NEXT GENERATION TUNABLE TECHNOLOGY AND APPLICATIONS

ethernet alliance

Introduction

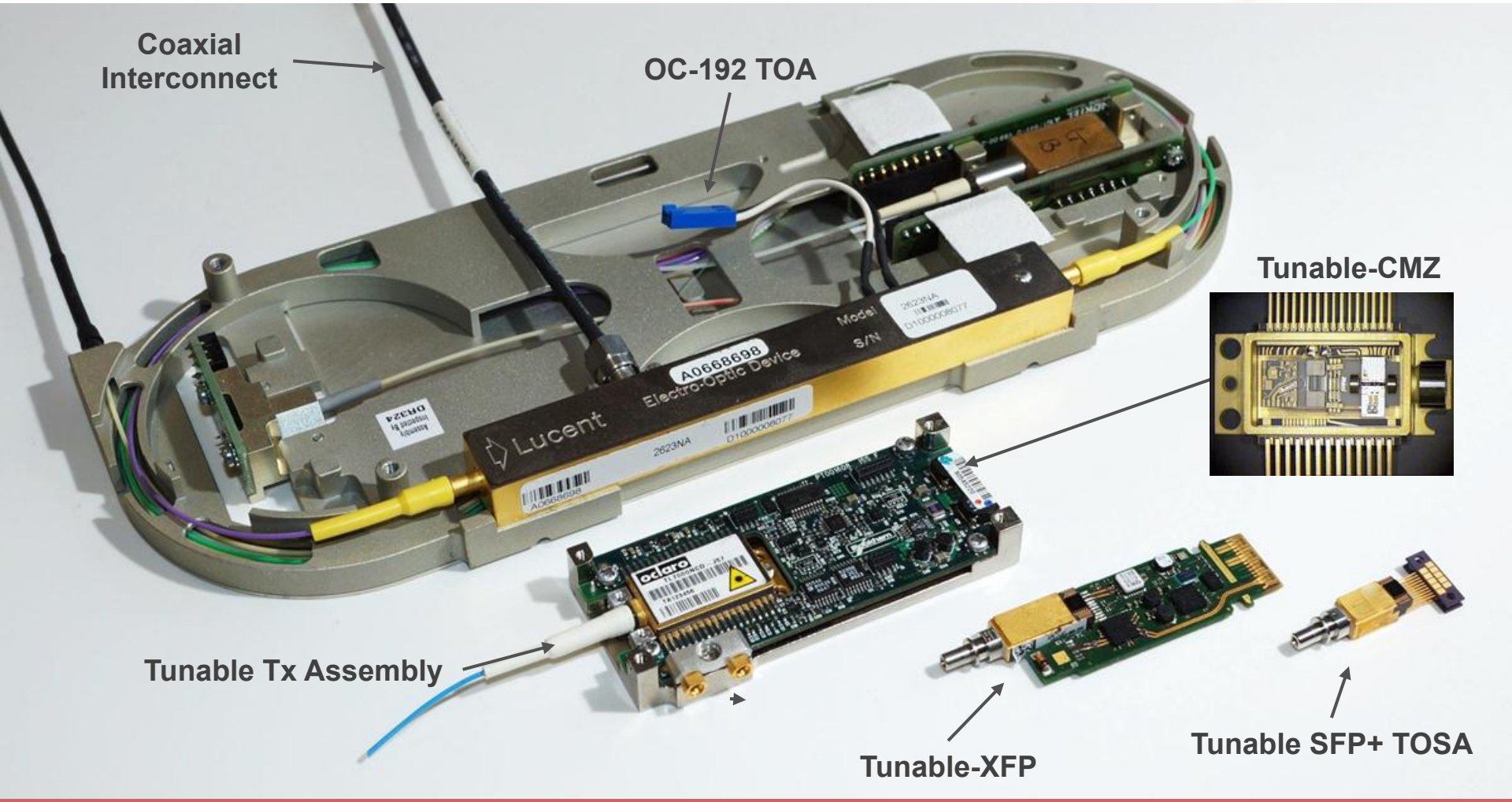
- Over the last 10-15 years the adoption of tunable based solutions has grown significantly.
- Innovation at the chip level has helped drive smaller size, lower power and lower costs and enabled products such as tunable XFP and tunable SFP+.
- Tunable lasers is an area of significant investment and innovation with a number of new applications where the technology can be applied.
- This panel will take a look at some of the latest innovations and applications being worked on today.

Speakers

- Kevin Affolter, Director of PLM for Tunable Transmission at JDSU
- Robert Blum, Director of Strategic Marketing at Oclaro
- Srinath Kalluri, Director of Transmission Components R&D at JDSU
- Vladimir Kozlov, founder and CEO of LightCounting

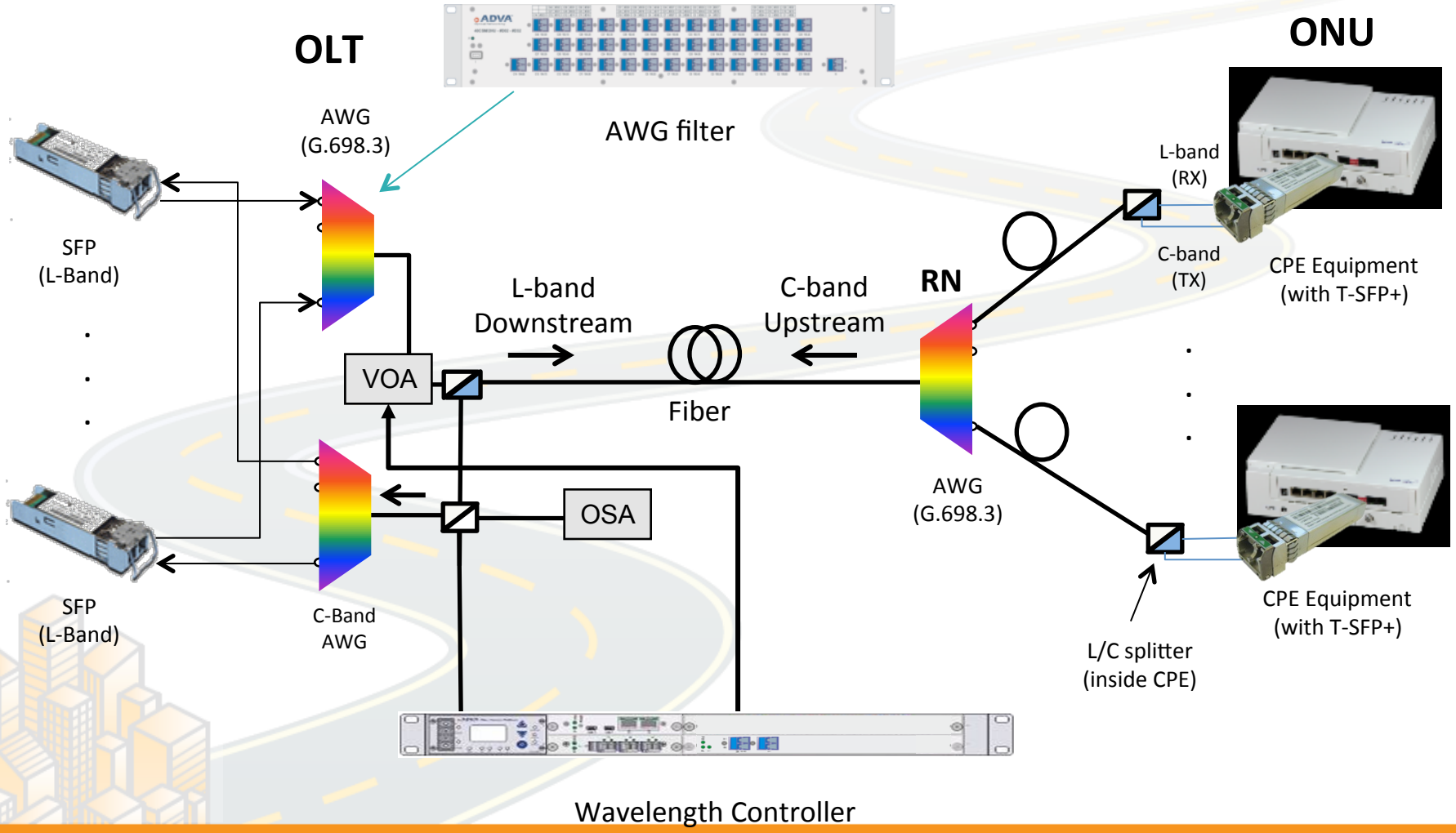
ROBERT BLUM
OCLARO

10G Footprint Evolution

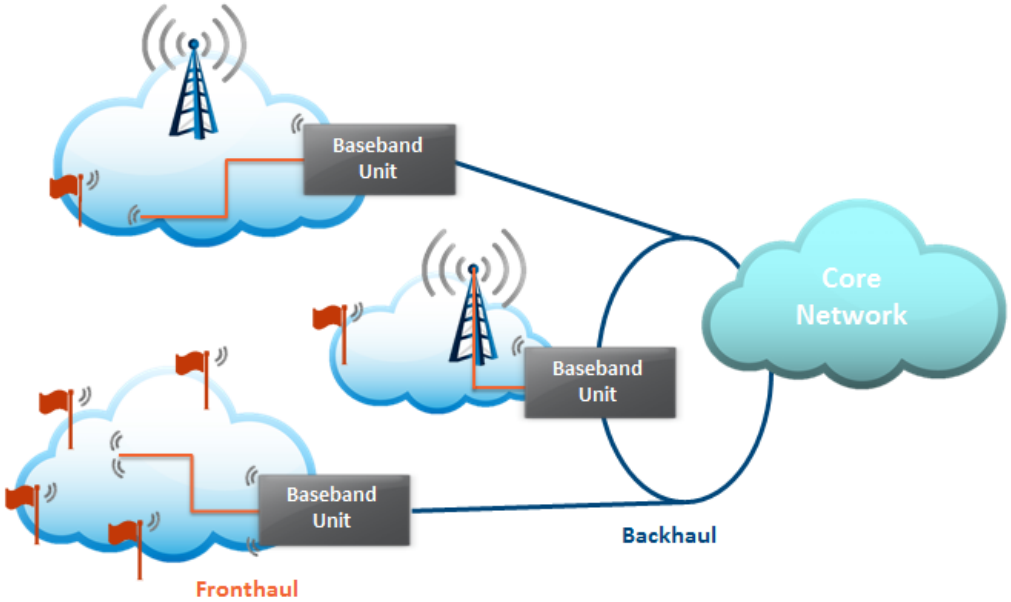


T-SFP+ TOSA has TOA functionality & wavelength tunability & control!

