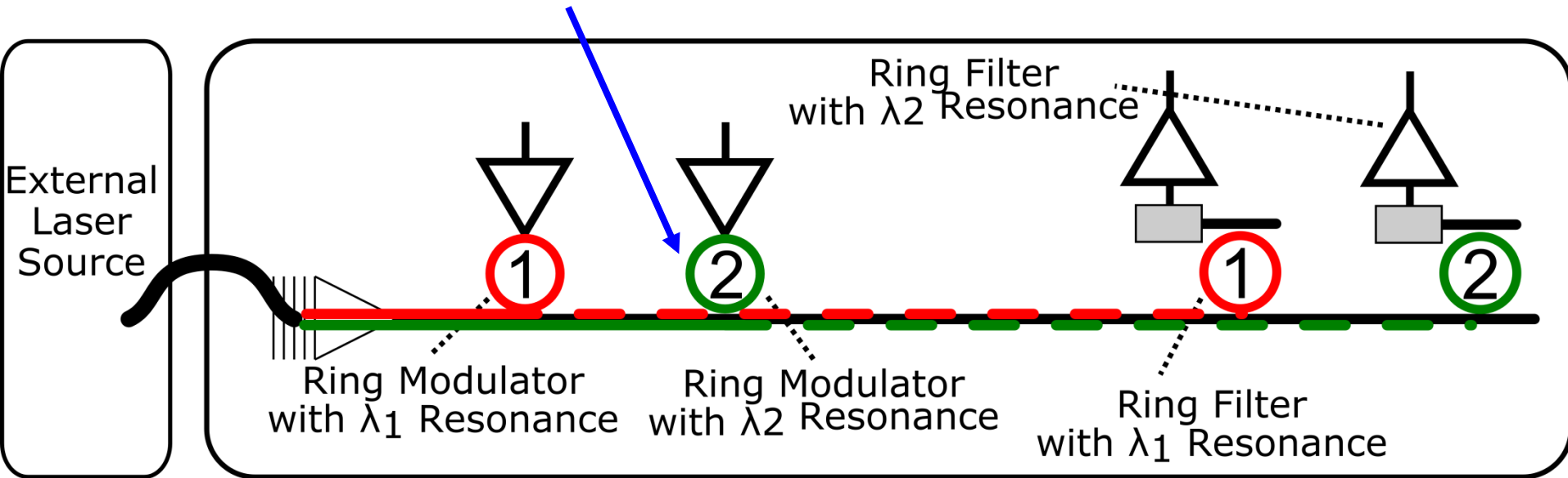


Silicon photonic link – Ring filter, photodetector



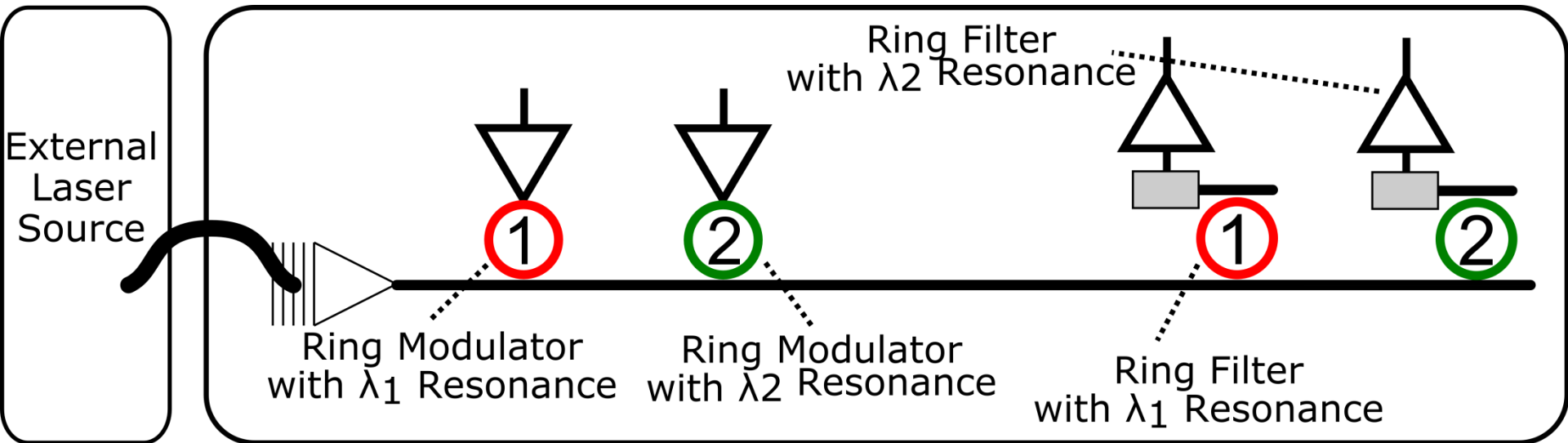
Silicon photonic link – WDM

Through ring loss = $1e-4 - 1e-2$ dB/ring



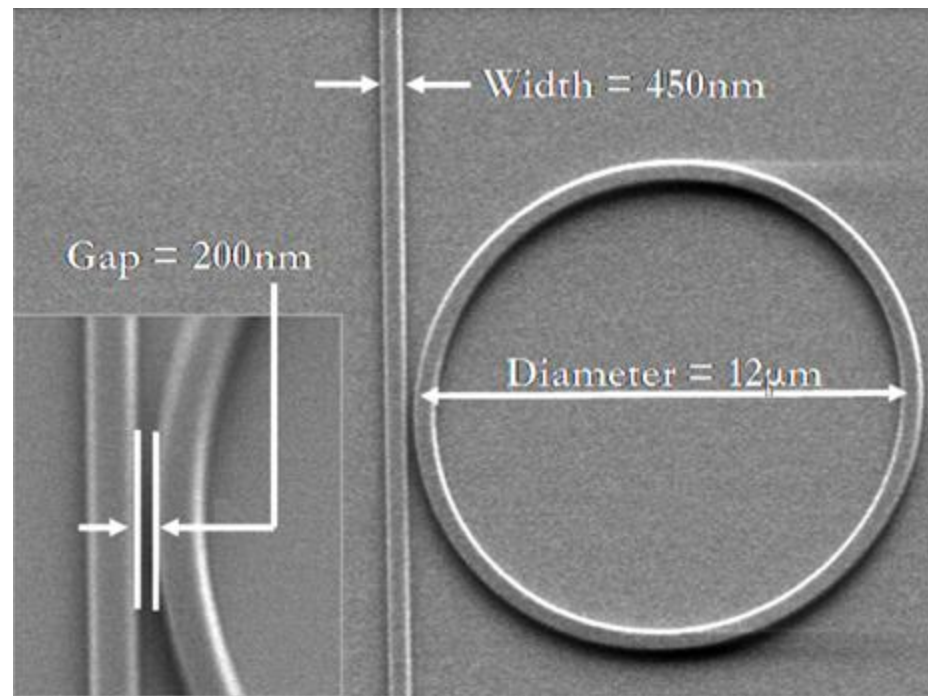
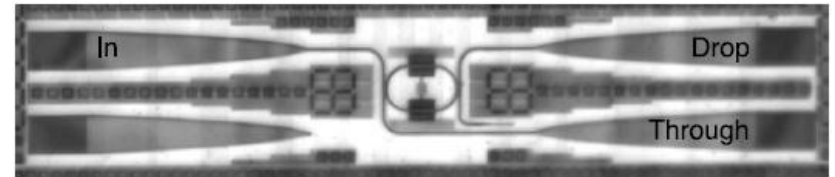
- Dense WDM ($128 \lambda/\text{wg}$, $10 \text{ Gbps}/\lambda$) improves bandwidth density (30x!!)

Silicon photonic link – Energy cost

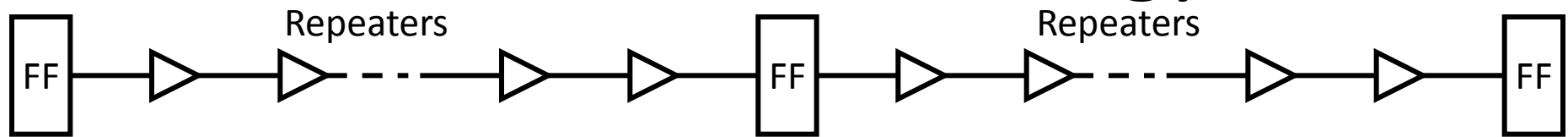


