Welcome!

Panel: OPTICAL SYSTEM TECHNOLOGIES AND INTEGRATION
Panelists

- Brice Achkir  |  Distinguished Engineer, Cisco Systems, Inc.
- Eric Bogatin  |  Signal Integrity Evangelist, Bogatin Enterprises
- Arlon Martin  |  Sr. Director of Marketing, Mellanox Technologies
- Mitchell Fields  |  Director of Product Strategy, Avago Technologies, Inc.
- Greg LeCheminant  |  Technical Applications Engineer, Agilent Technologies, Inc.
- Pavel Zivny  |  Domain Expert, Tektronix, Inc.
- Moderator: Janine Love, UBM Tech

Joel Goergen
Photonics for High speed Interconnect technologies

Brice Achkir
Cisco Systems Inc.
www.Cisco.com
Drivers

- Internet Of Everything
- More then 3.4 billion Internet Users. YIKES!!!
- More devices – nearly 19 billion connections. DOUBLE YIKES!!!
- Faster broad band speeds – more then 4X faster.
- More rich media content - 1.2 million minutes of video content crossing global networks every second.

- Power, Power, and More Power

Joel Goergen
What does this mean to an Engineer?

It Means

- Higher system performance
- Higher power consumption
- More effective cooling concepts
- Higher BW interconnect

It means provide faster systems with more effective Bandwidth / performance per Watt with highly efficient cooling

All this with improved cost points to the end user
Attributes

- Cooling
- Power
- CPU
- Storage
- Memory
- PCIe
- NIC
- High Speed Interconnect and Building Network
- …
DC - The Next Generation Eco System

- Intelligent Building Cooling
- Intelligent Building Power
- High Speed Interconnect - LL
- CPU Farm
- Storage Farm
- Memory Farm

Building Farms From the Optimization
• How about System Integration?
• Are the capabilities available for EOE architecture?
Key building blocks

Waveguides:
- 47 um high/18 um wide/4 um gaps

Cut line for edge view in inset

4 micron wide low index imaged barriers that guide light in crossing region
Crossover Losses with low index barriers

Cumulative crossover losses versus number of crossings

ie. 10 crossings at 90° have total ~ 0.2dB excess loss

Average Loss per crossover at 1, 5, 10, 15, 20, 25 crossovers
Other components & considerations...

Considerations

Fiber to Waveguide

- Output Fibre N.A. <= (smaller or equal to) Input Polymer WG N.A.
- Output Polymer WG N.A. <= Input Fibre N.A.

Waveguide to Fiber

- N.A. of conventional fibre ~ 0.2
- N.A. of polymer waveguide ~ 0.3

- Fibre Ø <= Waveguide Ø
- Waveguide Ø <= Fibre Ø

- Fibre core should fit completely into waveguide core
- Waveguide core should fit completely into fibre core

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Hybrid Photonic systems

Architecture proposal

WG/F Backplane – Edge Access

Optical conduit (Extension cable)

Optical cable path (Jumper cable)

Optical waveguide embedded backplane

Chassis configured to use waveguides within the backplane, but route line-card’s optical i/o to the front panel
- The line-card has a jumper cable to the top of the chassis
- Crossbar interconnect architecture by optical waveguides in backplane – Not doable with copper lanes at high frequencies cost efficiently
Toward all photonic Systems....

**Optical Backplane**

**TECHNICAL CHALLENGES**
- Realization of a complex connector for optical/electrical backplane with simple maintenance and operation
  - Improvement of the mechanical precision
  - Flexible (optical/electrical combination)
  - Easier plug-and-unplug

**KEY ACCOMPLISHMENTS**
- Efficient cabling with 1.6Tbps backplane bandwidth
  - 100Gbps×4ch×4card

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Panel: OPTICAL SYSTEM TECHNOLOGIES AND INTEGRATION

“The minority report”

Dr. Eric Bogatin
Signal Integrity Evangelist
Teledyne LeCroy
www.beTheSignal.com

copy available for download from beTheSignal.com
Attenuation in the Frequency Domain

In ALL real interconnects, amplitude drops off exponentially with distance.

