Optical Integration and the Role of DSP in Coherent Optics Modules

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Market Watch OFC 2014
Outline

• 100G Deployment
  – Rapid Growth in Long Haul
  – Role of Modules

• 100G Module Standards and their Applications
  – Gen1 5x7 MSA
  – Gen2 4x5 MSA
  – Pluggable Modules (CFP, CFP2…)

• Challenges for DSP and Optical Components
  – Lower Power Dissipation
  – Smaller Size
  – Packaging

• Discussion
Long Haul 100G Growth

- 2015: >100K LH Interfaces
- Only 15-20% modules

Ref: A. Schmitt, Infonetics, OIF meeting Jan. 2013

Source: Infonetics Nov 2012
Current OIF LH 100G MSA module:

- Size: 5 in. x 7 in.
- Power Dissipation: 80 W
NEL product lineup for 100G linecard

- **Driver**
- **MUX**
- **Modulator**
- **Receiver**
- **OTN Framer**
- **CFP (100GE)**
- **DSP-LSI**
- **Fiber**
- **µ-iTLA**

- **DP-QPSK modulator**
- **LD**
- **LD (LO)**
- **Integrated receiver**
- **SFF, same side I/O**
- **105 x 13.5 x 7 mm**
- **35 x 20 x 6.4 mm**
- **17 x 30 x 6 mm**

- **Integration is key to reducing size and power dissipation**

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Example of Module Layout in the 100G Transmission Line Card

a) Transponder
- CFP
- 100G LH MSA (4”x5”,<40W)
- DC/DC Conv. Area

b) Muxponder
- XFP ×10
- 100G LH MSA (4”x5”,<40W)
- DC/DC Conv. Area

c) Regenerator
- 100G LH MSA (4”x5”,<40W)
- DC/DC Conv. Area

Module size required for the line card

<table>
<thead>
<tr>
<th></th>
<th>a) Transponder</th>
<th>b) Muxponder</th>
<th>c) Regenerator</th>
</tr>
</thead>
<tbody>
<tr>
<td>5”x7” (Gen.1)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4”x5” (Gen.2)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

The module with the size of 4”x5” can enable three kinds of the line cards

Courtesy: Onaka, Fujitsu

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Evolution of 100G modules: LH Applications

Module Power dissipation dominated by electronic components such as DSP and MUX

Module Size (width, depth, height) determined by optical components such as Tx and Rx
Block Diagram of 100G Coherent DSP

- **In**
- **LDPC FEC encoder**
- **Training sequence Addition Framing**
- **Out**
- **MUX IC**
- **SD/LDPC FEC decoder**
- **Training sequence Remove Frame sync**
- **Adaptive equalizer**
- **Fixed equalizer**
- **4ch AD converter**
- **Line estimation**
- **Optical Hybrid**

- **40nm CMOS ~100M Gates**
DSP ASIC Milestones

- NEL (2011)
  ~70% per year

ADC resolution vs. sample rate

- ALU 56GS/s

Year
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011

Gate Counts (Million)
- $10^0$
- $10^1$
- $10^2$

Sample rate [GS/s]
- 0
- 10
- 20
- 30
- 40
- 50
- 60

Number of bit
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9

Noritel electronic pre-EDC 10G Tx (2005)
- 20GS/s DAC

Noritel 40Gb/s PDM-QPSK (2007)
- 20GS/s ADC/DSP

Alcatel-Lucent 112Gb/s (2010)
- 56GS/s ADC/DSP

~5 M gates EQ

~14 M gates EQ

70M+ gates

Xiang Liu and S. Chandrasekhar, OFC 2014 Tutorial W1H.5

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## Breakdown of 100G module power dissipation