- E-O-E conversion cost – 50-150 fJ/bt (independent of length)
- Thermal tuning energy (increases with ring count)
- External laser power (dependent on losses in photonic devices)

Silicon Photo

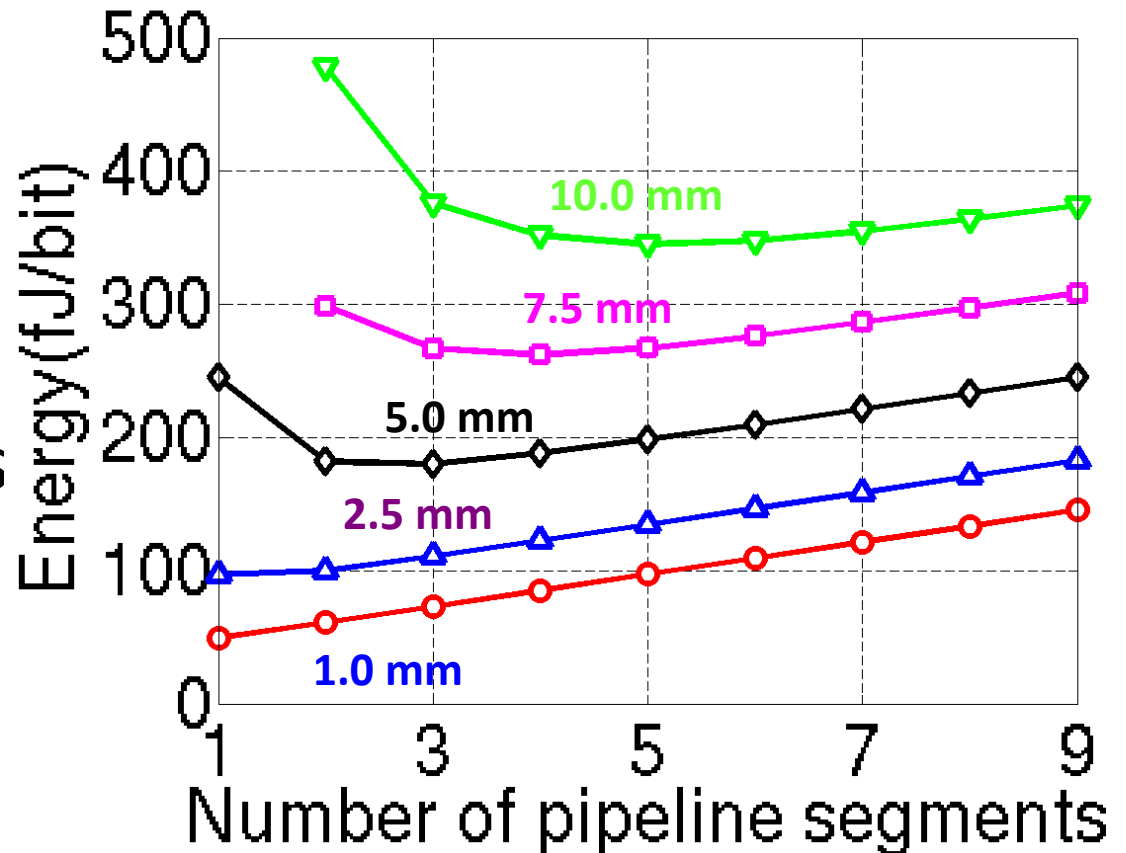


Electrical technology

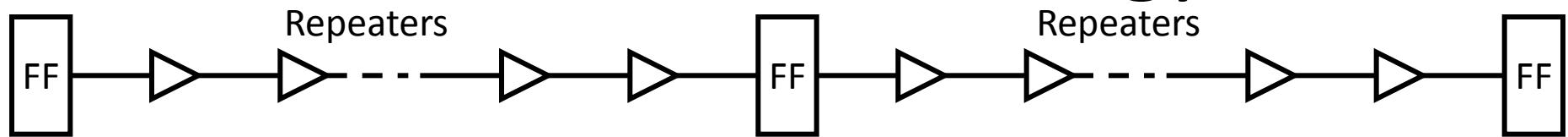


Repeater inserted pipelined wires

- Design constraints
 - 22 nm technology
 - 500 nm pitch
 - 5 GHz clock
- Design parameters
 - Wire width
 - Repeater size
 - Repeater spacing

