DESIGNCON® 2013

JANUARY 28-31, 2013
SANTA CLARA CONVENTION CENTER

Advances in Onboard Optical Interconnects: A New Generation of Miniature Optical Engines

Marc Verdiell
CTO Samtec Optical Group
Samtec, Inc.
01/29/2013

samtec

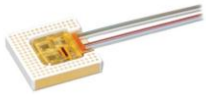
UBM Tech

Optical Engine? What's That?

Different things to different people…

In the context of this presentation (novel computer interconnects):

- Self contained electrical to optical transceiver unit
  - Miniaturized
  - Fits in Active Optical Cable, mounts on PCB or IC package
- Several lanes wide (x4, x8, x12, x16…)
- High speed (10 Gb/s per lane and up)
- Intended for computer interconnects / datacom links




DESIGNCON 2013

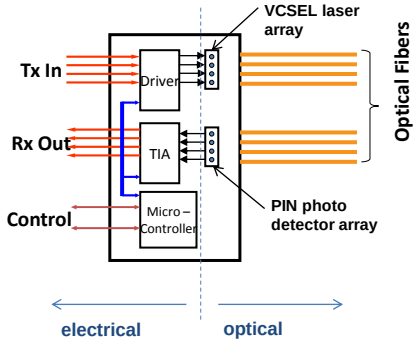
Anatomy of a VCSEL Based Optical Engine

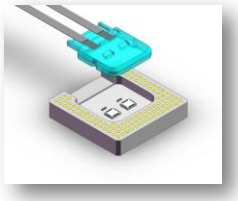
VCSEL = Vertical Cavity Surface Emitting Laser

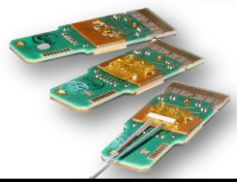
Typically analog EO-OE link, no retiming, but reshaping

Tx and Rx add (programmable) pre/de emphasis

Fiber transmission adds very little signal impairments







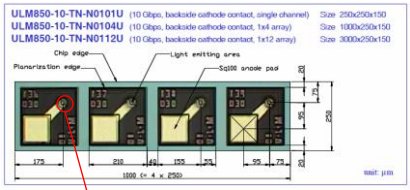
VCSEL

VCSEL = Vertical Cavity Surface Emitting Laser

Amplitude Modulated (OOK - On-Off Keying)

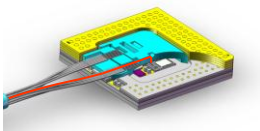
Very small emitting area

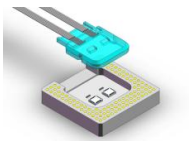
VCSEL Array (source: Philips)



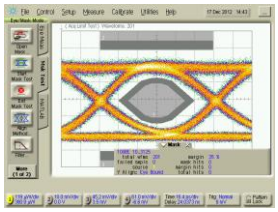
Laser Emitting Area (few microns dia.)

Light path in optical engine (source: Samtec)

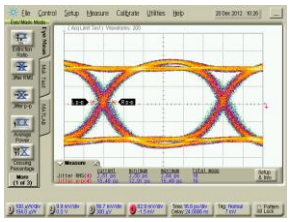




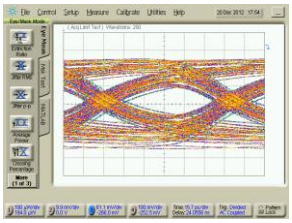
Optical Link Eyes (10 Gb/s)



Optical Eye travelling in fiber
(On-Off Keying)



Optical Engine Received Eye
(Electrical, pre-emphasis added,10m)



19" Copper eye for reference

DESIGNCON 2013

Control

Generally over I2C

- QSFP has hardware interrupt line for alarms

"Digital Diagnostics" and settings

- Laser on/off per channel
- Rx squelch per channel
- Loss of Rx signal
- Temperature
- Alarms for the two above
- Some engines: transmitted and received power (additional $$!)
- Some engines: pre-emphasis and amplitude settings

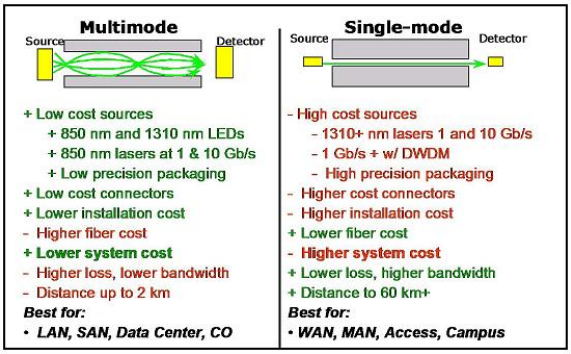
Lots of part information

- Manufacturer, part number, lot, manufacturing date, etc…
- Max rate of cable supported
- Optical technology (wavelength, type of fiber…)

DESIGNCON 2013

Single-mode and Multimode Fibers

Single-mode vs. multi-mode fiber (source: Furukawa)



Single-mode fiber core < 10 µm, multi-mode core = 50 µm

For distances below 100m, multi-mode is the standard

Exception: Silicon Photonics based engine must use single-mode fiber and are not compatible with standard short reach optics.

