SILICON PHOTONICS
for Future Systems

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Silicon Photonics Integration: A story of money and power

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EPSRC
Engineering and Physical Sciences Research Council

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

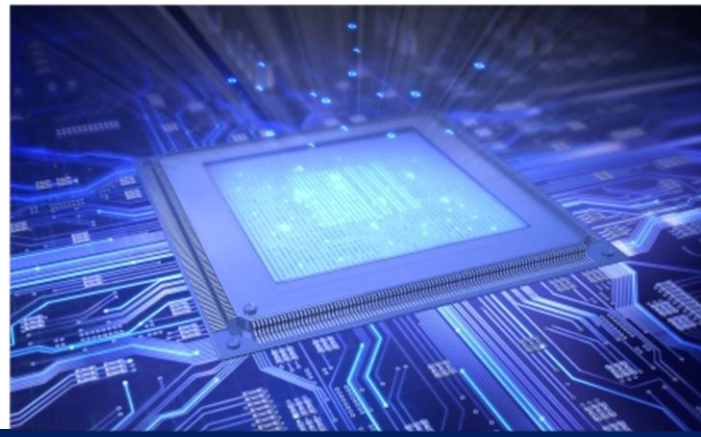
An incompatible technology division?

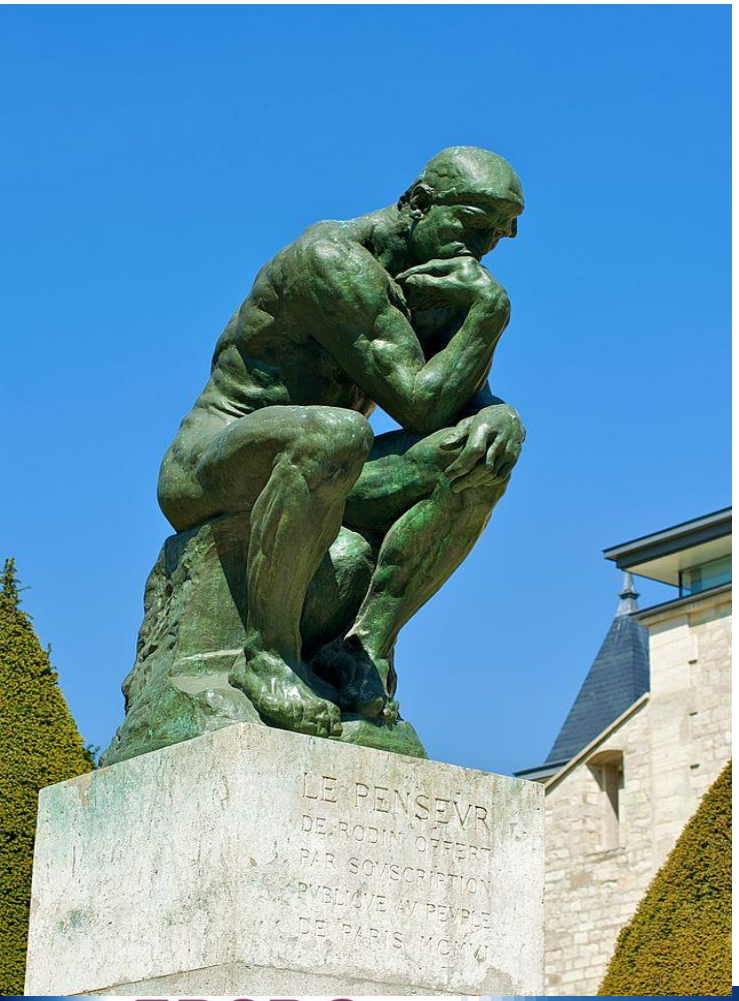