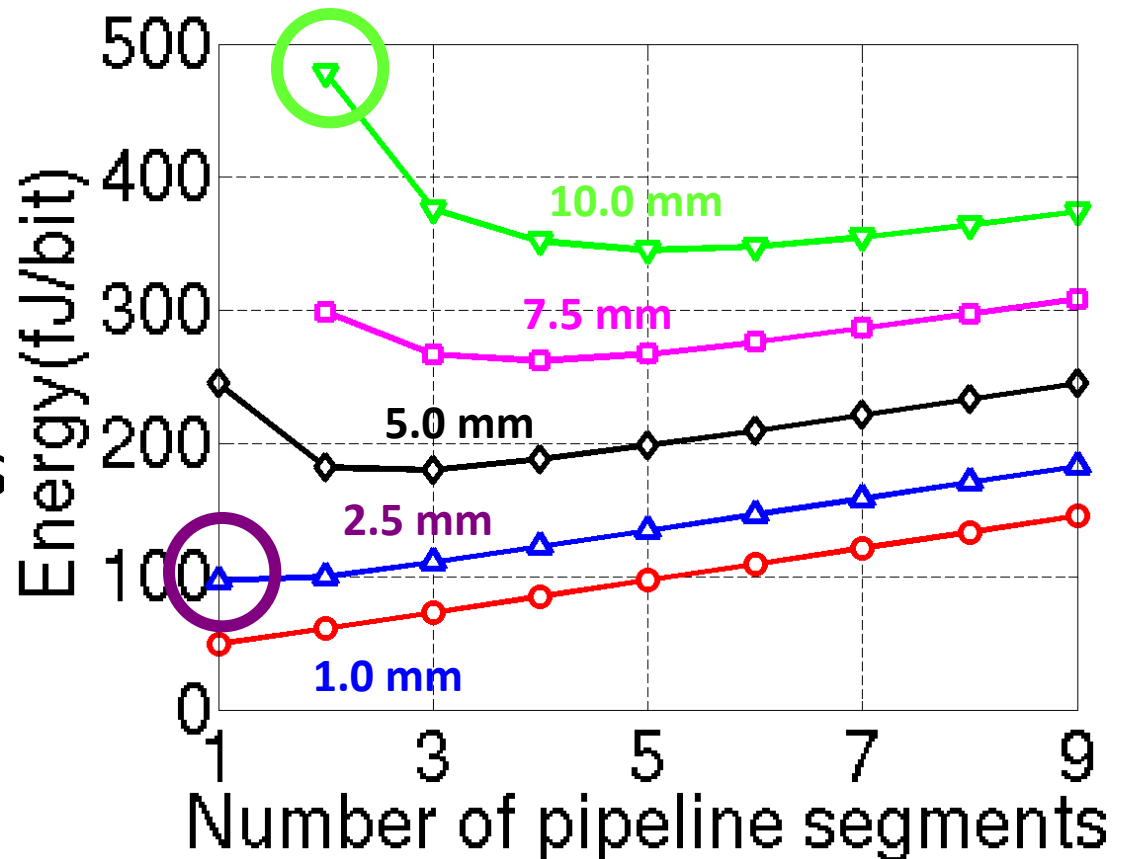


Electrical technology

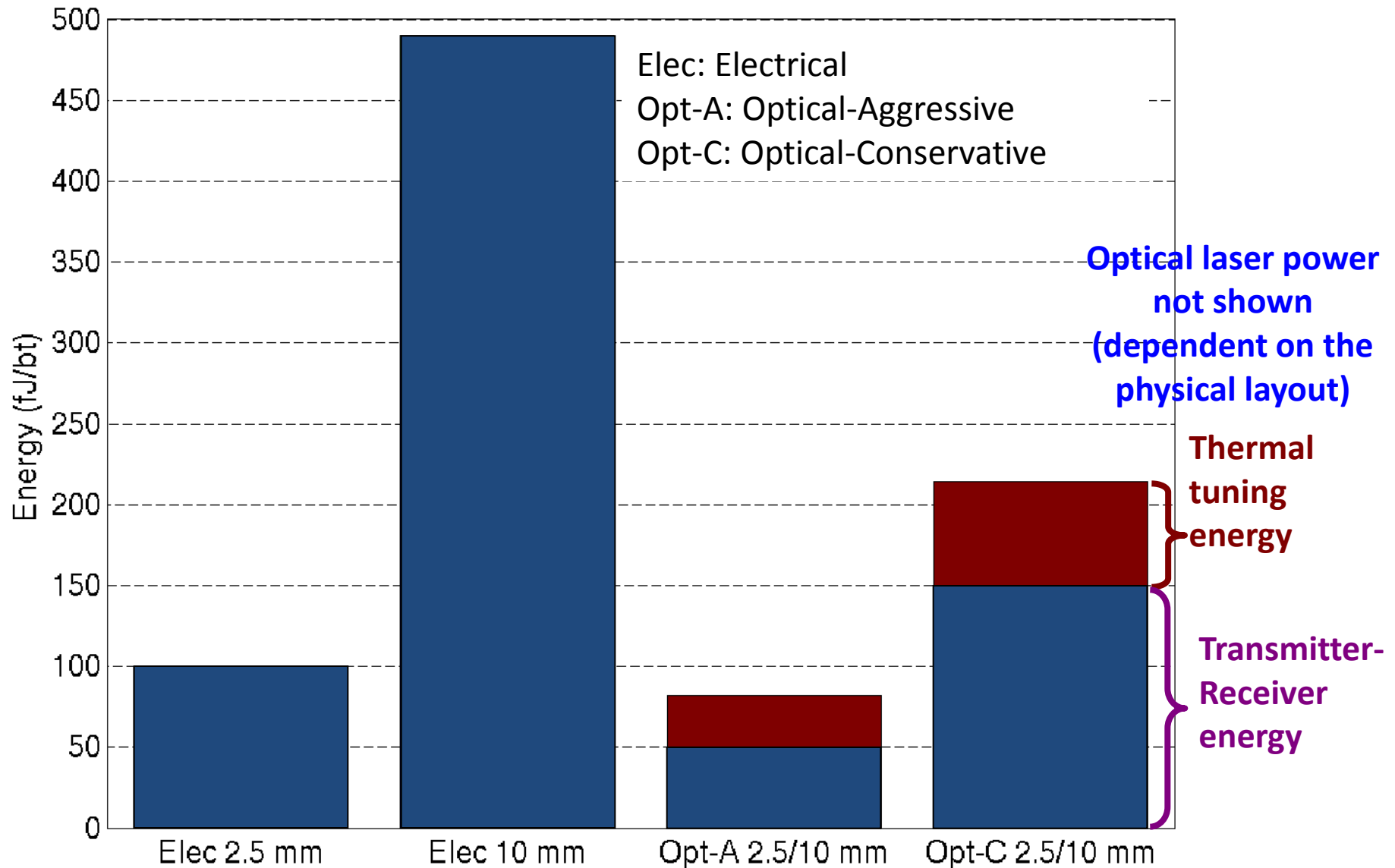


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