DESIGNCON 2013

Silicon Photonics

Silicon is transparent in the long wavelength "telecom" window (1550nm)

The following elements can be integrated into a single chip

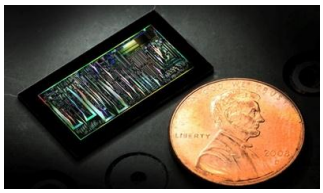
- Driver electronics
- Single-mode waveguides
- Modulators
- Photo detectors

In practice, some are really hard

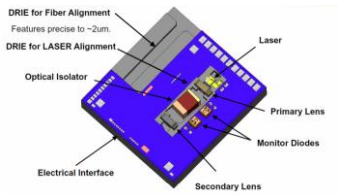
- Really good drive electronics
- Small modulators
- Any laser sources

Single-mode fiber coupling

- Negates size advantage
- Alignment cost



Silicon Photonics Chip (source: OpSIS)



Hybrid Silicon Photonics Chip (source: LightWire)

DESIGNCON 2013

Continuous Technology Progress

Integrated Photonics

- Silicon Photonics (e.g. Luxtera)
  - Good for high level of complexity / integration
  - Single-mode / long wavelength
- In Photonic integrated circuits (e.g. Infinera)
  - High end telecom single-mode / long wavelength / WDM/ long distance

VCSEL based technology

- Optical micro molding
  - Intel Lightpeak (consumer)
  - Micro-engines (Avago, Samtec)
- Multi-mode / short wavelength / parallel / short distance
- Interoperable with standard short reach

Micro-connector systems

- Specially adapted for miniature optics

DesignCon 2013

Historical Perspective: the SNAP12

12 lane unidirectional parallel optical module

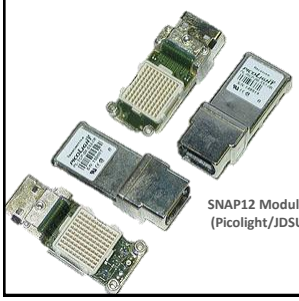
VCSEL based, multimode fibers

Was first implementation of short reach 10 Gb/s (12x 1Gb/s)

Uses MPO optical connector interface

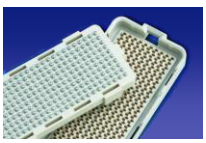
Initially for telecom / core router applications

Later evolved to the MEG Array connector de-facto standard



SNAP12 Modules (Picolight/JDSU)

MEG Array Connector



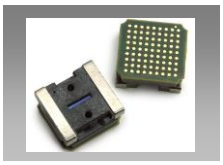
MTP Ferrule and MPO 12 fiber connector (USConnec)

DesignCon 2013

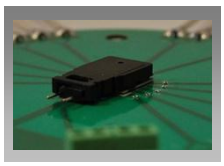
Small Engines – Large Modules

Optical Engines "cores" can be made very small

- ~10x10mm footprint



Avago Micropod (x12)



Reflex Photonics (x12)

Samtec FireFly™ (x12, x4 bidi)

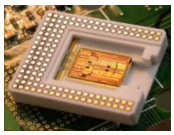
Luxtera (x4 bidi)

But something is missing here…

Practical Modules Are Not Small Enough

Finished practical engines many times the size of their optical "core"

- Electrical connectors
- Optical connectors
- Heatsinks



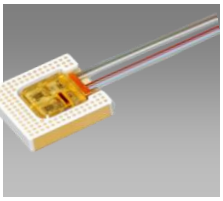
The Trouble with LGAs

Looks like a great solution at first (core)

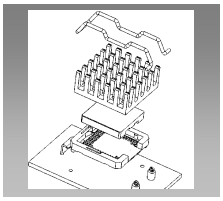
- Very dense
- Excellent high speed performance

But in practice board integration difficult (mounted engine)