10G Tunable DWDM PON demo - Block View



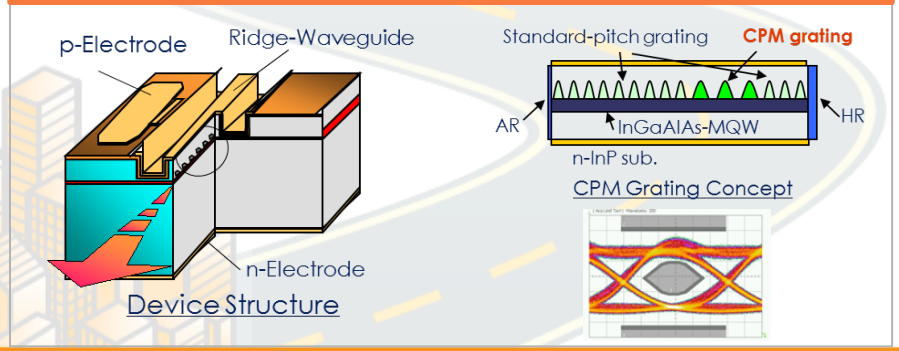
Low Power Indium Phosphide Addressing Mobile Applications



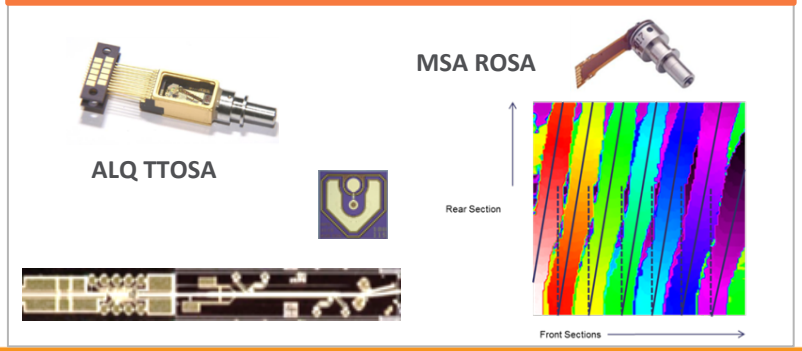
*"Mobile fronthaul is a key enabler of low-cost, high capacity mobile broadband networks. LightCounting estimates that **fronthaul networks will use more than 14 million optical transceivers in 2014**, with a market value of **$530 million**, and we expect this market to grow to more than $900 million over the next five years, driven by initial deployments and subsequent capacity upgrades of mobile 4G networks around the world."*

– Lightcounting, November 2014

28G 1.3mm Uncooled DML For SFP28 CPRI



Next Gen 10G Tunable Technology For Low Cost Tunable WDM-PON



Features and Trends for Fronthaul Optical Modules

- CPRI optical modules
  - 10G: High temperature operation to 90°C and beyond
  - Next generation 25G?
- Low cost WDM/ Colorless transmitters

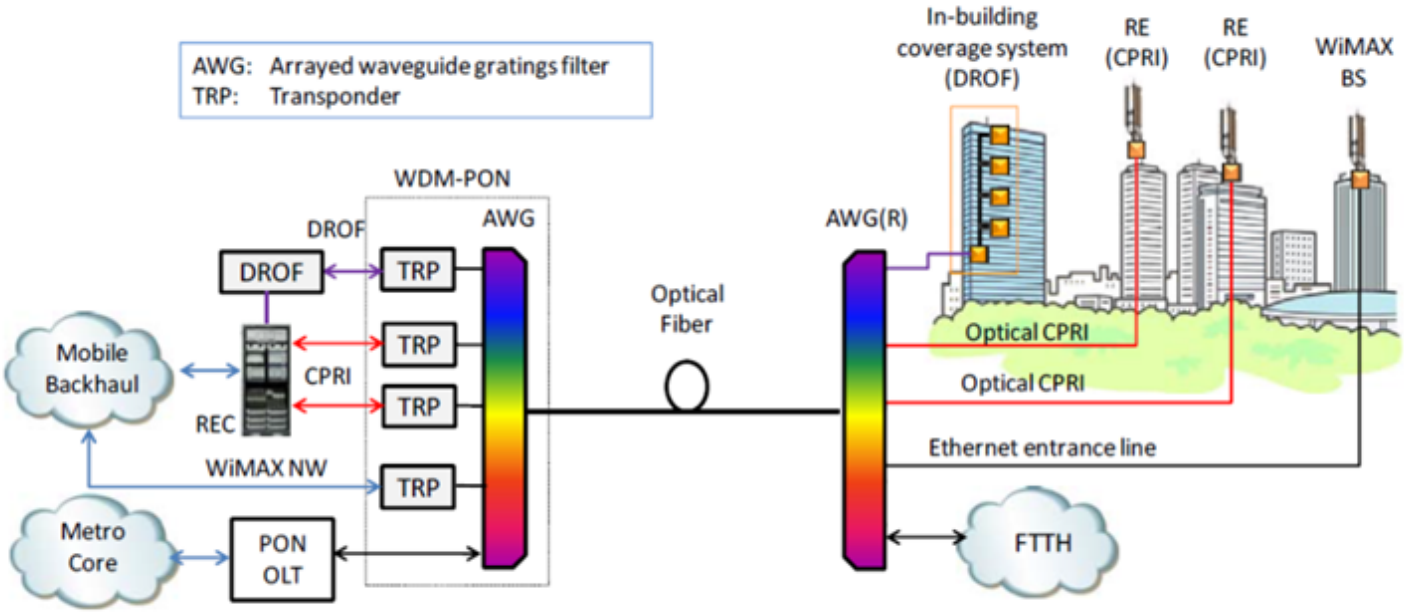
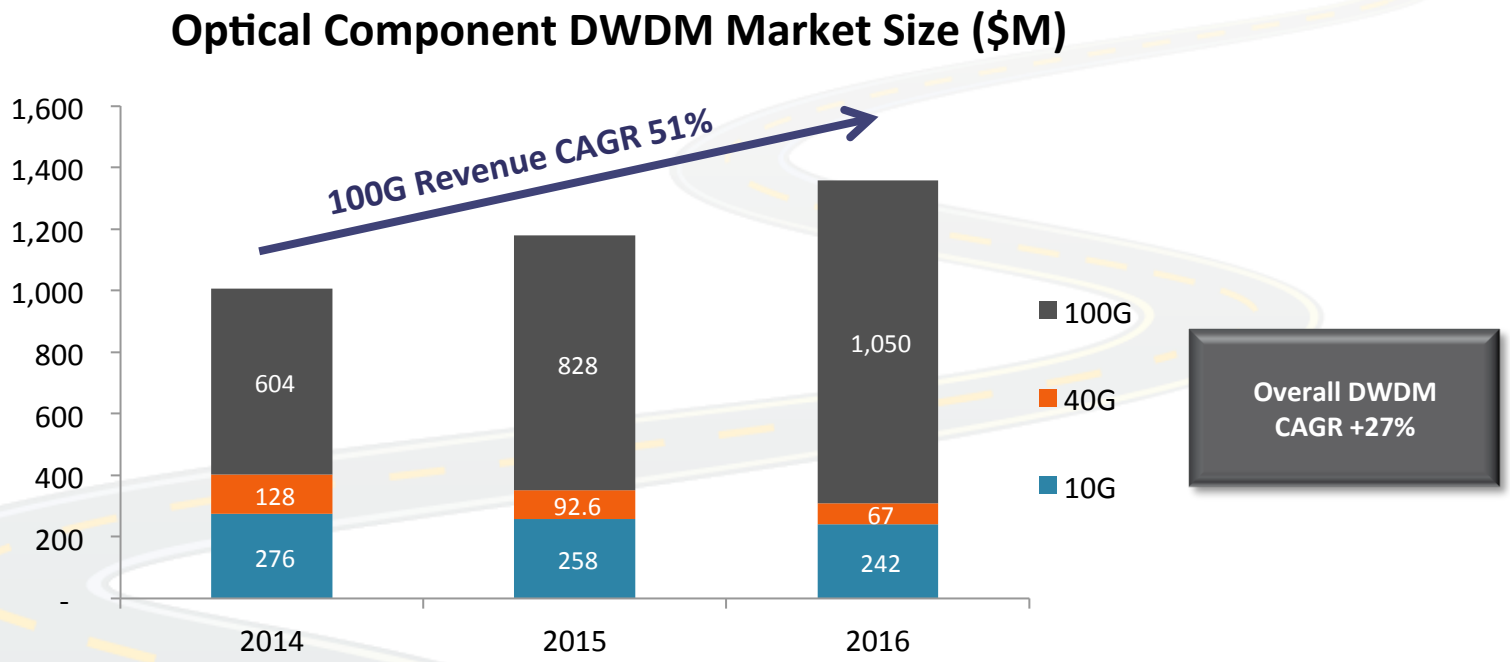


Fig. 1. Radio access network over WDM-PON.

Strong DWDM Growth Driven by 100G Coherent

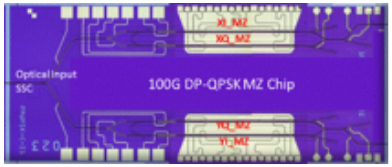


"Demand for 100G components and modules is a big driver for growth in WAN. We expect strong demand for pluggable coherent transceivers in 2015 and beyond. Vendors have a good reason to be optimistic about this market."