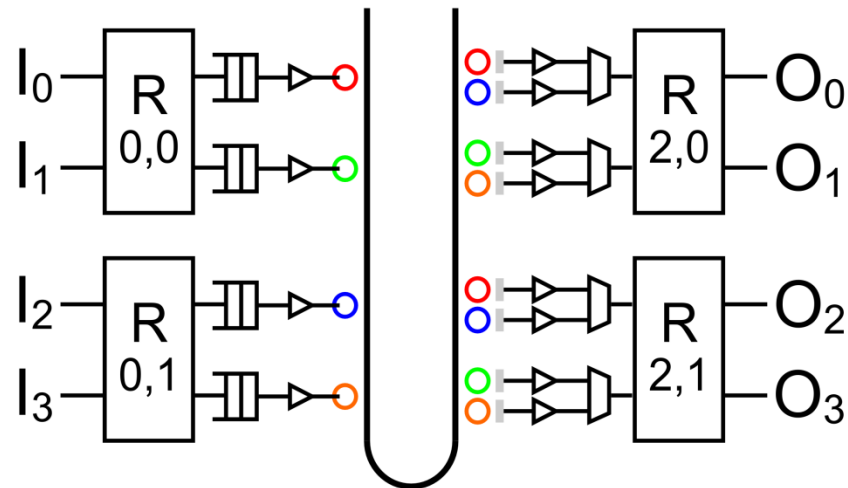
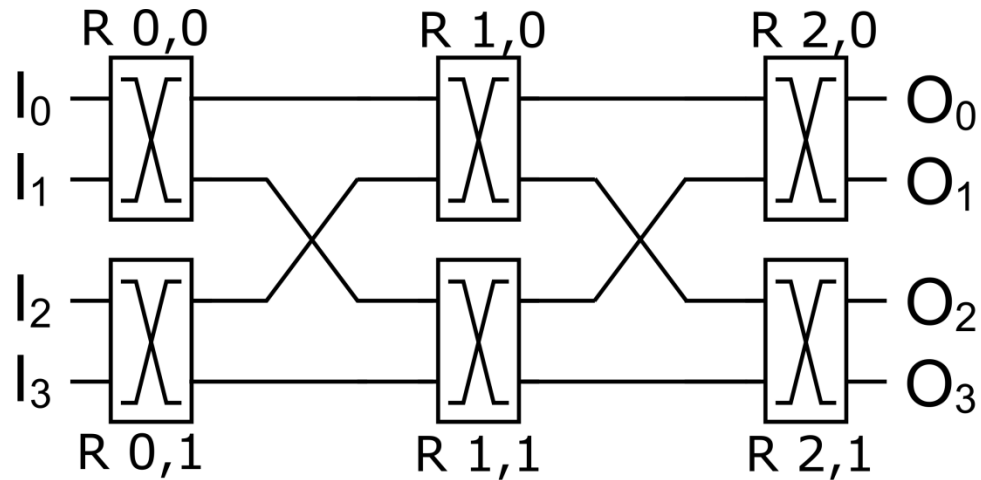
Electrical vs Optical links – Energy cost