- Compression hardware
- Fine pitch
- Exotic ceramic substrates



Nice

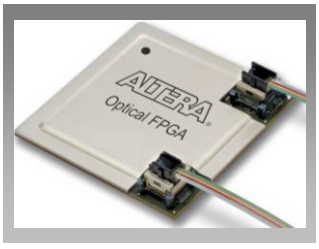


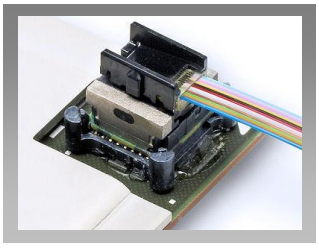
Less Nice

Not So Nice

DesignCon 2013

The Trouble with LGAs





DesignCon 2013

Miniature Optical Engine and Connector System

Miniature edge connector

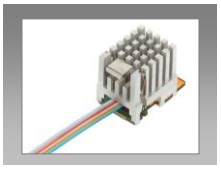
- No LGA, no compression
- Designed for 28G
- Small enough to put on edge of IC package (6mm x 11 mm x 3mm)

PCB and micro-molded lens based engine

- Low materials cost
- Ease of assembly

Integrated heat sink

- Customizable form factors



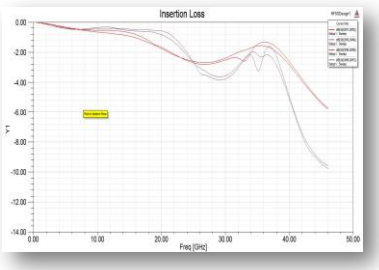
DESIGNCON 2013

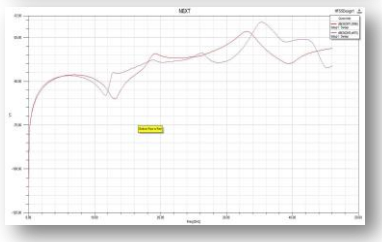
FireFly™ Connector

Designed for 28 Gb/s

Separate high speed connector and control signal connector

Latch locking mechanism for the optics

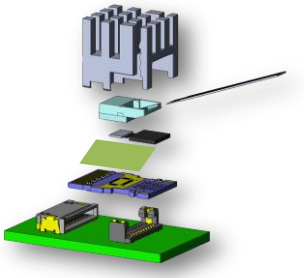


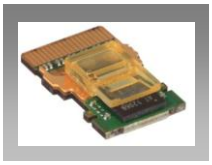


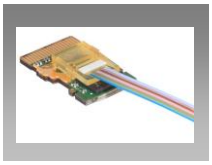
DESIGNCON 2013

Optical Engine Construction

- Micro-molded plastic optics technology
- "Just in time" heat sink and fiber attach
- Passively aligned optical fibers
- Integrated AC coupling caps
- Integrated micro-controller