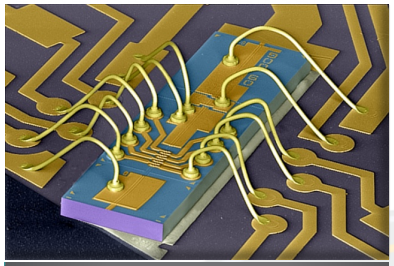
Daryl Inniss, Practice Leader for Telecoms Components at Ovum

100G Analog Coherent CFP2

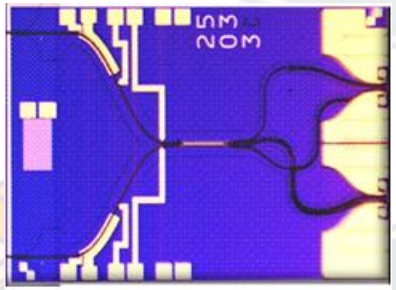
Differentiation Enabled by InP Photonic Integration



Mach Zehnder Modulator Chip



Tunable Laser Chip



Coherent Receiver Chip

Co-Packaging of Key Indium Phosphide Elements

Integrated 100G InP Transmitter Package

InP Micro Coherent Receiver Package

"CFP2-ACO technology is the most important catalyst for cutting the cost of coherent equipment and accelerating the rollout of 100G metro networks."

Andrew Schmitt, Principal Analyst, Infonetics Research

100G CFP2 Module

- Next generation 100G coherent pluggable
- Metro, regional and high performance long-haul applications
- Delivers maximum faceplate density
- Provides scalability to enable bandwidth as required

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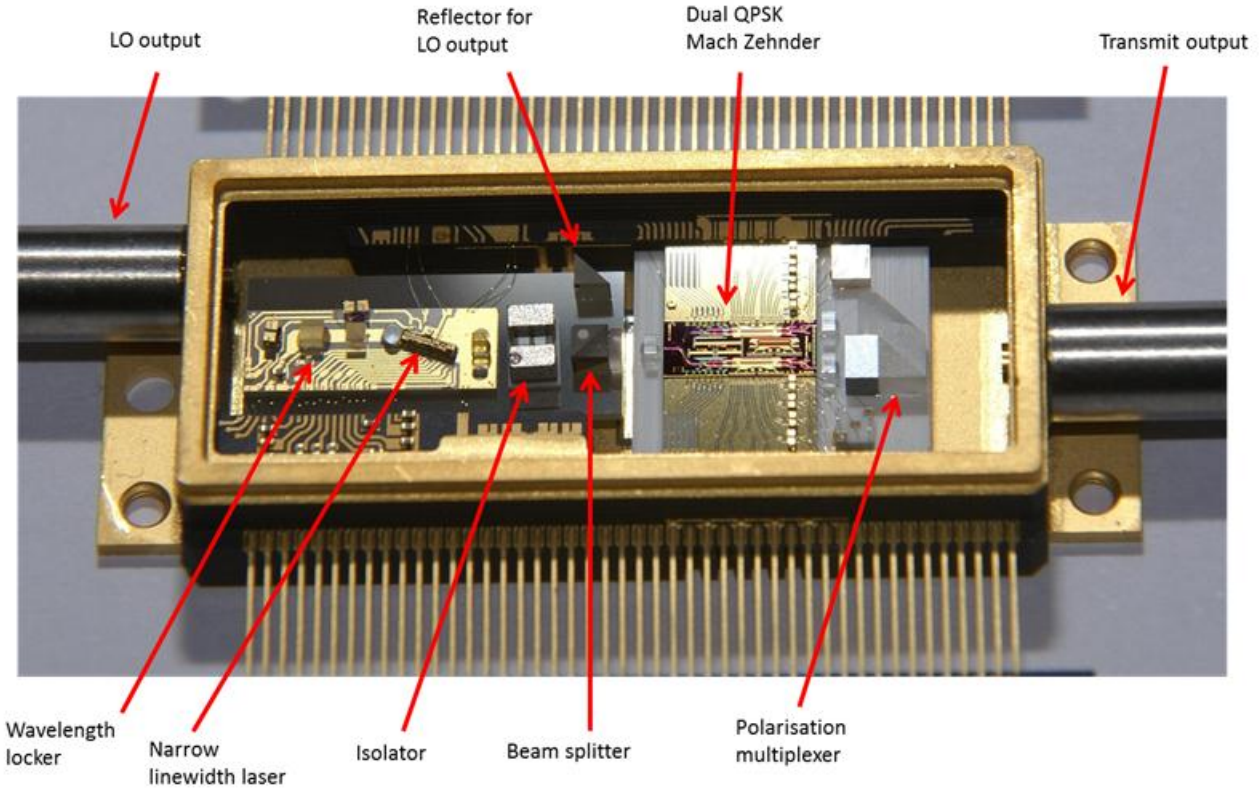
Packaged NLW laser, dual QPSK MZ and polarisation multiplexer with LO output

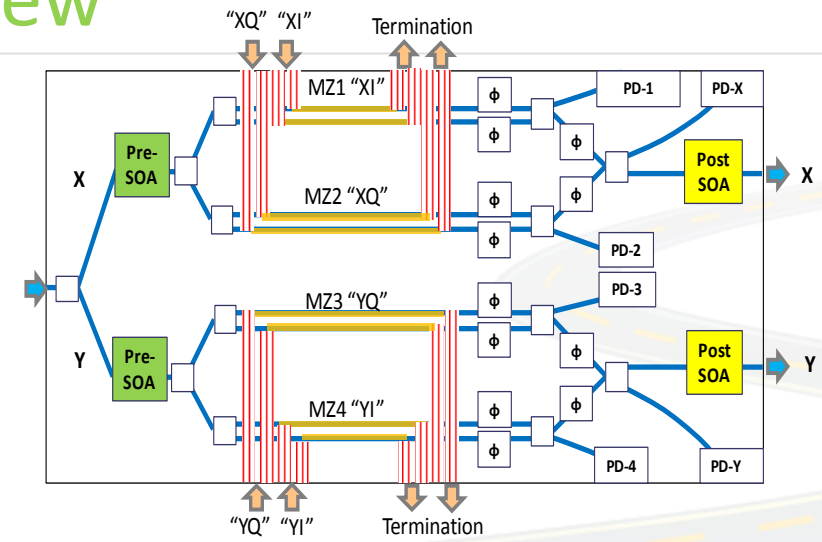


1st Generation Engineering Prototype Based on 40G DQPSK package

2nd generation transmitter designed for CFP2

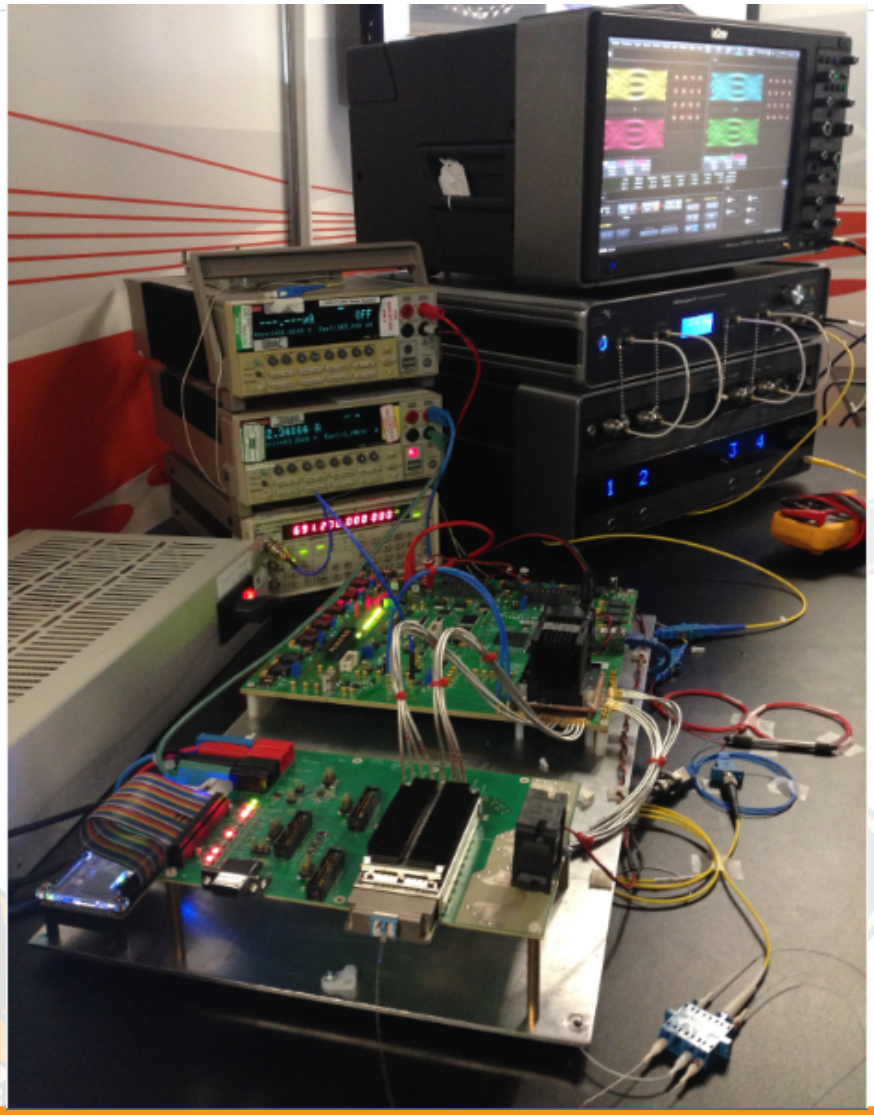
- RF on rear of package; DC on long side of package