Photonics

- Fast
- High Power
- Novel Materials

Electronics

- Low Power
- Mobile
- Cheap





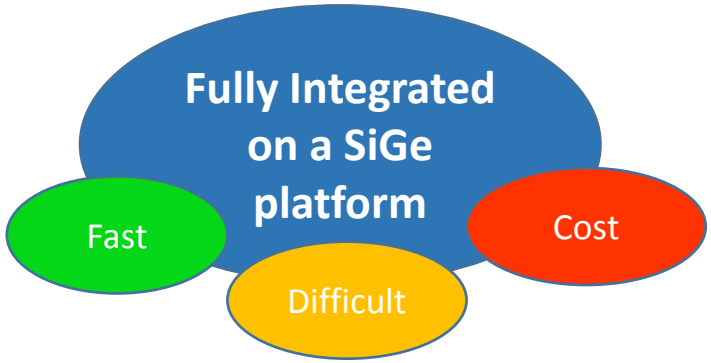
How can we address this challenge?

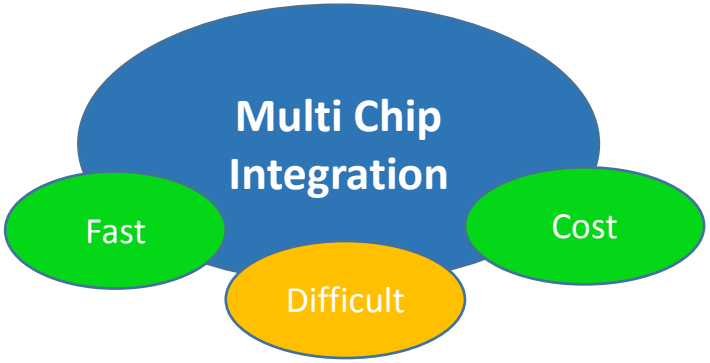
What options do we have?

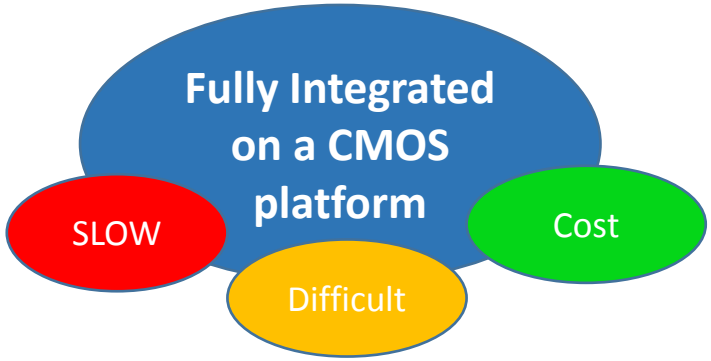
What has been done?

What resources do we have?

Options…

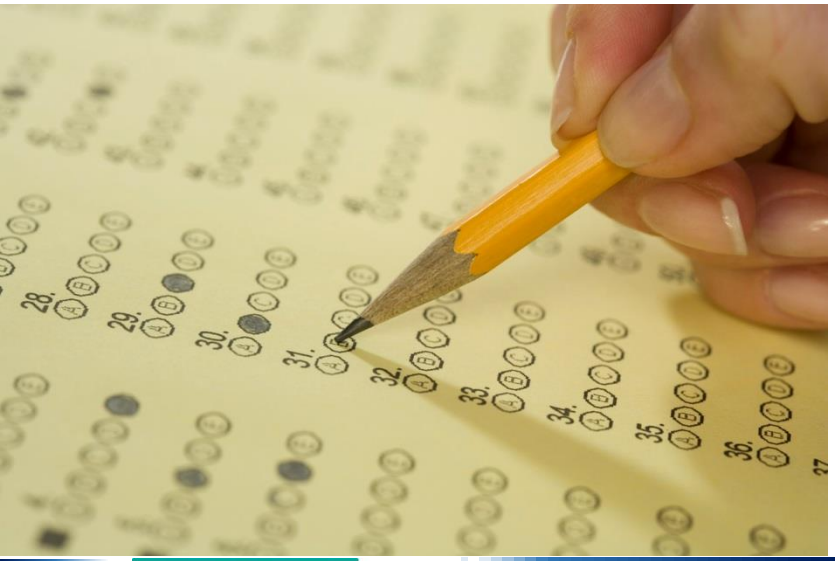






Is this the way to go?