<table>
<thead>
<tr>
<th>Component</th>
<th>Gen1 MSA</th>
<th>4”x5” Gen2 MSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSP</td>
<td>35.0</td>
<td>20.0</td>
</tr>
<tr>
<td>MUX</td>
<td>6.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Modulator (TEC)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Driver</td>
<td>10.0</td>
<td>7.0</td>
</tr>
<tr>
<td>ITLA (Tx&amp;LO)</td>
<td>6.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Receiver FE</td>
<td>3.5</td>
<td>1.5</td>
</tr>
<tr>
<td>MISC</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>DD-conv.</td>
<td>16.0</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>79.0 W</strong></td>
<td><strong>40.0 W</strong></td>
</tr>
</tbody>
</table>
100G Transceiver Module/DSP Power Dissipation

![Graph showing power consumption against parts mounting area for different technologies including CFP, 40nm CMOS, 18-20nm, 28nm, and 20nm.]
100G Cohernet DSP ASIC Gen -1

- 40nm CMOS with External Functions
  - External Framer ASIC
  - External Transmit Mux
100G Cohernet DSP ASIC Gen -2

- Next Gen CMOS with Additional Functionality
  - Internal Framer
  - Internal 4x DAC
100G Transceiver Module Landscape

- 100G Coherent
  - Metro
  - Regional 500-1000 km
  - Core 100-500 km
  - Access 40-100km
- Higher volume
- Lower cost
- High density
Integrated Components for smaller pluggable modules

- ICR
- iTx
- ASIC

CFP (24W)
CFP 2 (12W)
CFP4 (6W)

Dimensions:
- 82 x 145 x 14 mm³
- 41.5 x 107.5 x 12.4 mm³
- 21 x 88 x 9.5 mm³
# Integrated Components for Coherent CFP module

## Size
- dimensions: **82 x 145 x 14 mm**

## Power dissipation
- **Total**: 24 W

<table>
<thead>
<tr>
<th>Component</th>
<th>Power dissipation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFP target</td>
<td>24.0 W</td>
</tr>
<tr>
<td>DSP</td>
<td>12.0 W</td>
</tr>
<tr>
<td>MUX</td>
<td>0 W</td>
</tr>
<tr>
<td>Modulator (TEC)</td>
<td>1.0 W</td>
</tr>
<tr>
<td>Driver</td>
<td>3.0 W</td>
</tr>
<tr>
<td>ITLA (Tx&amp;LO)</td>
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<td>1.0 W</td>
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<tr>
<td>DD-conv.</td>
<td>1.5 W</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24.0 W</strong></td>
</tr>
</tbody>
</table>
100G CFP2 Analog Coherent Optics module

DSP on Host Board                          CFP2 ACO

CFP2 ACO IA currently under discussion in OIF

Size: 42 x 106 x 12 mm
Power 12W
Pluggable Digital Coherent TRx

- Optics part will be separated from DSP
- CFP2 will be no more than single optical component
Compact Optical Tx and Rx ...DSP Assist

Future Higher Performance DSP-ASICs

- Higher FEC
- Non-linear Compensation
- Cycle Slip Control

Performance enhancement by DSP
Multi carrier options for 400G and 1T systems

- Dual carrier 2x200G for 400G switching to DP-16QAM
- Additional carriers can be added to make a 4 X 100G, or 10 X 100G, or 5 X 200G superchannel
Reach and Capacity Tradeoff

G. Bosco et al., JLT, vol.29, No.1, p.53, 2011
Reach and Capacity Tradeoff

- Solid lines SMF, Dashed ELEAF, no Raman
- 90 km and 25 dB per span
- Symbol-rate 27.75 Gbaud
- BER 4E-3

G. Bosco et al., JLT, vol.29, No.1, p.53, 2011
ADC in CMOS for 400G and 1T

1Tbit/s/ch in 2017, the baud-rate 40GB. Modulation format may be,
1) 2SC-DP-64QAM (40GB)
2) 3SC-DP-16QAM (40GB)
3) 4SC DP-8QAM (40GB)
4) 6SC DP-QPSK (40GB)

400G technology available in 2014
Similar sampling frequency of 100G DP-QPSK
Candidates:
1) 2SC-DP-16QAM (25GB)
2) 3SC DP-8QAM (25GB)
3) 4SC-DP-QPSK (25GB)

40G coherent was realized in maturity.
Thank You !!

Questions?