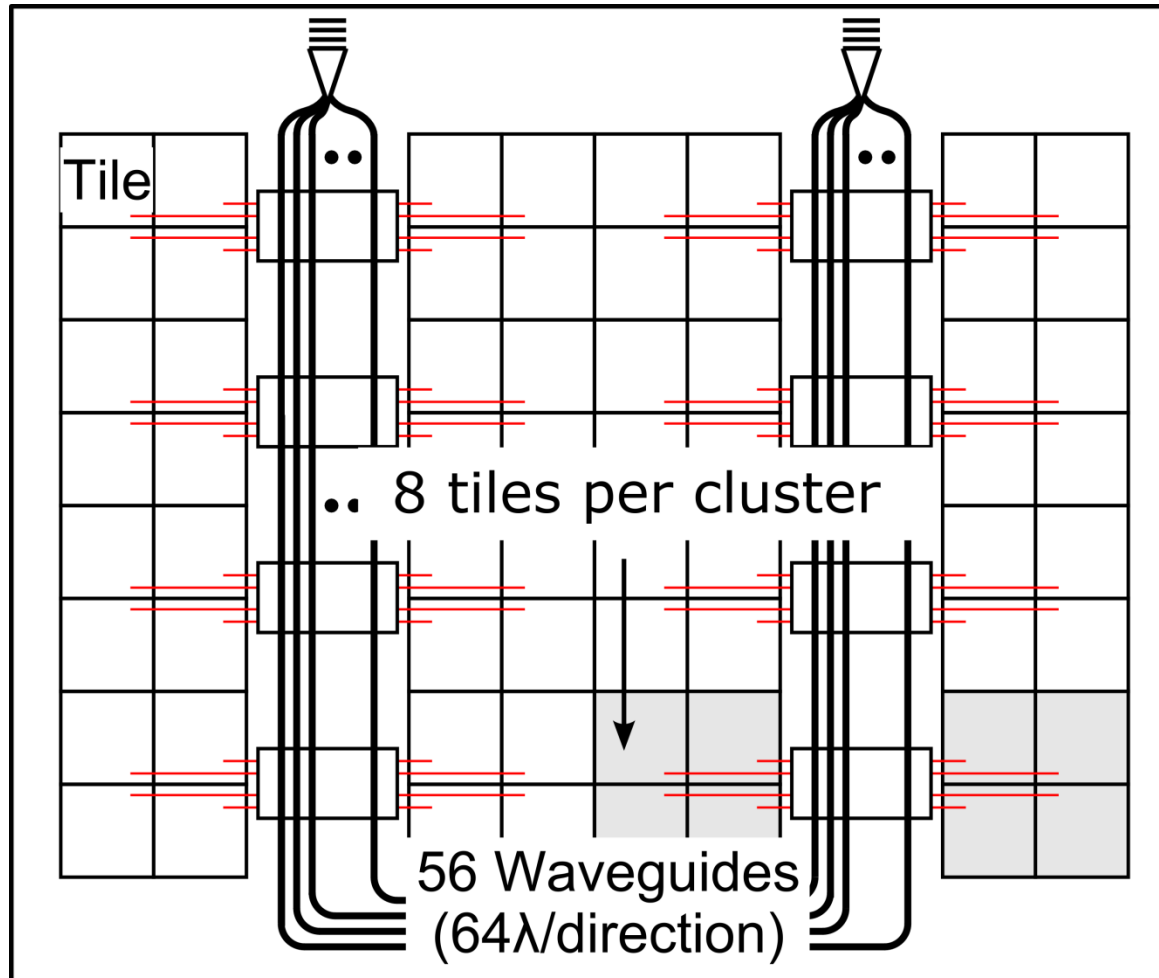
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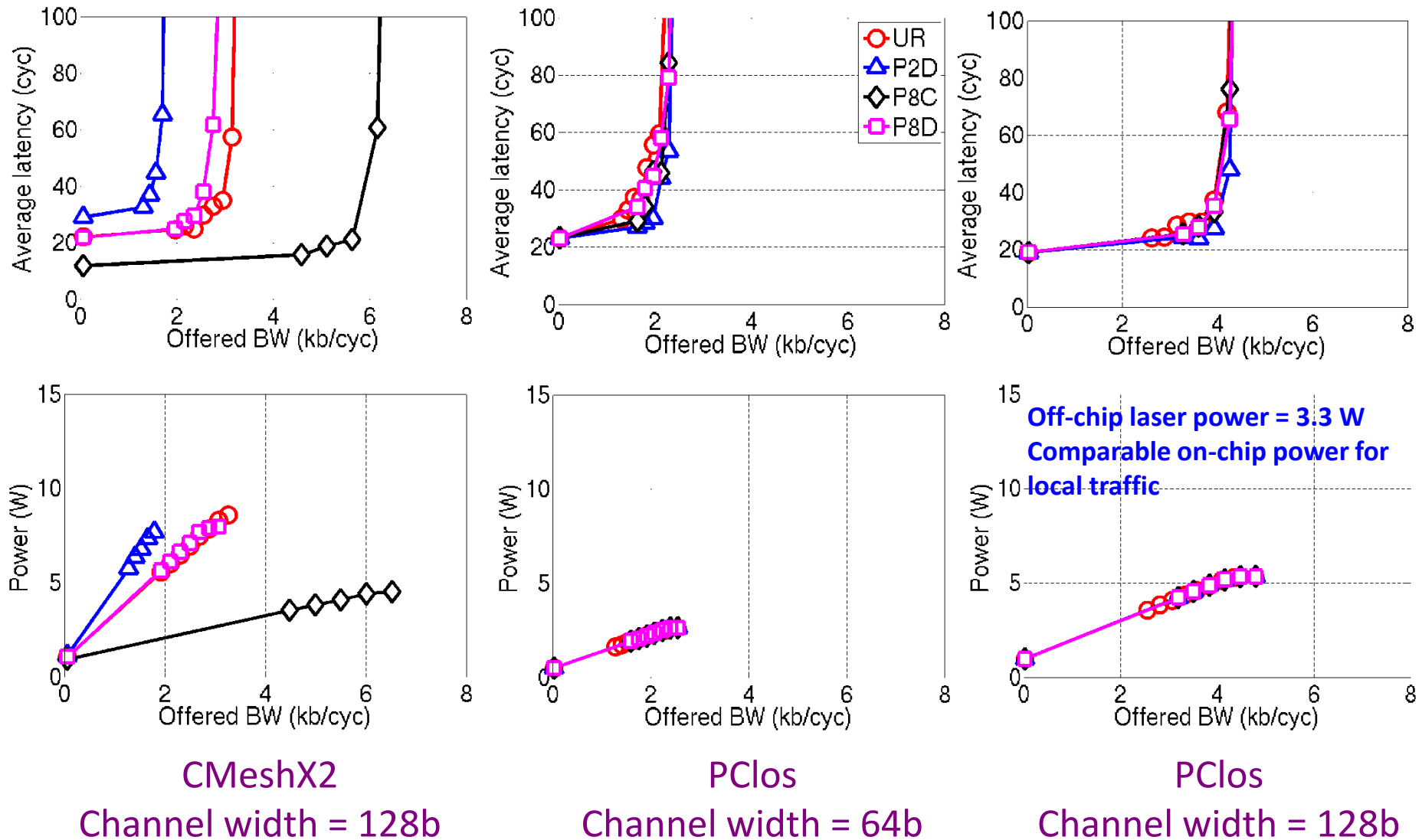
Clos Network