How do we quantify the choices?



Speed of Operation (Gb/s)
Power consumption (W)

→ **Energy/bit (J/Bit)**

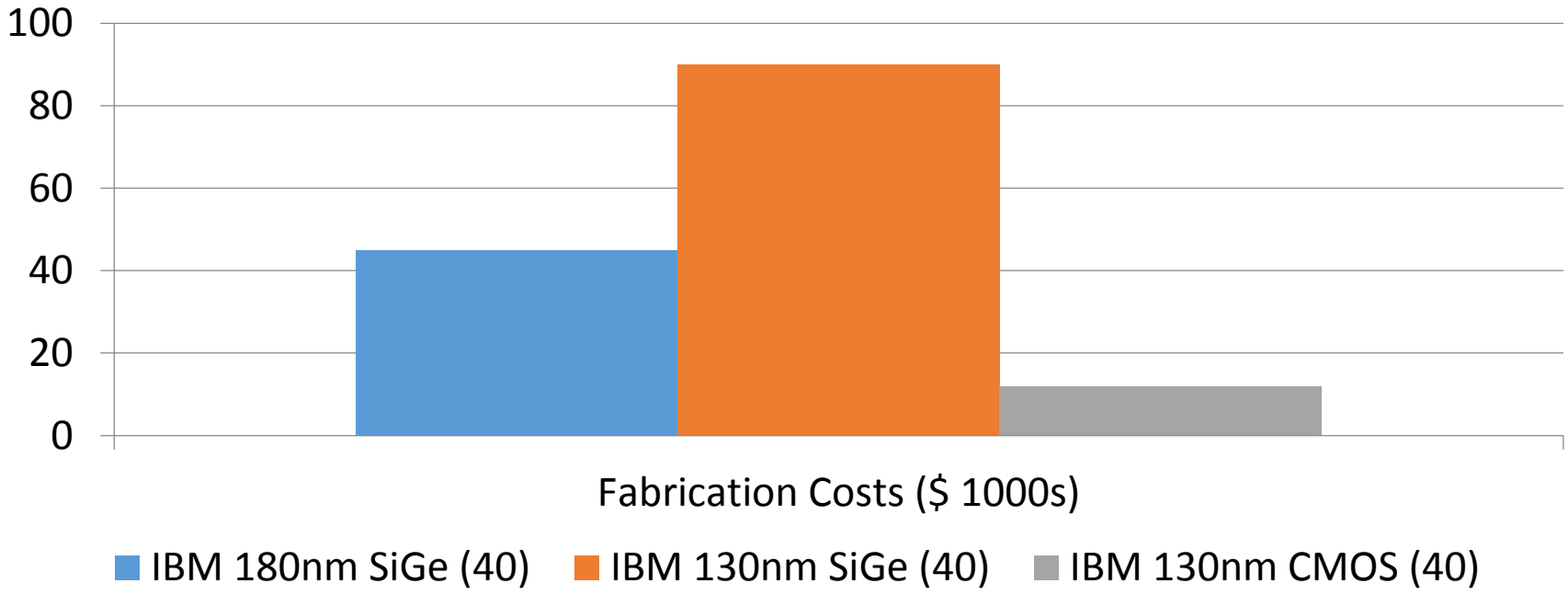
But what about the cost?

We need to consider the costs…

As a research team, given by the limited research resource, what is the fabrication cost *per bit*?

