Silicon Photonics Integration: A story of money and power

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http://www.uksiliconphotonics.co.uk
We live in a communications world

- Internet
- Networks
- Wireless
- Sensors
- Global
- Social Media
- Instant
What is the vision for an integrated Silicon Photonics World?

- Low Cost
- Simple Integration with CMOS
- Low Power
- Standard Platforms

Source: travelwellworldwide.com
But, there’s a problem....

Source NASA: Apollo 13 Mission
An incompatible technology division?

Photonics
- Fast
- High Power
- Novel Materials

Electronics
- Low Power
- Mobile
- Cheap
How can we address this challenge?

What options do we have?
What has been done?
What resources do we have?
Options...

Fully Integrated on a SiGe platform
- Fast
- Difficult
- Cost

Fully Integrated on a CMOS platform
- SLOW
- Difficult
- Cost

Multi Chip Integration
- Fast
- Difficult
- Cost

Is this the way to go?

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How do we quantify the choices?

- Speed of Operation (Gb/s)
- Power consumption (W)
- Energy/bit (J/Bit)

But what about the cost?

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We need to consider the costs...

As a research team, given by the limited research resource, what is the fabrication cost \textit{per bit}?

Dollars/bit ($/bit)
Example IC Fabrication Costs...

Fabrication Costs ($ 1000s)

- IBM 180nm SiGe (40)
- IBM 130nm SiGe (40)
- IBM 130nm CMOS (40)

...and TSMC 65nm is $21000 for 100 samples
Choice for electronics devices depends on budget....

Unlimited budget and no power issues => SiGe
“No” budget and limited power => CMOS

But we need to think about more than just a single demonstrator.....
Comparison of SiGe and CMOS process

Additional benefit of CMOS?

- Reduced costs open the possibility of multiple runs and a research platform for different modulation formats.
- Advanced coding algorithms can be realized as a DSP.

![Comparison of SiGe and CMOS process](image-url)
Strategy for practical success...

- Use CMOS for electronics
  - Low cost, low power
- Custom Silicon for Photonics
  - High performance, made in Southampton
- Hybrid Integration using bonding
  - Optimal platforms, rapid prototyping of separate technologies, simple integration
Achievement in 2011

1st Gen driver integrated with modulator based on 0.35um CMOS

Modulator

Driver

1Gbit/s
Achievement in 2012

2nd Gen driver integrated with modulator based on 0.13um CMOS
Achievement in 2013

A complete transceiver link operating at 10Gbit/s.
Comparison of cost with commercial product

Intel achieve similar performance at year 2011. Were two years behind Intel. BUT, the cost?

<table>
<thead>
<tr>
<th>Product (MZM driver)</th>
<th>Speed</th>
<th>Process</th>
<th>Cost of each 10Gb/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>TriQuint TGA-4954</td>
<td>10Gb/s</td>
<td>GaAs</td>
<td>£119 (^1)</td>
</tr>
<tr>
<td>Analog Devices ADN2526ACPZ</td>
<td>11.3Gb/s</td>
<td>SiGe</td>
<td>£24.19 (^1)</td>
</tr>
<tr>
<td>SOTON ECS 2013</td>
<td>12.5Gb/s</td>
<td>CMOS</td>
<td>£46.8</td>
</tr>
</tbody>
</table>

Our cost are based on small volume tape out price, and are comparable with commercial products (remarkable!).

Furthermore, we have created a useful research platform!

[1] price obtained from mouser electronic (www.mouser.com)
Advanced modulation format realized in 2014

1.25mm

Driver

MZM

£50/10Gbs (approx)

5Gbit/s

10Gbit/s
Future work

• Flip Chip Bonding
• Deep sub micron CMOS (65nm and smaller)
• Much faster channels
• Lower Power.
• Better integration with Photonics
• Multiple Channels.
• Coding schemes in hardware and software