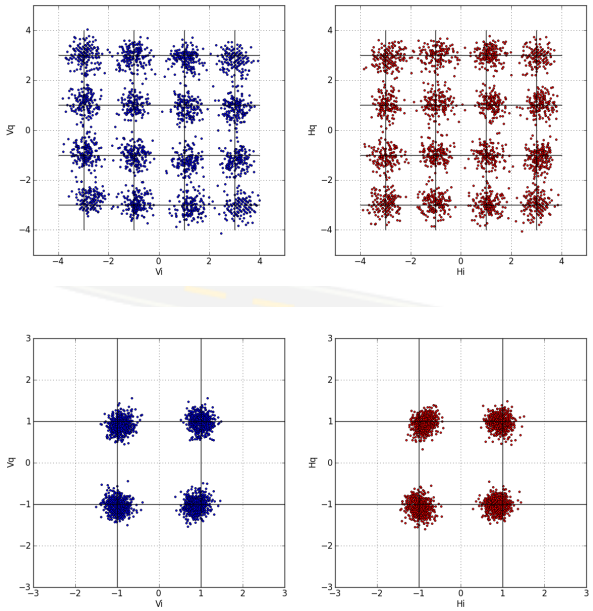
SOA Overview



- Semiconductor Optical Amplifiers (SOAs) integrated pre- and post Mach-Zehnder modulator
- Integration of SOAs onto dual polarization I&Q modulator chip allows enhanced output power for linear modulation formats with large 'modulation loss'
- Also provides greater flexibility for various applications
  - X-Y power balance
  - Trace-tone provision
  - VOA capability
- See Th4E paper at OFC 2015 for details
  - ***R. Griffin et al., "InP Coherent Optical Modulator with Integrated Amplification for High Capacity Transmission"***

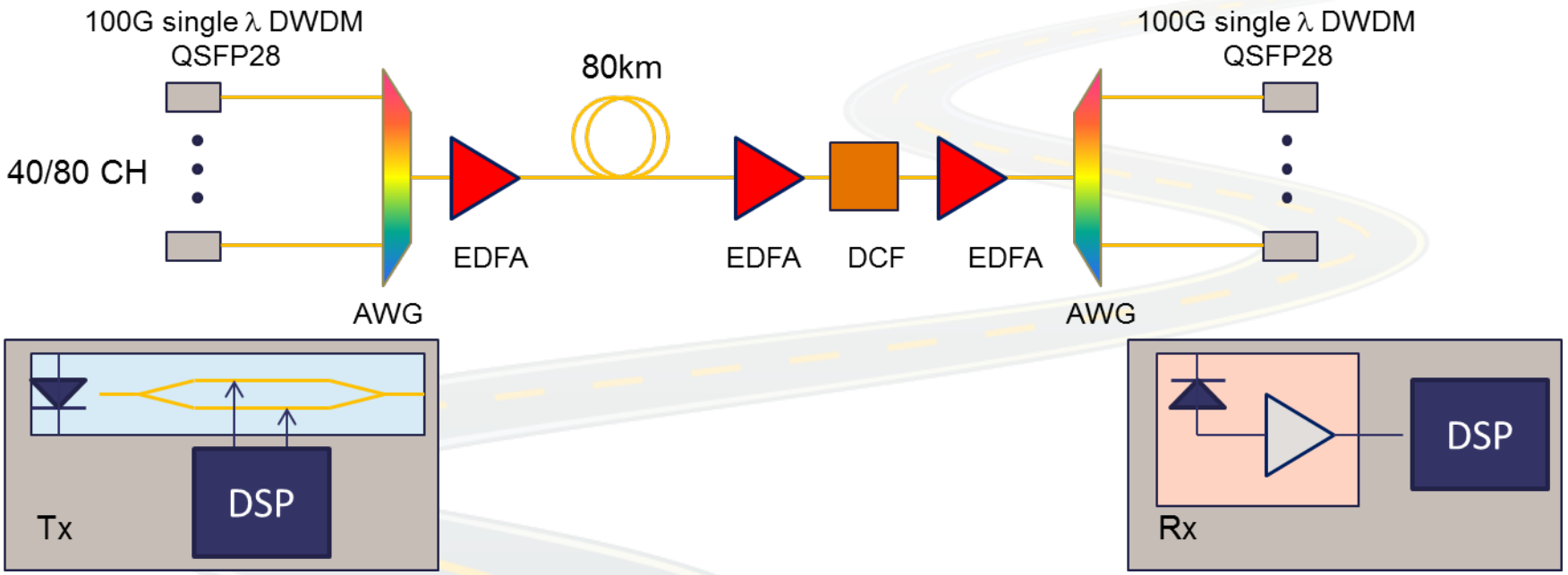
200G 16-QAM Demo at ECOC 2014





- Demonstrated 200G 16-QAM operation
  - 100G for each polarization
- Oclaro CFP2 and ClariPhy LightSpeed-II™ CL20010
- Continuous error-free 200G operation for 8+ hours daily at ECOC 2015

Tunables for data center interconnect



ILMZ Chip

- High bandwidth monolithically integrated laser + modulator
- 40/80 DWDM channels for 80km point-to-point link

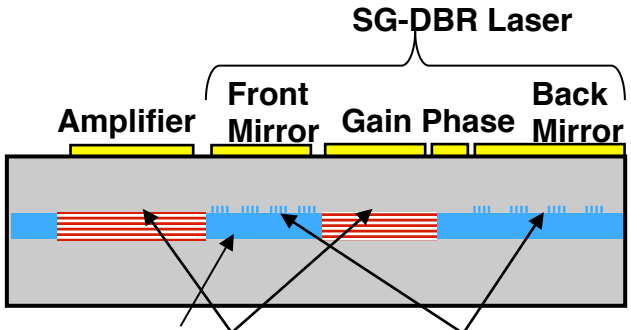
Summary

- Tunable lasers have been very successful in DWDM long haul and metro applications
  - Discrete → 300-pin MSA → TXFP → TSFP+ → CFP2-ACO
- Integration of lasers with InP modulators has enabled pluggable form factors for 10G and 100G
- InP platform allows for integration of SOAs and waveguide PD's and monitors onto one chip
- New applications are emerging that will drive the need for DWDM and – if cost points are right – to tunable lasers
  - Wireless fronthaul, DWDM PON, Data center interconnects

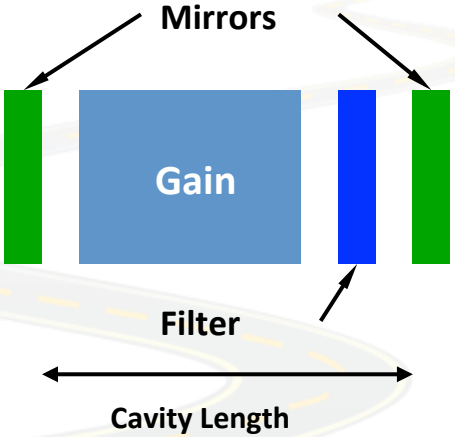
SRINATH KALLURI
JDSU

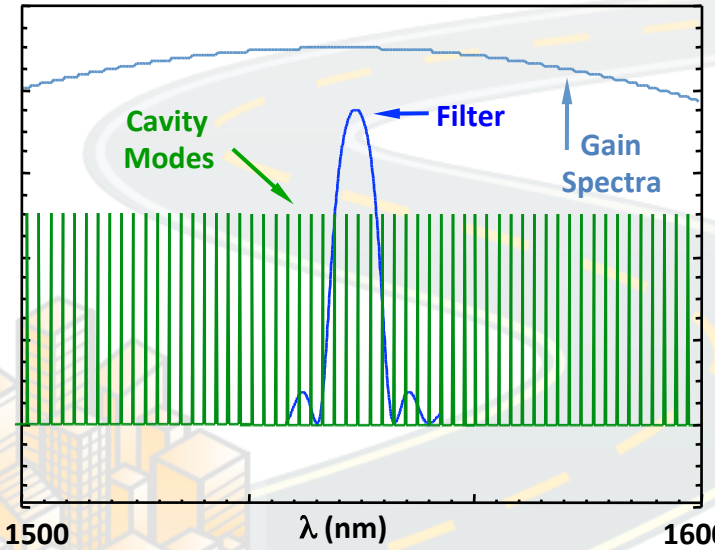
ethernet alliance

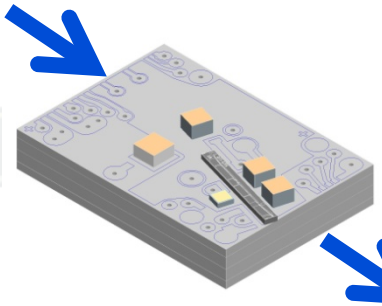
Tunable Laser Basics

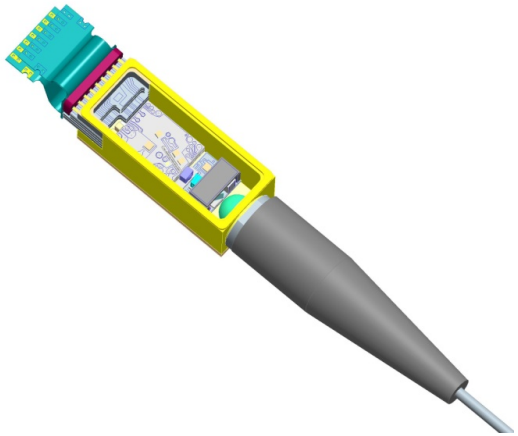


Butt-joint integration



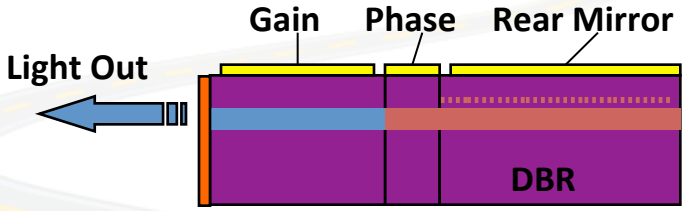




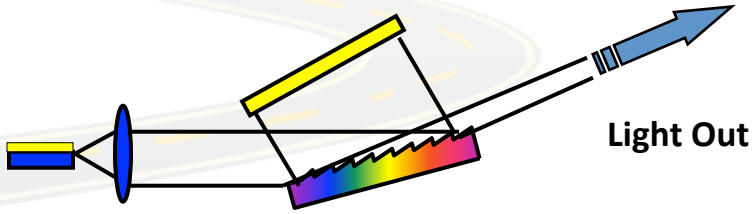


A few examples of tunable lasers…

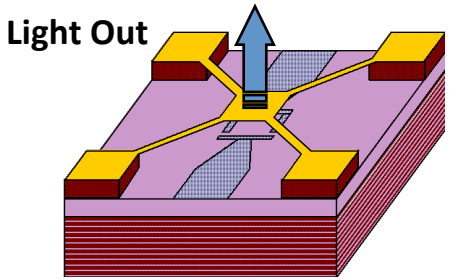
- DBR Lasers
  - Conventional DBR (<~15 nm)
  - Extended Tuning DBR's (≥ 40 nm)