Dollars/bit ($/bit)

Example IC Fabrication Costs…



…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

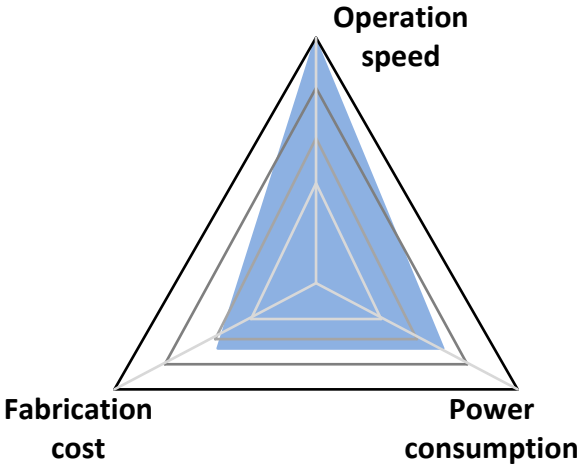
But we need to think about more than just a single demonstrator…..

Comparison of SiGe and CMOS process

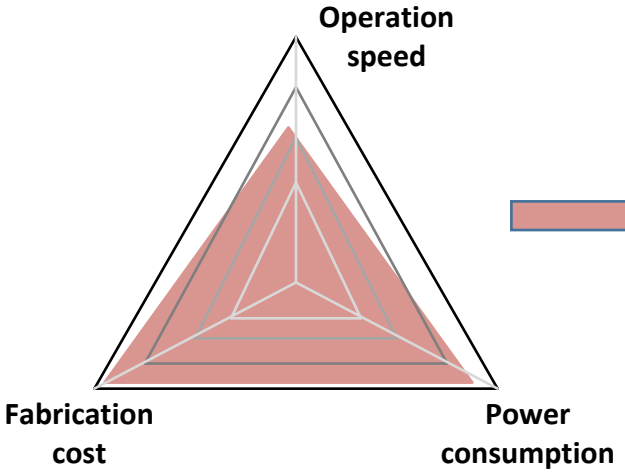
Additional benefit of CMOS?

- 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.

SiGe/GaAs



CMOS



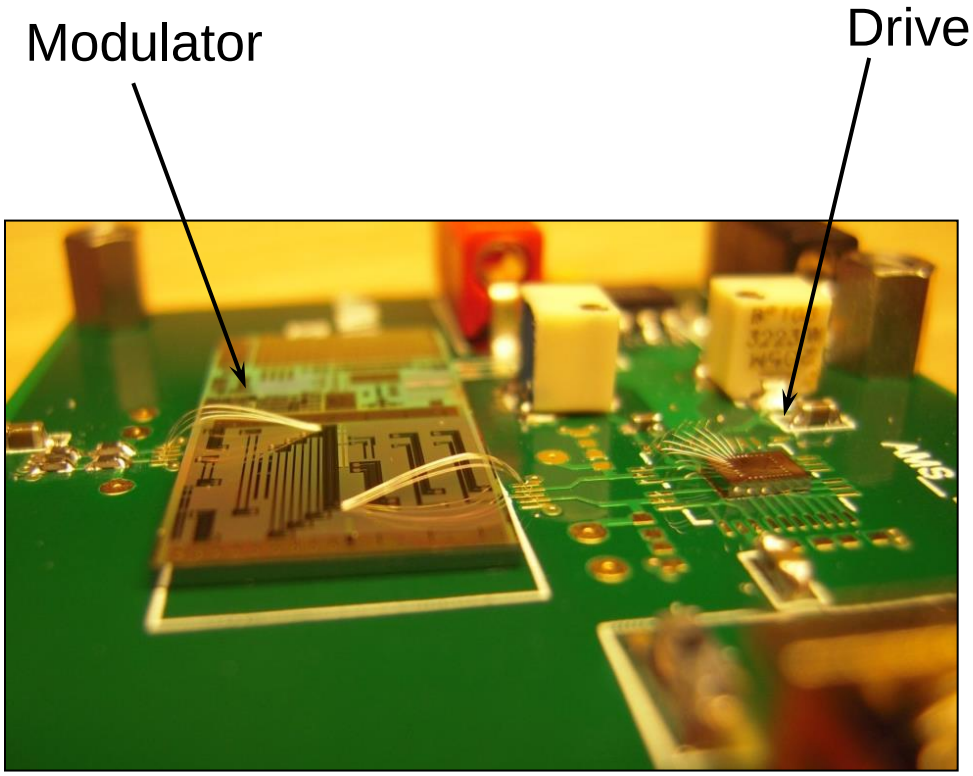
- **Multiple runs**
- **Different modulation formats**
- **DSP**