\[ V_{out}(d) = V_{in} e^{-\alpha \text{nepers/len} d} = V_{in} 10^{-\frac{\alpha \text{dB/len}}{20} d} \]

\[ \text{atten[dB/in]} \sim \frac{1}{w[\text{mils}]} \sqrt{f[\text{GHz}]} + 2.3 \times f[\text{GHz}] \times Df \times \sqrt{Dk} \]

- \text{Copper}
- \text{Skin depth}
- \text{Current on both sides}
- \text{Return path}
- \text{2x from roughness}

January 28–31, 2014 | Santa Clara Convention Center | Santa Clara, CA
Ultimate Limits from Just Losses Using Equalization
(and doing everything else right!)

\[
\text{atten}[\text{dB}] \sim \left( \frac{1}{w[\text{mils}]} \sqrt{\frac{1}{2} \text{BR[Gbps]} + \frac{2.3}{2} \times \text{BR[Gbps]} \times Df \times \sqrt{Dk}} \right) \times \text{Len[\text{inches}]}\]

For A = -25 dB
(10GBase KR)

\[
\text{Len[\text{inches}]} = \frac{25\text{dB}}{\left( \frac{1}{w[\text{mils}]} \sqrt{\frac{1}{2} \text{BR[Gbps]} + \frac{2.3}{2} \times \text{BR[Gbps]} \times Df \times \sqrt{Dk}} \right)}
\]

\[w = 7\text{ mils}\]
The future of backplanes may be "cable" based backplanes.
40 Gbps Backplanes? If it stays in copper, cabled backplanes

40 Gbps channels: will optical backplanes be cheaper than cabled backplanes?

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Back to the Future?

“Reports of copper’s death are greatly exaggerated”

Seymour Cray and the Cray-1

1976

60 miles of twisted pair wiring as the backplane

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Using silicon photonics to address the tradeoffs of cost, power, speed, and complexity

Arlon Martin
arlonm@mellanox.com
Constraint: How do we fit 100G in QSFP?

• QSFP is the most popular 4-channel form factor
• Enables 36 ports in a 1ru switch
• Physical size requires intensive optical integration
• Max power consumption of 3.5W
• Must support reaches of >2 km
Examples of silicon photonics
Tx and Rx chips

Integration: 100 Gb/s Tx and Rx chips
Simple FTTH style laser
Single laser for 4 channels
Integrated modulators and detectors
Silicon photonics cost tradeoffs

- Use CMOS wherever possible
- No WDM specific lasers, no laser sub-assembly (no isolators, beam collimators, lens cap, etc.)
- Flip-chip laser array bonding
- No hermetic packages
- No active laser alignment
- No detector sub assembly
- No TEC
- No WDM assembly
- Die attach driver array
- Die attach TIA array
Silicon photonics enables 100G in QSFP

- Implements the best tradeoffs for data center applications
- Fits in standard QSFP
- Supports reaches of > 2km
- Consumes < 3.5W of power
- Incorporates a host of low-cost techniques
Making the 10G to 40G upgrade easy on MMF

Mitchell Fields, Ph.D.
Director of Product Strategy
Fiber Optics Products Division
Avago Technologies
40GbE over MMF: 40GBASE-SR4

Standardized by IEEE
QSFP+ form factor with MPO connector
4x10GbE or 1x40GbE links up to 100/150m of OM3/4.
10GBASE-SR per lane links up to 300/450m of OM3/4.
Do we need a better 40G MMF solution?

- 10GBASE-LR and 40GBASE-LR4 SMF solutions both use duplex fiber infrastructure allowing an easy migration from 10GbE to 40GbE connectivity.
- 10GBASE-SR and 40GBASE-SR4 MMF interfaces use different connectors and infrastructure.
- Is there a 40GbE MMF solution that can reuse 10GbE MMF infrastructure?
Bidirectional optics for 40GbE on MMF

- Use electronics to scale signaling to 20G.
- Use dual-wavelength bidirectional optics to make each port 20G full-duplex.
Silicon Photonics: What About Test?

Greg LeCheminant, Technical Applications Engineer, Agilent Technologies, Inc.
Testing questions and issues

Today traditional optical transceiver manufacturers ‘tune’ transmit eye to achieve key specifications. Intense pressure to reduce cost, with test being 5-15% of total MFG cost, much of that attributed to the eye test.
What will be different with Silicon Photonics?

• Will tuning be required and can it be done in a more cost effective way?
  – Will the manufacturing process evolve to the point that testing of key performance parameters can be eliminated?