Photonic Clos for a 64-tile system



Power-Bandwidth tradeoff



Problems and Motivations

- A mesh-like topology is highly optimized for local communication and hard to beat
 - Solution: use a underlying mesh topology
- A fully photonic network has higher power numbers on low utilization
 - Solution: make the photonic channels to be turned off at low utilization

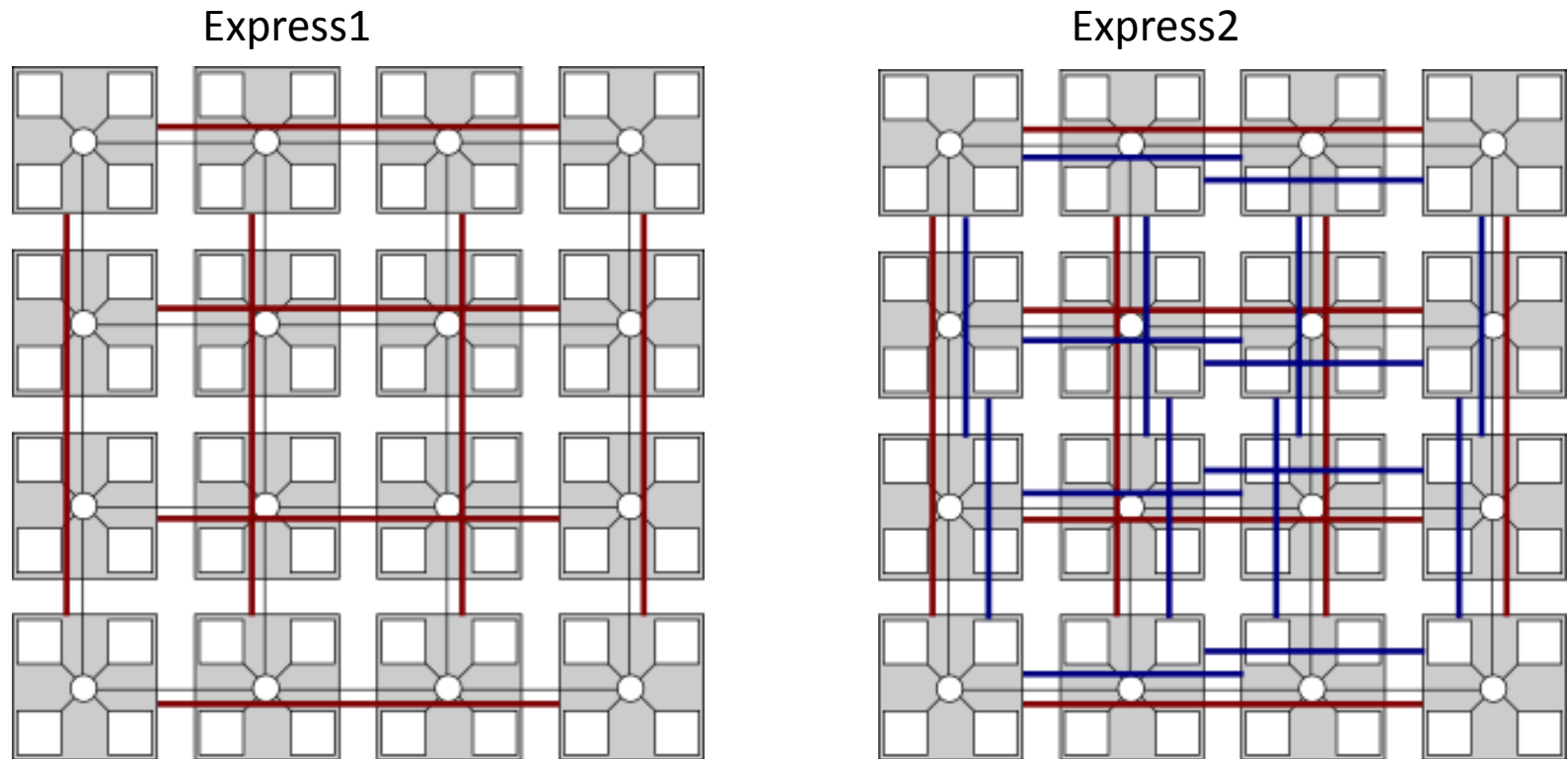
What Do We Need?

- An electrical network which connects all-to-all even when the laser is turned off
- A photonic network which (when turned on) provides benefits to the base electrical mesh

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Concentrated Mesh with Photonic Express Channels