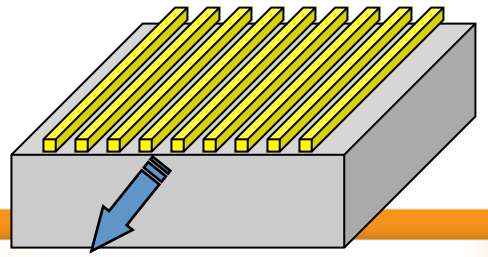
- External Cavity Lasers (≥ 40 nm)



- MEMS Tunable Lasers (≥ 40 nm)
  - VCSEL
  - In-Plane



- Multi-wavelength DFB array (35 nm)
  - MEMs mirror or power combiner
  - <4nm per element



Device architectures in more detail

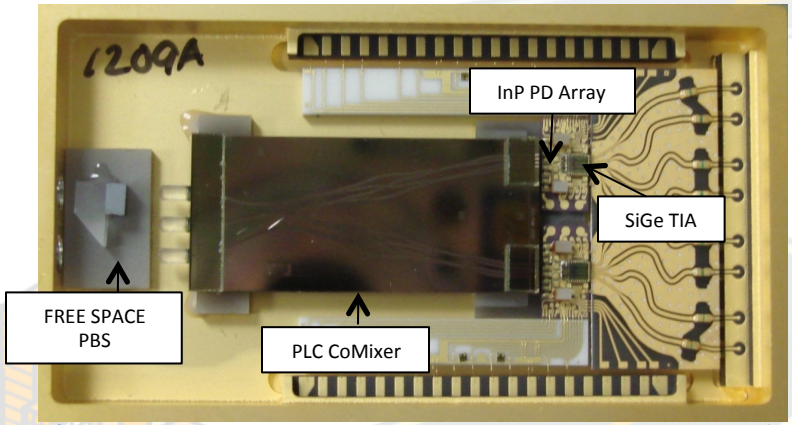
Device Architecture	Wavelength Selection	Tuning Physics	Integration	Commercial Example	R&D Example
S(S)G-DBR, DS-DBR, MGY	Passive WG Grating(s)	Current injection	Monolithic	JDSU (Agility), Oclaro, Finisar (Syntune)	UCSB, NTT
DBR	Passive WG Grating(s)	Thermal (microheater)	Monolithic		NTT, JDSU
Distributed Reflector	Active & Passive WG Grating	Thermal (microheater)	Monolithic	Sumitomo (Eudyna)	
DFB Array	Active WG Grating	Thermal (TEC)	Hybrid (MEMs coupling optics)	Neophotonics (Santur)	
DFB Array	Active WG Grating	Thermal (TEC)	Monolithic (power combiner+SOA)	Furukawa	NTT
Microring Resonator	Passive WG Resonator(s)	Current injection	Monolithic		NTT
ECL	Etalon(s)	Thermal (microheater)	Hybrid	Neophotonics (Emcore / Intel)	
ECL	Surface normal grating resonator (+50GHz etalon)	Electrooptic (Liquid Crystal)	Hybrid	Cyoptics (Pirelli)	NEC
ECL	Diffraction grating (Littman or Littrow)	Micromechanical	Hybrid	Iolon	Various
ECL	Diffraction grating (Littman or Littrow)	Mechanical	Hybrid	Various	
VCSEL	Cavity mode	Micromechanical	Monolithic or Hybrid	Coretek, Bandwidth9/10	

Tunable Winners – Depends on architecture

- Telecom (circuit switch) requirements
  - Power dissipation and Size
  - Output power, LW, SMSR, RIN
  - Vernier-tuned multi-section lasers (integrated or external cavity) or DFB arrays are leaders
    - All quasi-continuous tuning
- Packet switching
  - Fast channel switching (~ns) favors carrier injection and small tuning volume to counteract thermal transients
    - micro-rings
- Uncooled operation
  - Use tunability to compensate for temperature effects
  - Favors temperature-insensitive tuning elements and/or mode-hop free continuous tuning – MEMS diffraction gratings or VCSELs

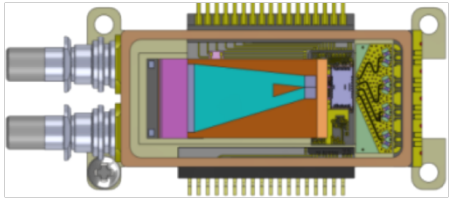
Hybrid Integration Value Proposition

- When system deployment can tolerate higher cost and size but cannot compromise on performance or market timing
  - Monolithic approaches mature later in time as many functional elements need development and high yields
  - First gen 100G coherent Rx was an example of a hybrid integration platform incorporating free space optics, PLC, and III-Vs
  - Some level of hybrid-integration is present in all components



100G Coherent Rx(~ 50mm)

PLC miniaturization

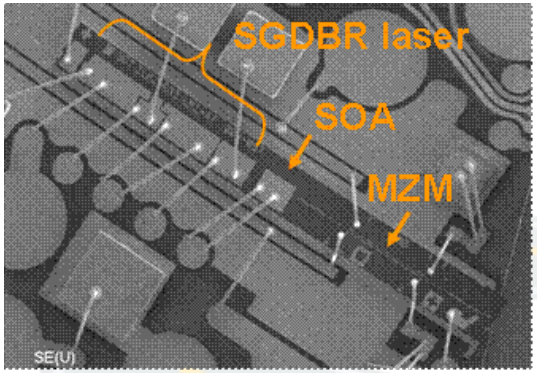


100G Micro ICR (~ 25mm)

Monolithic Integration Value Proposition

- Volume deployment typically needs form factors optimized for port count, size, power dissipation and cost
- When module form factors are standards driven and ecosystem is more mature

10Gb/s: *Monolithically integrated InP tunable laser and DP-IQ modulator*

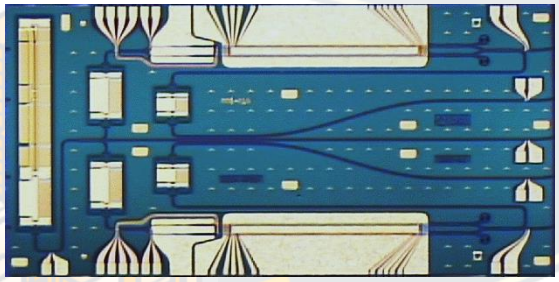


ILMZ chip (~4mm)

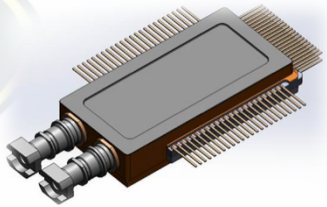
ILMZ TOSA (~18mm)

T-SFP+

200Gb/s: *Monolithically integrated InP tunable laser and DP-IQ modulator*



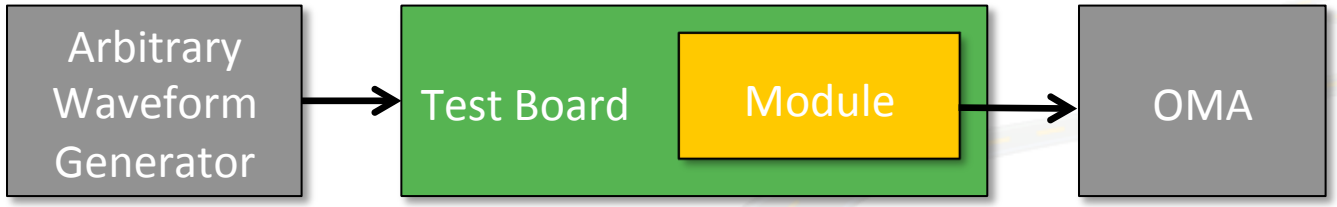
IL-QPMZ Chip



IL-QPMZ TOSA

CFP2-ACO

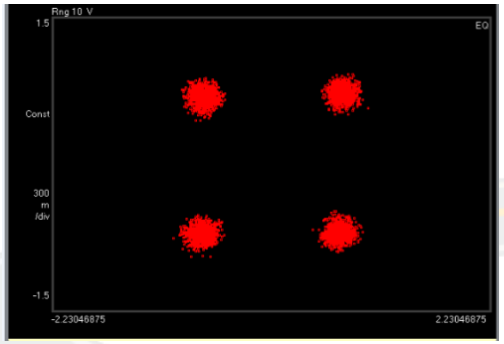
Monolithic IL-QPMZ Transmitter:

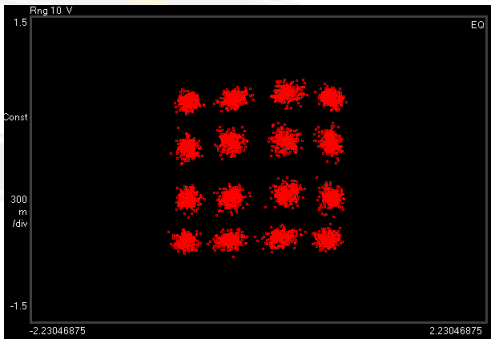


QPSK

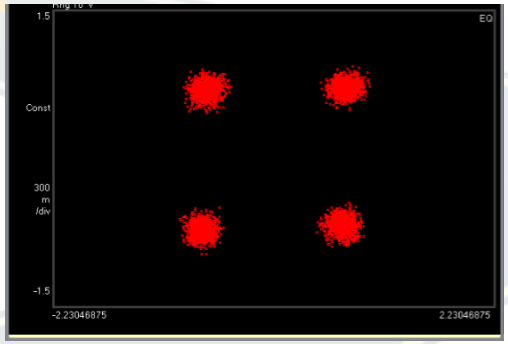
16-QAM

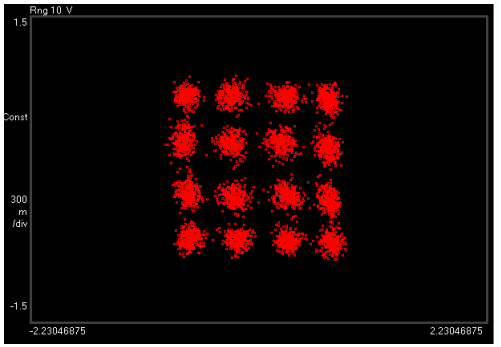
X-Pol





Y-Pol



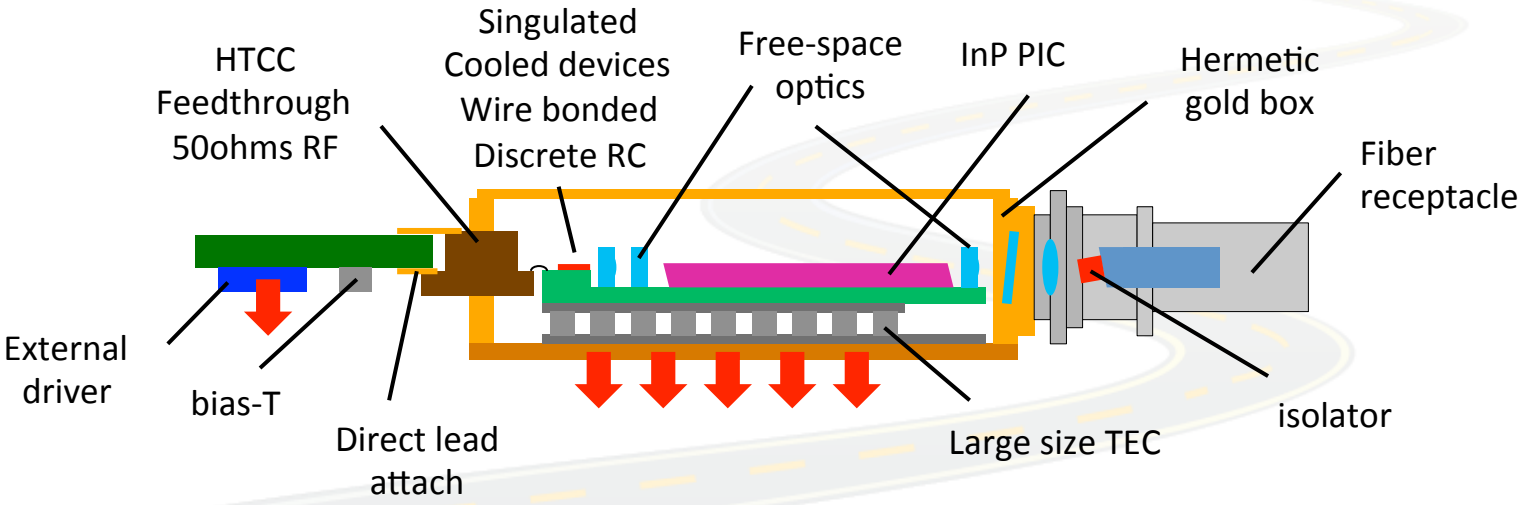


32Gb/s EVM ~10.5%

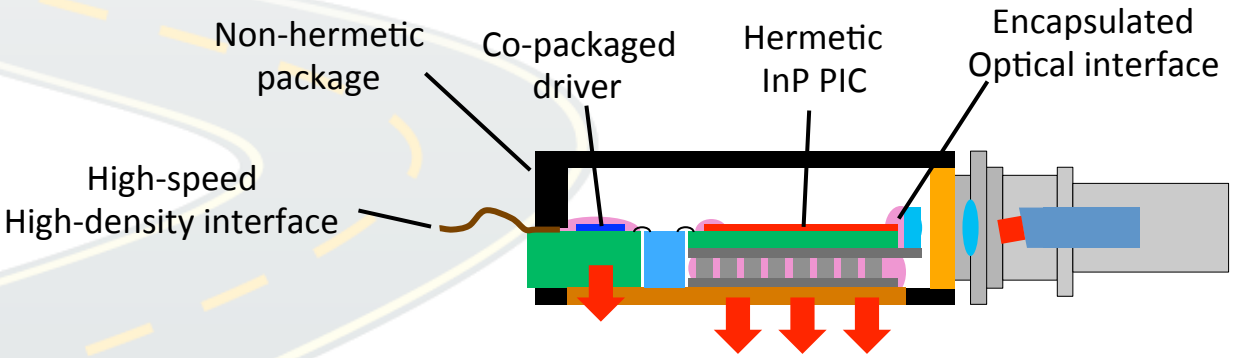
32 Gb/s EVM ~10.5%

Packaging Evolution

CURRENT STATE



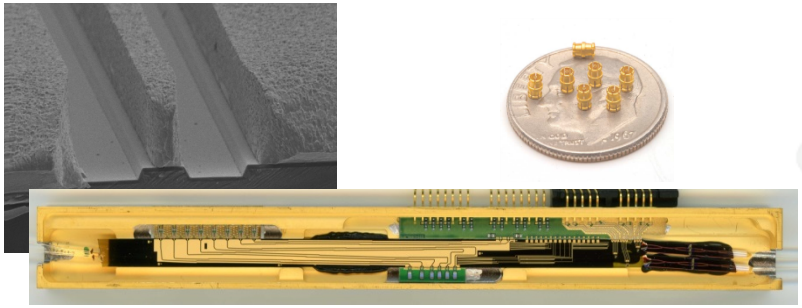
FUTURE STATE



Parallel Integration: Multicarrier

Lithium Niobate

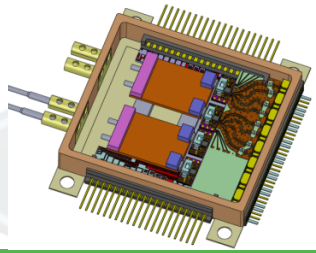
Dual carrier in a single package to reduce cost and better interface with dual-ASICs



- Dual carrier monolithic integration
- Size reduction, cost reduction wrt single package options

Receivers

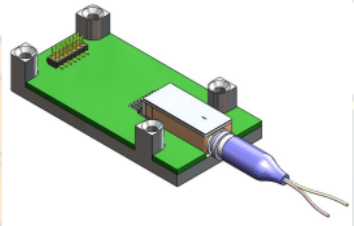
Shrink size, increase bandwidth, multiple carriers



- Co-packaging multiple receivers for size and cost savings
- Communication interfaces (SPI) pulled into package to reduce I/O

Integrated InP

Integrated multi-carrier approaches



- Dual/Quad tunable lasers with shared flex locker
- Size reduction, cost reduction
- Super channel applications

Summary

- Tunable laser products have been widely deployed in DWDM applications for > 10 years
- Hybrid integration widely used in optical components
- Increasing functional monolithic integration enables lower cost and greater scalability
- Packaging approach needs to be addressed for new, lower cost (shorter life) applications
- Parallel integration starting but not pervasive

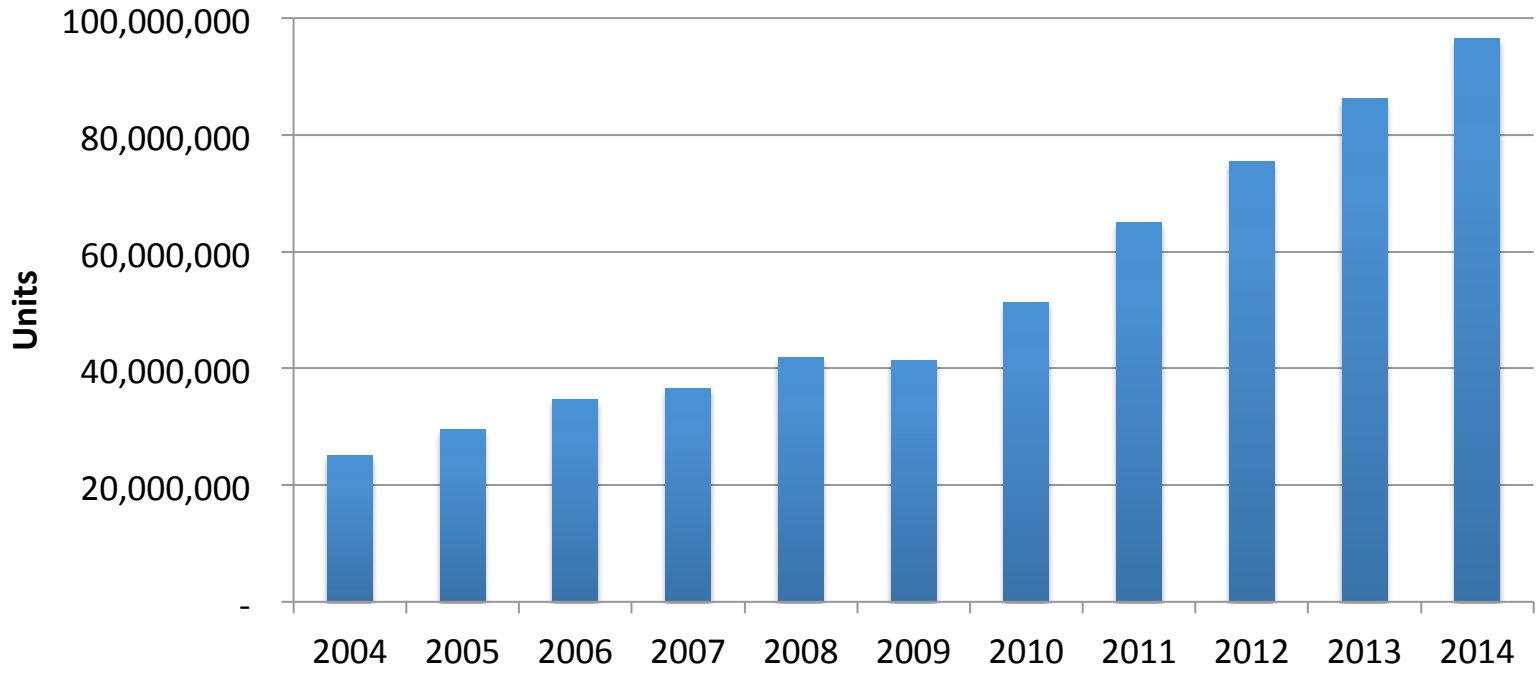
To tune or Not to tune? Market in Numbers.