Strategy for practical success…

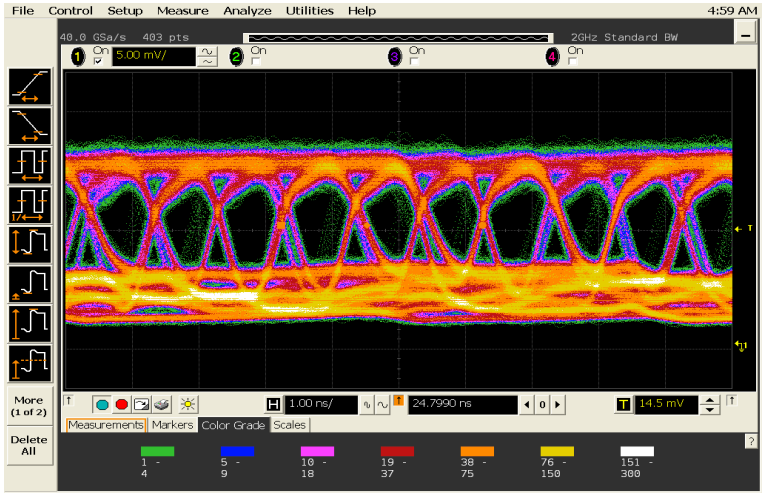
- Use CMOS for electronics
  - Low cost, low power
- Custom Silicon for Photonics
  - High performance, made in Southampton
- Hybrid Integration using bonding
  - Optimal platforms, rapid prototyping of separate technologies, simple integration