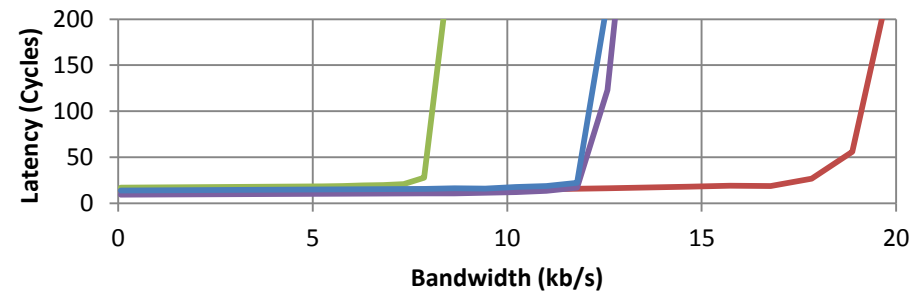
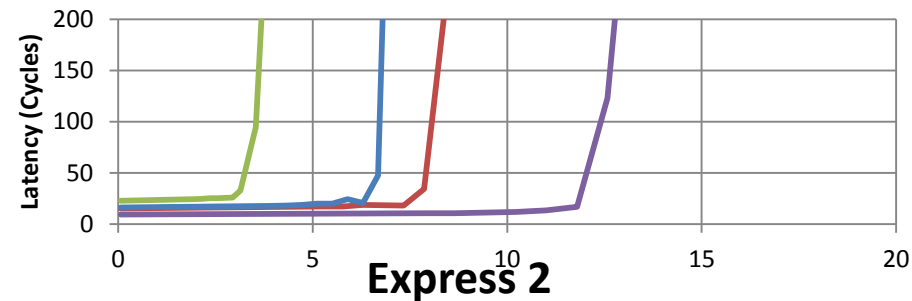
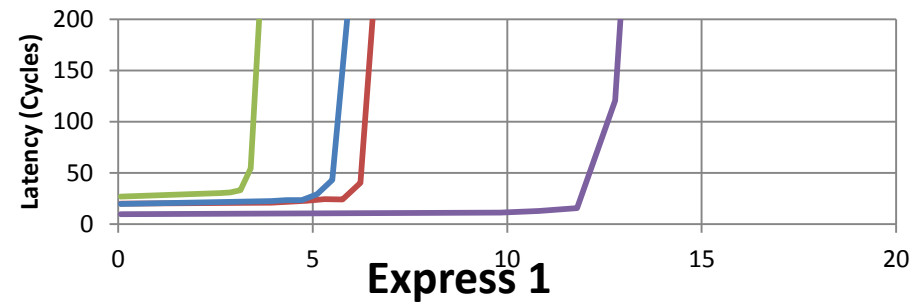


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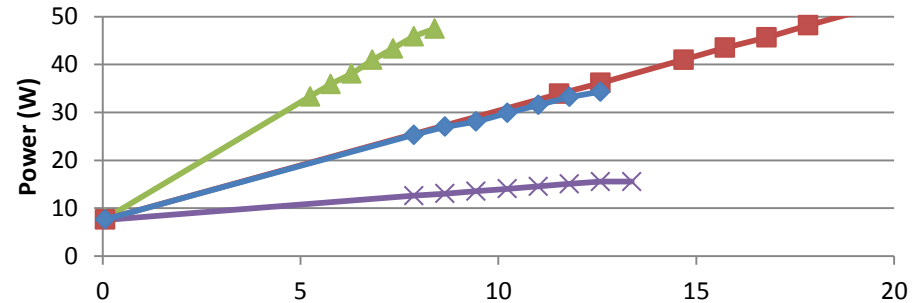
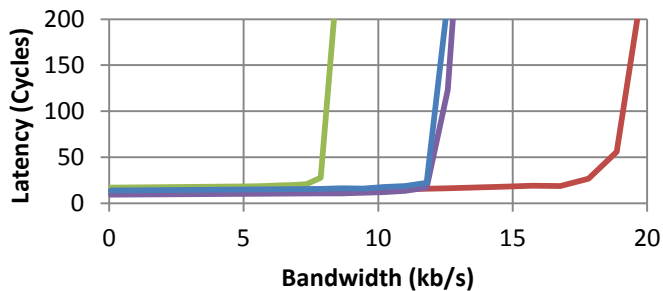
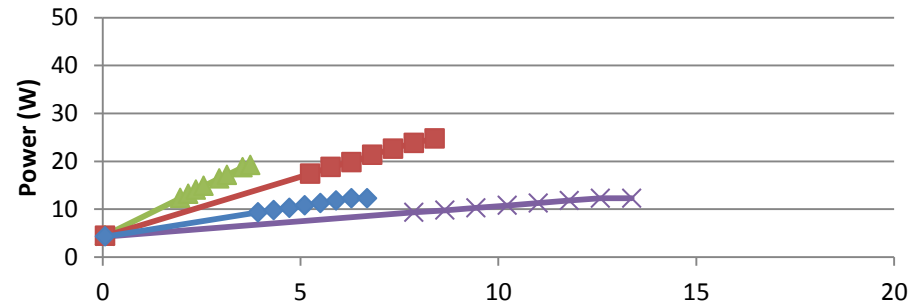
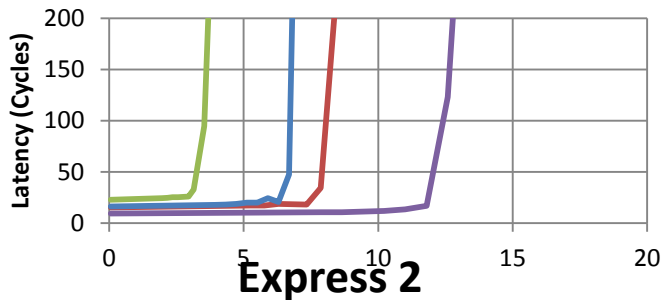
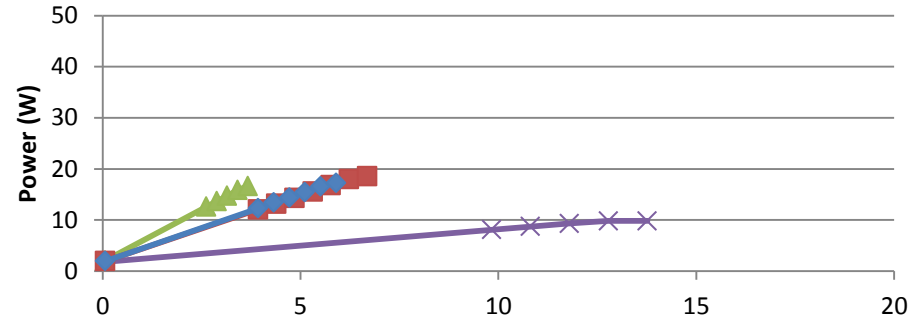
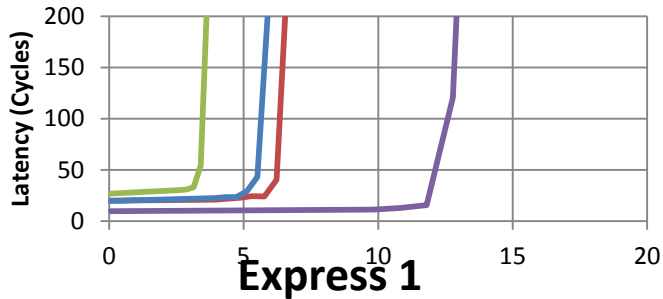
Performance