LightCounting
Market Research

OFC 2015

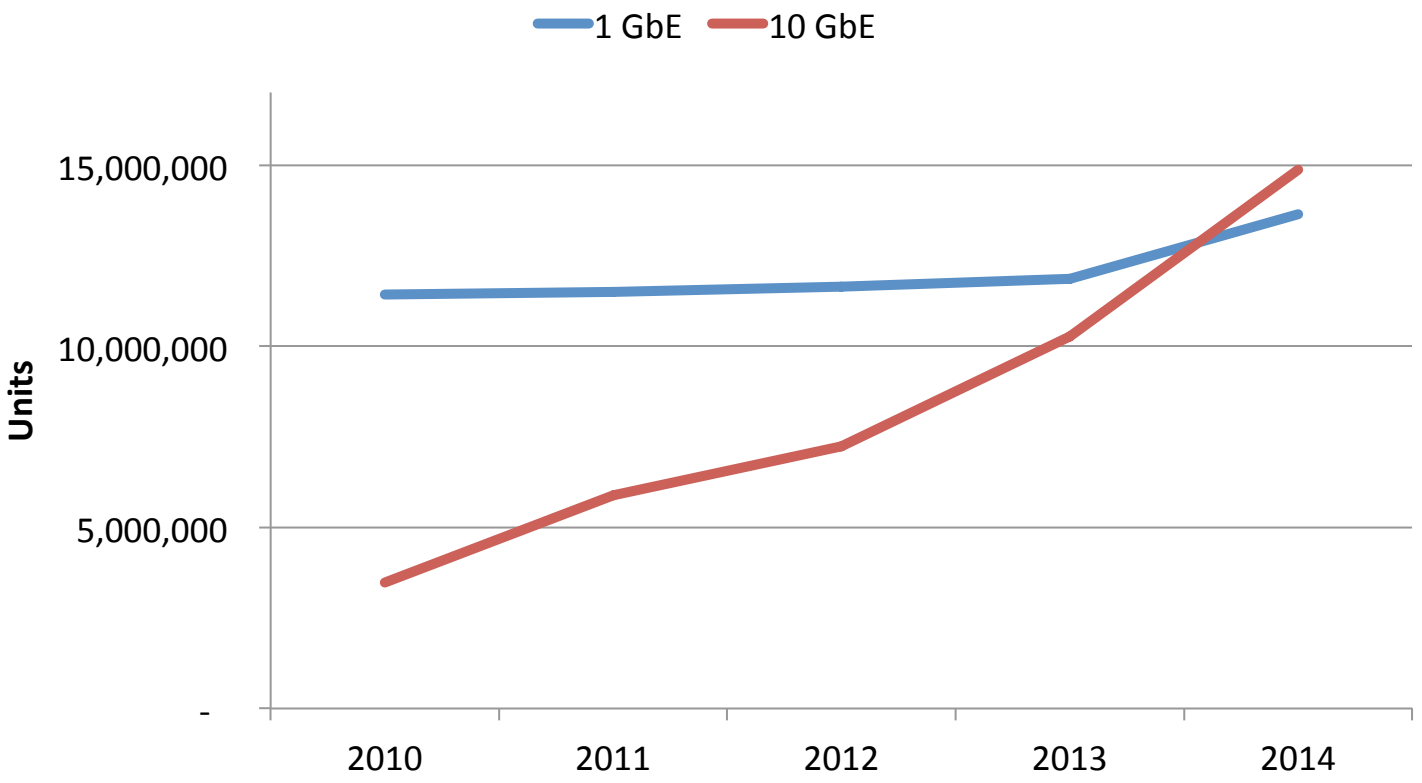
Vladimir Kozlov • March 24, 2015

Optical Transceiver Shipments



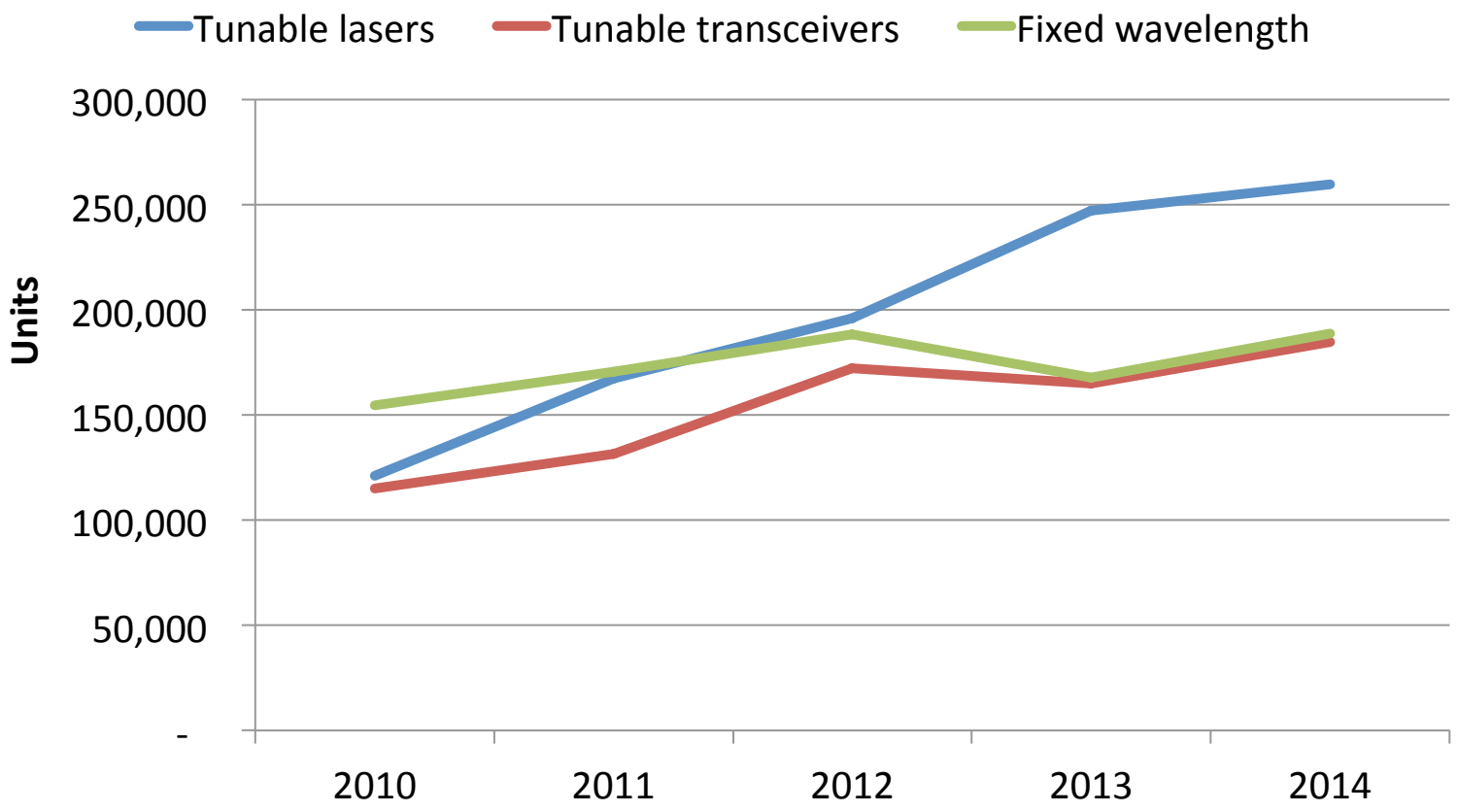
Sales of optical transceivers exceeded $4 billion in 2014