• What advantages does the Silicon Photonics architecture provide in terms of link budgets?
  – What specs determine ‘good’ and can they be minimized to reduce test/cost?
Silicon Photonics challenges: Test and Measurement

Pavel Zivny, Tektronix
Currently many silicon photonics signaling methods and speed track the mainstream optics, such as 100 Gb/s Ethernet.

These rates are already supported by the T&M: example: single-mode oscilloscope supports nearly 100 GHz bandwidth... (next slide)

New technologies different from mainstream will be helped by closer cooperation with T&M.
Equipment from mainstream is ready

- 80 Gb/s RZ
- Just 5 dB down at 100 GHz
Probing matters

- Optical systems change the probing technology, new methods of probing are possible
- Some of the problems of electrical probing (large ISI, for example) are alleviated in Silicon Photonics
Interconnect verification

- Interconnect: just like in electrical domain, OTDR verifies your interconnect ... just the resolution needs to be increased relative to the ‘cable-fault-finder’ tools.
- The same optical scope module as for waveform acquisition can be used,
- In SM environment the near 100GHz BW in Tek’s scope module 80C10C yields resolution of several mm;
- In MM the resolution is more limited due to dispersion of test interconnect and lower oscilloscope BW (~ 33 GHz BW in Tek 80C15)

Standard optical oscilloscope can be used as a high resolution OTDR
<table>
<thead>
<tr>
<th></th>
<th>Copper Interface</th>
<th>Optics Interface – QSFP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Rate (max)</strong></td>
<td>28G per channel</td>
<td>28G (for now – it will go higher for next generations)</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>0-100G (zQSFP)</td>
<td>0-100G (4 x 28)</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>Targeting 5m for passive copper</td>
<td>4KM. Very long range with LR</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>n/a for passive cables</td>
<td>.7w @ 10G, 1W @ 14G, 1.5W @ 28G</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>QSFP MSA</td>
<td>QSFP MSA</td>
</tr>
<tr>
<td><strong>Design Complexity</strong></td>
<td>Proven technologies are being used</td>
<td>Complex</td>
</tr>
<tr>
<td><strong>Environmental Conditions</strong></td>
<td>0-70C (some cases pushing to 85C)</td>
<td>0-70C</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>Passive cables</td>
<td>1E-18 BER, FIT&lt;1</td>
</tr>
<tr>
<td><strong>Upgradability</strong></td>
<td>Backwards compatible with legacy speeds, upgrades will depend on standards bodies decisions on form factor.</td>
<td>Easily upgradeable</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Around $90 for 5m passive zQSFP cable but will depend on volume.</td>
<td>$150-$350 dependent on bandwidth and volume</td>
</tr>
<tr>
<td></td>
<td>Multi-Mode Optics</td>
<td>Single-Mode Optics</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Data Rate (max)</strong></td>
<td>28G</td>
<td>28G</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>100G</td>
<td>100G</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>10G 20-300 meters dependent on the vendor. 25G 100M but likely much shorter.</td>
<td>4KM for 10G and 25G.</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>QSFP MSA</td>
<td>QSFP MSA</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>1W 10G 1.5W 28G</td>
<td>1W 10G 1.5W 28G</td>
</tr>
<tr>
<td><strong>Design Complexity</strong></td>
<td>Complex. Each new speed upgrade requires new VCSEL technology.</td>
<td>Medium complexity. Speed upgrades met with higher speed modulation schemes which are easier to design and implement.</td>
</tr>
<tr>
<td><strong>Environmental Conditions</strong></td>
<td>0-70C</td>
<td>0-70C</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>Medium reliability 1E-12 BER, FIT 3-4</td>
<td>Exceptionally high reliability 1E-18 BER, FIT&lt;1</td>
</tr>
<tr>
<td><strong>Upgradability</strong></td>
<td>Time consuming &amp; expensive. Each upgrade requires new and significantly more expensive structured cabling</td>
<td>Upgradeable. SM cabling will deal with practically unlimited bandwidth so no need to change structured cabling</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>$120-$350 dependent on bandwidth and volume Expensive cabling (OM2, OM3, OM4, OM4+ etc.)</td>
<td>$150-$350 dependent on bandwidth and volume Inexpensive cabling (SM)</td>
</tr>
</tbody>
</table>
Questions?