CMesh



Power - Electrical

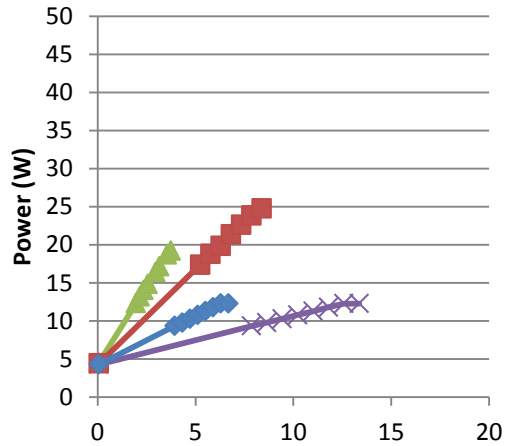
CMesh



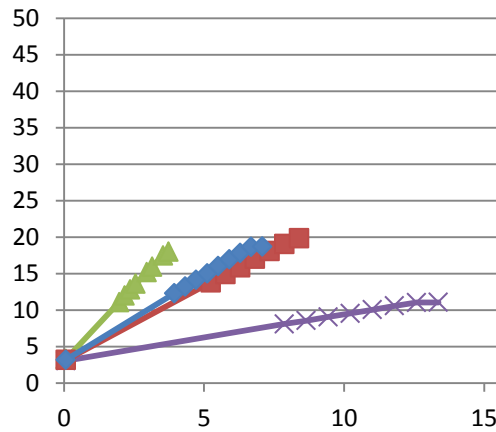
Uniform Random Partition 2 Distributed
Partition 8 Colocated Partition 8 Distributed

Photonic vs Electric Power Comparison

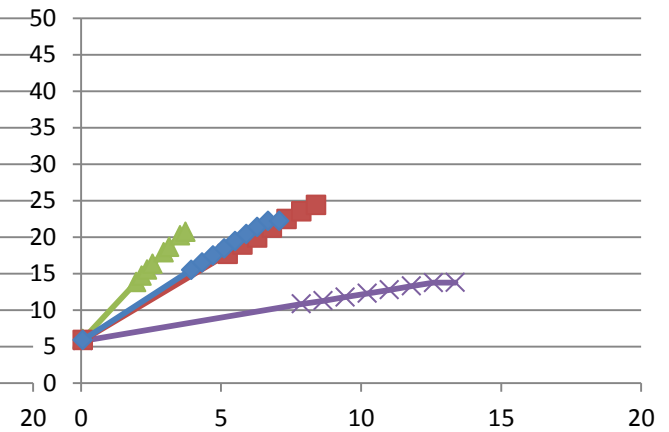
Express1



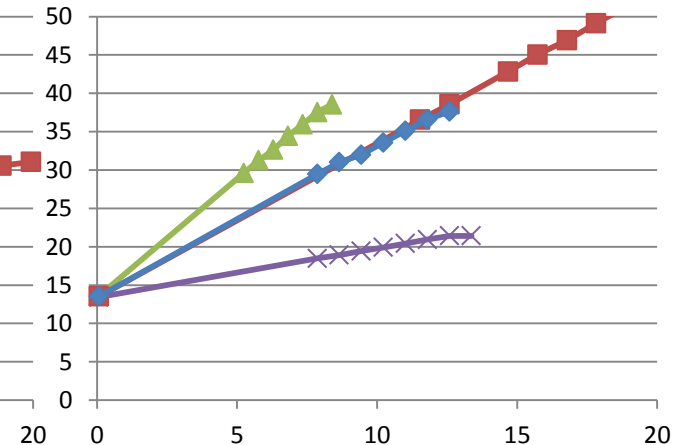
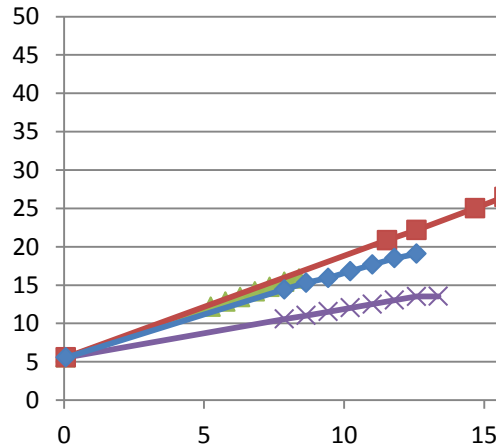
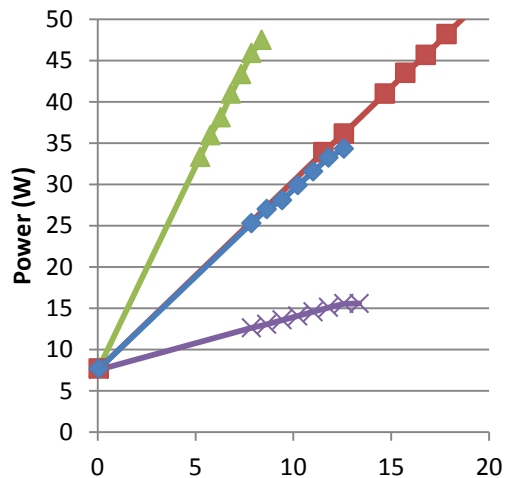
Aggressive



Conservative



Express2



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Conclusion

- Maybe we do not need to shut down photonics on low utilization
- In order for photonics to be effective we need better devices
 - There is no power advantage in using photonics if we can't get to aggressive
 - We do win in bandwidth density but area is cheap

Acknowledgement

- Ajay Joshi
 - Help in power calculations and images
- Chris Batten
 - Brainstorming help

Thanks for your time