High Speed Detectors

Andreas Umbach
ECOC 2009, Workshop 7
Monolithic and Hybrid Photonic Integrated Transceivers for Advanced Modulation Formats
Optical networks use "standardized" optical transmission lines, i.e. 50 GHz channels of 10 Gbit/s DWDM systems and ROADM.

Back-to-back BER comparison for 100 Gbit/s modulation formats

→ PolMux DQPSK with coherent detection gives best OSNR performance

(Source: G. Raybon, P. Winzer, Alcatel-Lucent, ECOC 2007)
**100G Hardware Complexity**

Transponder hardware comparison (prominent 100G options)

<table>
<thead>
<tr>
<th>Modulation format</th>
<th>TX Hardware complexity</th>
<th>RX</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRZ-OOK</td>
<td>Data Mach-Zehnder modulator</td>
<td>If modulator bandwidth too low</td>
</tr>
<tr>
<td></td>
<td>Preceded Data</td>
<td>Low pass at ~25% of bit rate</td>
</tr>
<tr>
<td>Duobinary</td>
<td>Clock</td>
<td>Delay interferometer (or use limited modulator bandwidth)</td>
</tr>
<tr>
<td>(RZ-)DPSK</td>
<td>Preceded Data Clock</td>
<td>Optional RZ carver</td>
</tr>
<tr>
<td>(RZ-)DQPSK</td>
<td>Preceded Data Clock</td>
<td>OR:</td>
</tr>
<tr>
<td>Polarization-mux’ed</td>
<td>Preceded Data Control</td>
<td>OR:</td>
</tr>
<tr>
<td>QPSK w/ coherent RX</td>
<td>Clock</td>
<td>90deg hybrid</td>
</tr>
<tr>
<td></td>
<td>Laser</td>
<td>90deg hybrid</td>
</tr>
<tr>
<td></td>
<td>Pol.</td>
<td>DSP</td>
</tr>
</tbody>
</table>

"System intelligence" has to be built into the optoelectronics, higher value creation AND higher cost of the components.
Phase and polarisation information has to be maintained in the entire receive path.

⇒ skew control makes use of fibers problematic.

Development of long-haul transceiver modules (300pin MSA).

⇒ miniaturisation becomes major issue.

Integration is required for functionality.
Challenges for Integration

- size
- functionality
- performance
- cost

→ many options, but not so many solutions
Market Requirements

- **Sufficient Performance**
  - High speed
  - Good sensitivity
  - High functionality

- **High Reliability**
  - Long lifetime
  - Robustness
  - Zero failures

- **Low Cost**
  - High yield, limited complexity
  - Small chip size
  - Low power consumption

*These are the goals of Photonic Integration*
Responsivity [dB] = 10*LOG ( R [A/W] / 1A/W )

* -5dB equals 0.32 A/W
Hybrid Integrated DPSK Receiver

SOI – DLI and integration platform

PRBS word length

\[ 2^{31} - 1 \]

BER

-40 -38 -36 -34 -32 -30 10 ps/div

12.5 mV/div
Monolithic InP DQPSK 53.5-Gb/s receiver

Monolithic integration on InP
- small size

- polarization dependent frequency shift compensated by current-controlled phase shifter

C. R. Doerr et al., PDP ECOC 2007, Berlin, Germany
Bell Laboratories, Alcatel-Lucent, Holmdel, NJ, USA
More results: ECOC2009, Poster P3.20, Wednesday

Coherent Detection of a 50 Gb/s QPSK Signal Using an InP 90° Hybrid Monolithically Integrated with Balanced Photodetectors

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FhG-Heinrich-Hertz-Institut, u²t Photonics AG

90° hybrid receiver comprising a 2x4 MMI with tapered input waveguides and two pairs of balanced detectors
Integrated 100 Gbit/s Coherent Rx

- 90°-hybrid with balanced photodiodes on InP
- Dual-polarization linear coherent receiver

Compact Coherent Receiver (CCRx) MSA
Picometrix, u²t Photonics
Integration Options

- Free-space optics and direct coupling to optical devices
- Planar optics (SiO₂, SOI, Polymers), hybrid integration
- Integration on GaAs
- Monolithic integration on InP

**figures of merit:**
- chip size, chips/wafer
- wafer size, cost/wafer
- yield (process maturity)

→ figures will change with time

AND with investment!

(When will we have 6-inch InP wafers?)

Who pays for the component level innovation?
The Future Might Look Easy

One material system might suit all

- Everything on Si
- Everything on InP
- Everything on whatever…

→ standardisation
→ large volumes
→ low cost
→ very few suppliers

BUT: I don't believe it !!
Transmission capacity increase by complex multilevel modulation formats at 40..56 Gbaud at most (DP-QPSK, X-QAM, OFDM, …)

Components will have to modulate and detect all optical signal properties of the photons: intensity, phase, polarisation, wavelength

One transmitter and receiver architecture each could fit all applications, but: performance will still depend on application (cost, reach, density, …)

Different requirements of different markets will lead to a variety of solutions and technologies
Thank you for your kind attention!

Questions?

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