1GbE and 10GbE Optics



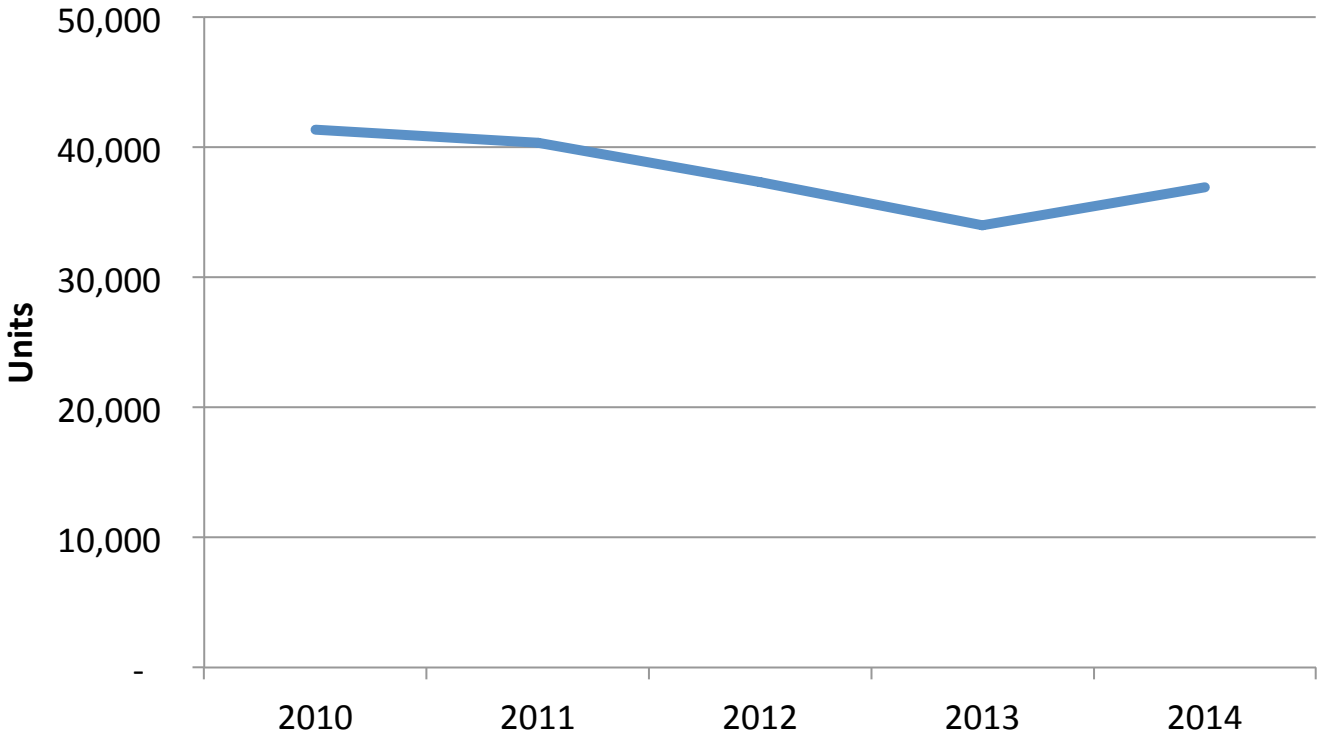
Sales of Ethernet Optical transceivers exceeded $1.5 billion in 2014

DWDM Lasers and Transceivers



Sales of tunable lasers and transceivers reached $350 million in 2015

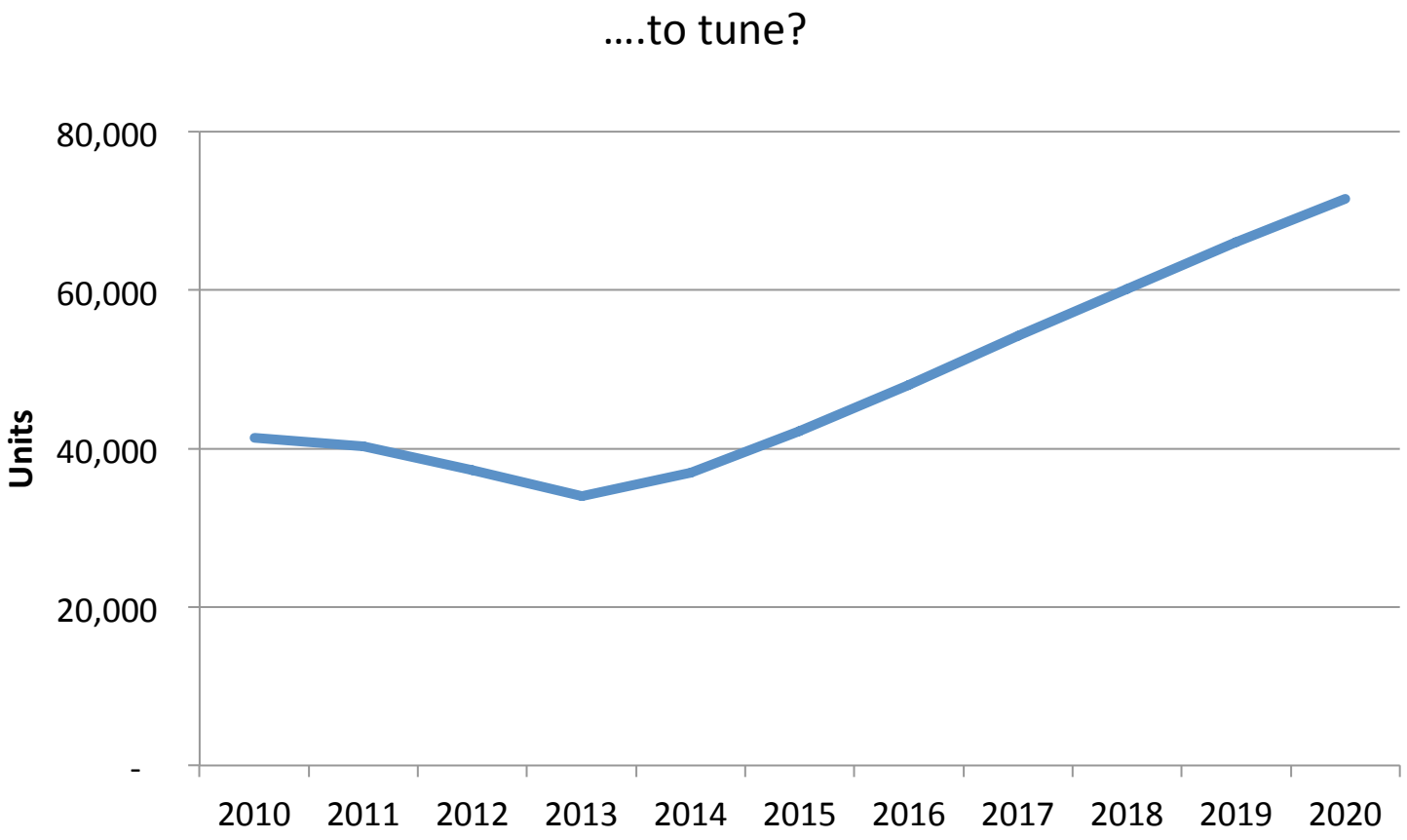
Wavelength Selective Switches (WSS) modules



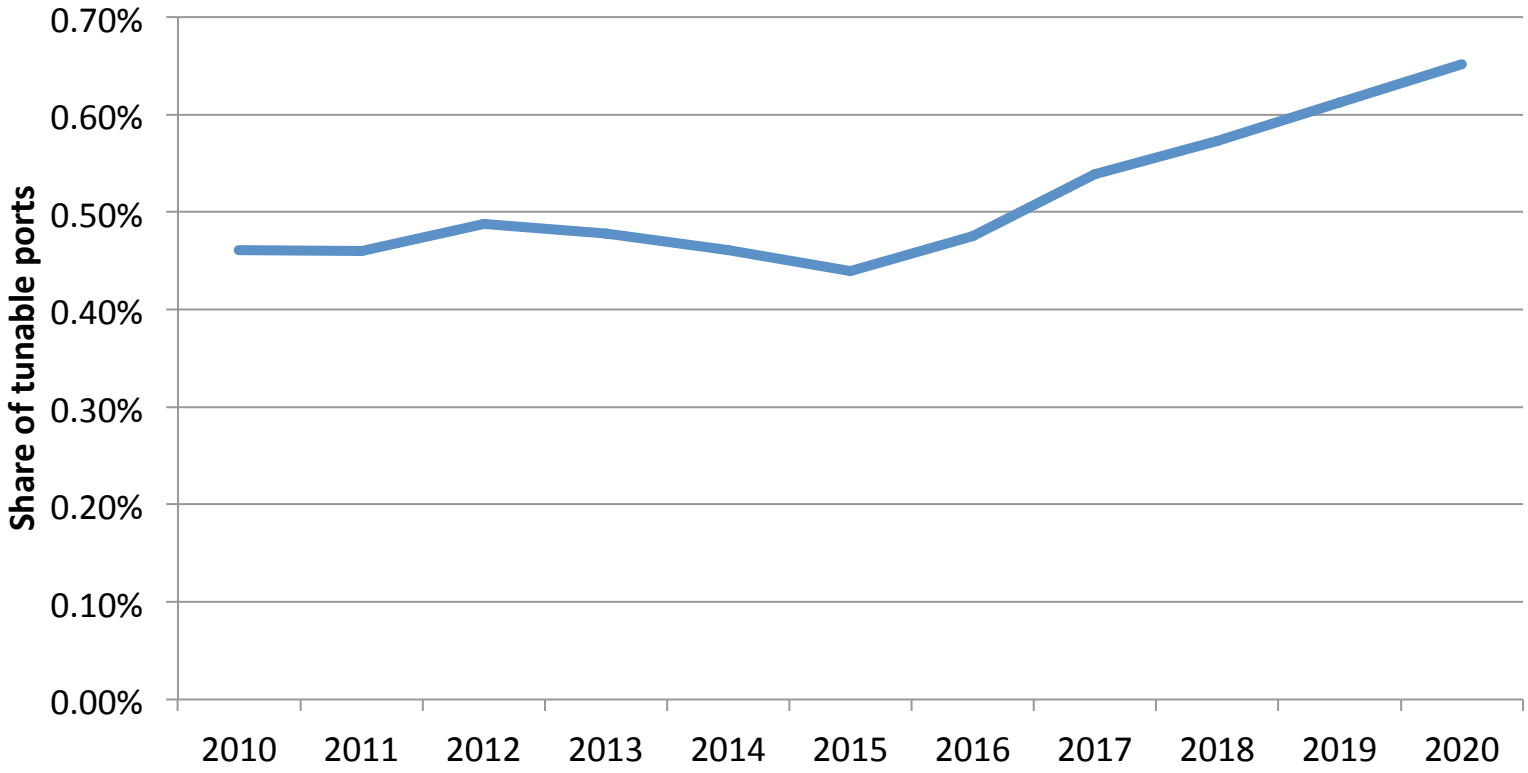
Sales of WSS declined from $280 million in 2010 to $200 million in 2014

To tune
or
Not to tune?

Forecast for WSS modules



Tunable ports as a fraction of the total optical transceiver shipments



More than 99% of the optical connectivity will remain fixed!

Disclaimer

The views we are expressing in this presentation are our own personal views and should not be considered the views or positions of the Ethernet Alliance

Thank You!

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