Achievement in 2011

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

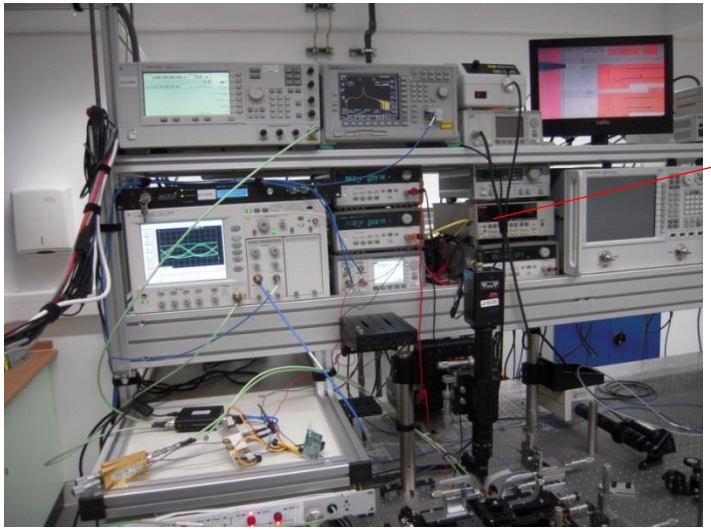


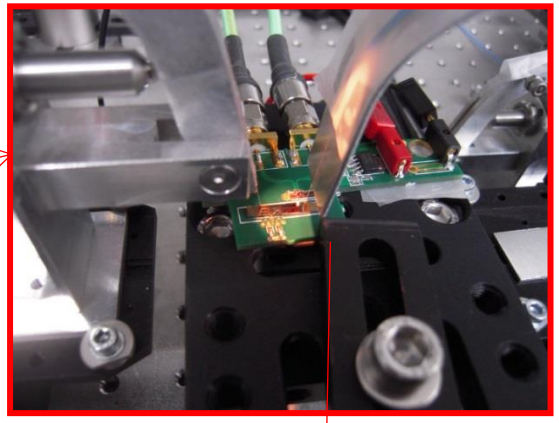
1Gbit/s

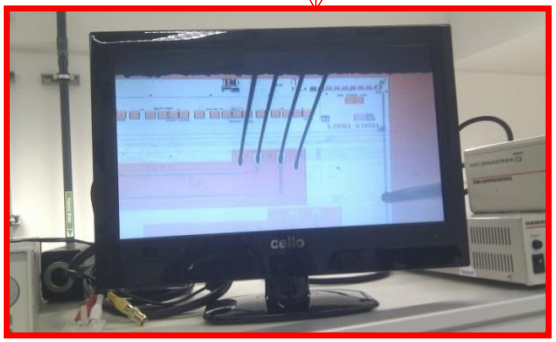


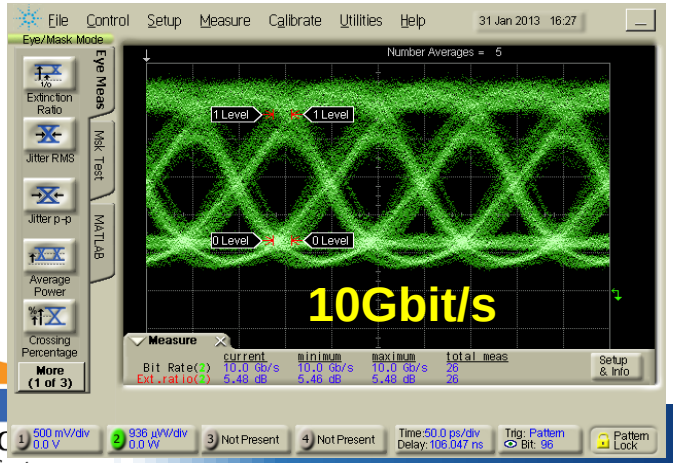
Achievement in 2012

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









Achievement in 2013

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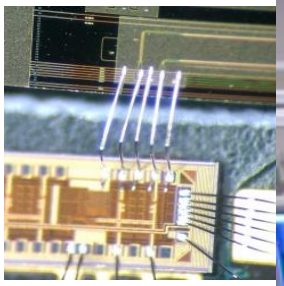

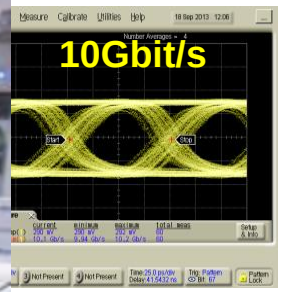

Silicon **oards.**

Coun
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Disp

A2

LCD
Display

Comparison of cost with commercial product

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

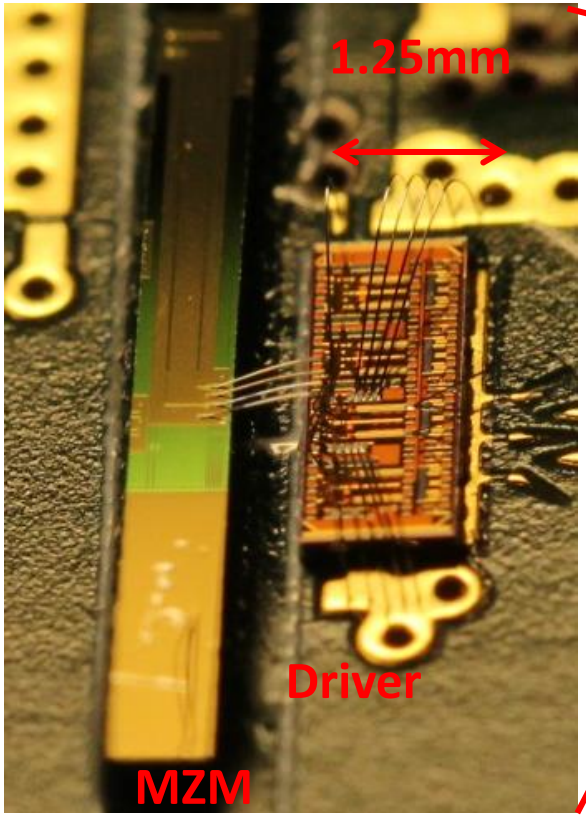
Product (MZM driver)	Speed	Process	Cost of each 10Gb/s
TriQuint TGA-4954	10Gb/s	GaAs	£119 [1]
Analog Devices ADN2526ACPZ	11.3Gb/s	SiGe	£24.19 [1]
SOTON ECS 2013	**12.5Gb/s**	**CMOS**	**£46.8**