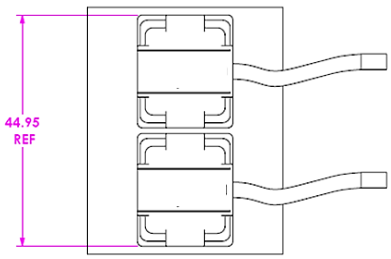




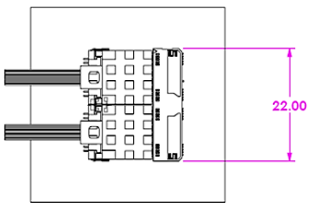


DesignCon 2013

Size Comparison



MiniPod



FireFly™

DesignCon 2013

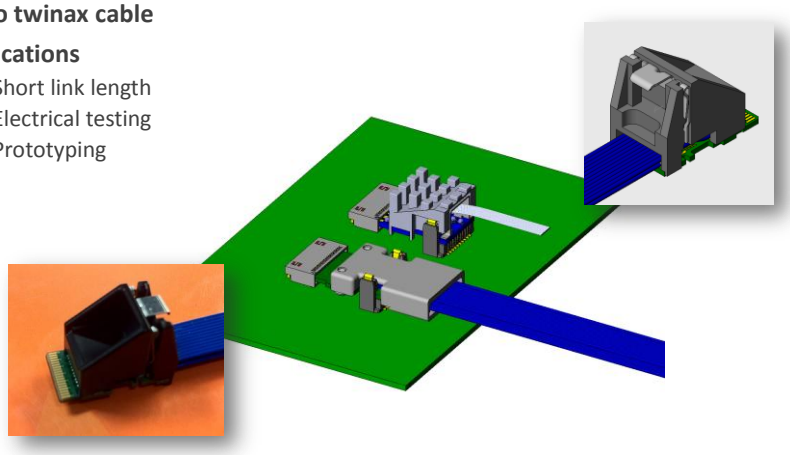
Copper "Flyover" Option

Fits in the same connector system

Micro twinax cable

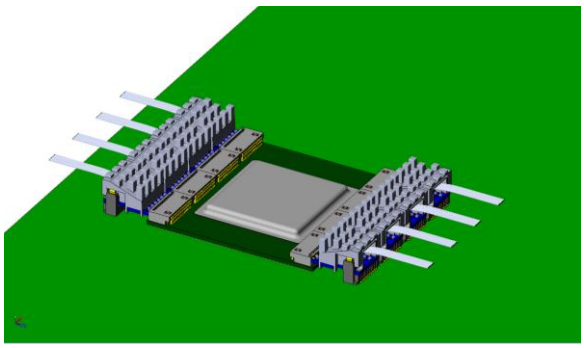
Applications

- Short link length
- Electrical testing
- Prototyping



DesignCon 2013

"On IC" Arrangement



Eight x12 modules on 45x45mm IC BGA package

DesignCon 2013

Optical Connectors: the MT Ferrule

x12, x24 most commonly available

Plastic molded

Physical contact

x8, x12 and x24 MT Ferrules
(source: USConec)

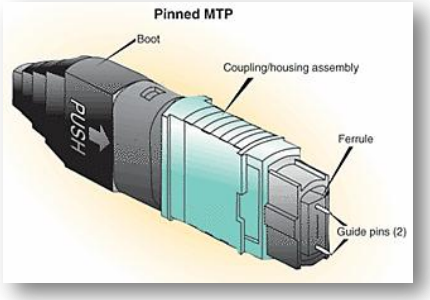
Male and female MTs, clip
(source: OE-Tek)

MPO/MTP Connector

MPO connector uses the MT ferrule

Fiber friendly latching mechanism

Orientation Key

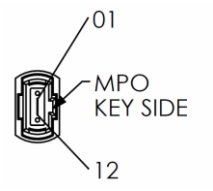


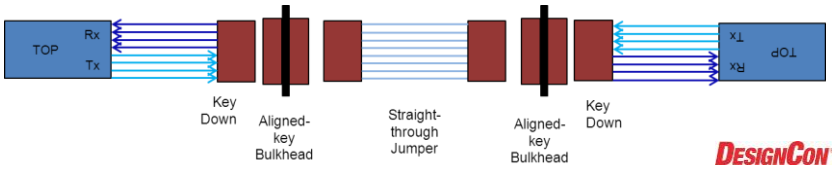
MPO Polarity Considerations

The MPO connector has keying for orientation

Two types of couplers: aligned and anti-aligned keys

Several types of jumpers: straight through, inverted…





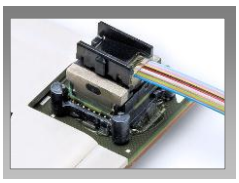
DesignCon 2013

Pigtail Connectors

Two main approaches:

- Detachable on the engine end
  - Match any engine with any pigtail
  - Size, cost penalty?
  - Might interfere with heat sink?
  - Deal with two separate vendors?
- Fixed (permanently attached) pigtail
  - Fixed configuration
  - Length and connector customized at order

Prizm optical connector
(source: USConec)

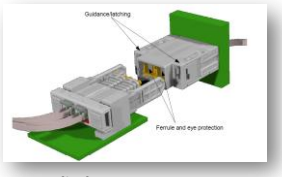


Detachable pigtail & connector
(source: Avago/Altera)

Pigtail premanentaly attached at order
(source: Samtec)

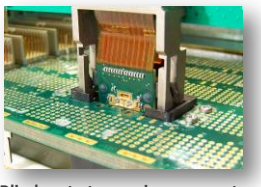
DesignCon 2013

Backplane Solutions

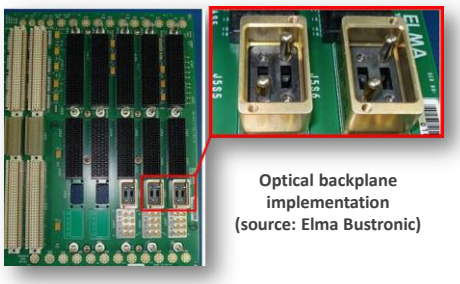


Blind mate connector
(source: Amphenol)

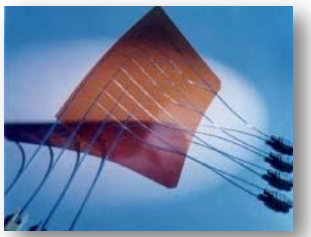
Blind mate MPO system
(source: TE Connectivity)



Blind mate transceiver connector
(source: Samtec)



Optical backplane
implementation
(source: Elma Bustronic)



Fiber shuffle on flex circuit
(source: Molex)

DesignCon 2013

Optically Friendly Protocols

Standardized protocols with optical options:

- Ethernet
- Infiniband
- Fibre channel
- SAS 12G (with optical option)

Most are derived from the SFF standards

- SFF-8436 (4 channel, bidirectional, 4x 10Gb/s QSFP+)
- SFF-8431 (SFP+, single channel, 10 Gb/s signaling)

Standard specified mostly by:

- Electrical input mask
- Optical output mask, optical modulation amplitude and average power
- Optical link penalty
- Optical receiver sensitivity (including stressed sensitivity)
- Electrical output mask
- Added jitter
- Link bit error rate

DesignCon 2013

SFF/Standard Based Engines

A signal that passes the input mask

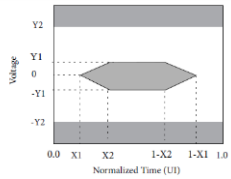
- Guarantees a signal that passes the output mask
- Guarantees a BER lower than 10-12 (10-15 for AOCs)

Interoperability between engines

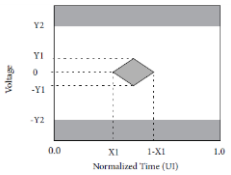
- For engines that also comply OPTICALLY to SFF
- Signal in the fiber is standardized too
- Engines that support the SFF spec can interoperate
- Typically miniature engine on one side, QSFP on the other side

Control and Diagnostic (I2C)

- Also defined by standard
- All modules respond to the same basic commands
- Some commands are optional (mostly telco related)



SFF Tx Compliance Mask



SFF Rx Compliance Mask

Operating Outside the Standard Protocols

Most engines are rate independent

- 28 Gb/s might return to CDR

Optical transport usually requires the following conditions:

- Bit rate below the maximum supported by the engine (duh)
- No spectral rate content below the cutoff of the engines (~100 MHz, engine dependent)
  - Slow protocols with long strings of zeros are an issue
- Signal must be DC balanced
- No copper exotics
  - No idle state, unless specifically supported by the engine
  - No sidebands
  - No impedance or remote load sensing
- Turn off (excessive) pre or post compensation
  - Pre and post compensation techniques that expect linear copper cable impairments are unnecessary and may (will?) fail on an optical link

Good candidates

- Anything 8B/10B or 63/64B encoded

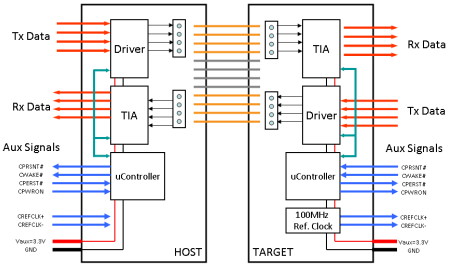
Bad candidates

- PCIe, unless…

PCIe Specific Support

Samtec's Active Optical Cable (AOC) PCIe support (for Gen2):

- Link training
- Electrical idle
- Auxiliary signals / sidebands: cable present, wake, reset, power-on
- Power up/down from either side
- 100 MHz clock forwarding (asynchronous)



DESIGNCON 2013

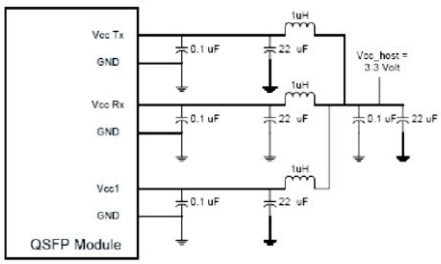
External Components

Power filtering

- Always external - Tx and Rx have separate filtering

Decoupling caps

- Sometimes external, sometimes integrated



Schematic from SFF spec
Power filtering is usually required and separate at least for Tx and Tx sections to minimize crosstalk

Decoupling caps (circled in red)
Not all engines have them integrated

DESIGNCON 2013

Heat Sinking

Engines are not very power hungry

- 1 to 3 W range

They have limited operating range compared to ICs

- 70C max case for most

They sit next to very hot chips

Pre-engineered heat sink solutions might be a plus

Summary

Optical engine coming into new exciting form factors

- Smaller form factors
- Better connector solutions
- Compatibility with copper
- Easier to integrate parts with embedded micro-controllers

Around the corner are higher speeds, more width options

- 28 Gb/s per lane
- x8 bidirectional
- PCIe and other computer bus support

Questions?


DESIGNCON® 2013
JANUARY 28-31, 2013
SANTA CLARA CONVENTION CENTER
Advances in Onboard Optical Interconnects:
A New Generation of Miniature Optical Engines
Marc Verdiell
CTO Samtec Optical Group
Samtec, Inc.
01/29/2013
samtec
UBM Tech