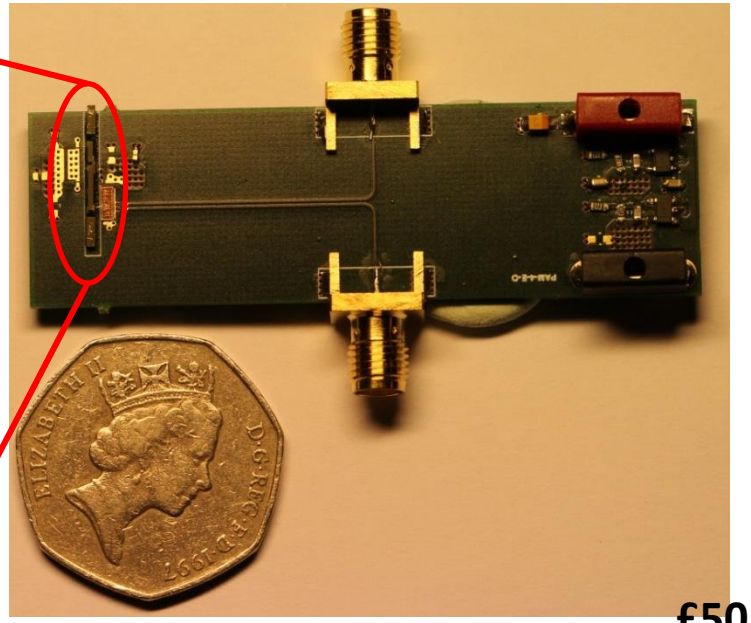
Our cost are based on small volume tape out price, and are comparable with commercial products (remarkable!).

Furthermore, we have created a useful research platform!

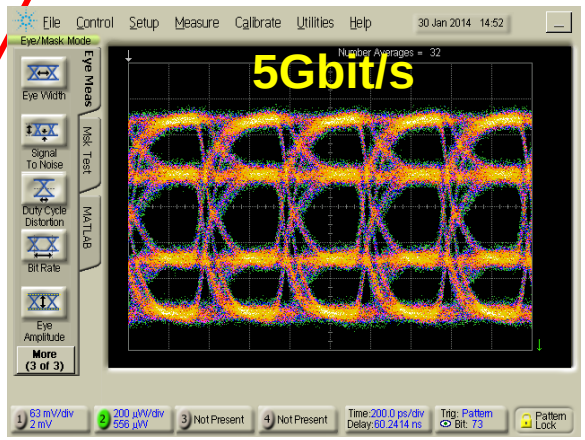
[1] price obtained from mouser electronic (www.mouser.com)

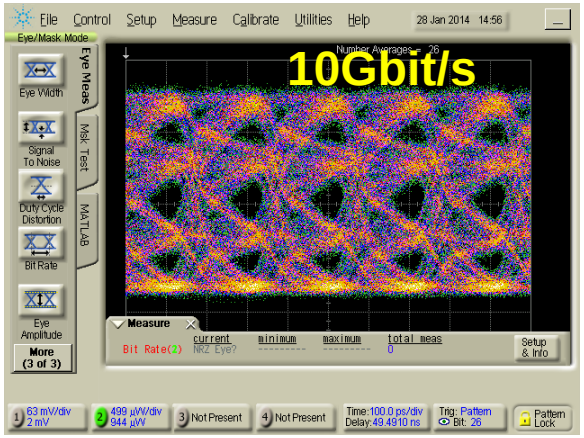
Advanced modulation format realized in 2014





£50/10Gbs(approx)





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