

40G/100G Mach-Zehnder Modulator Driver Technology

Loi Nguyen



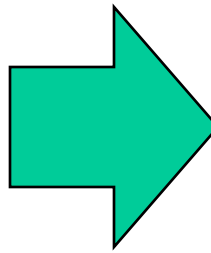
Inphi

Think fast.

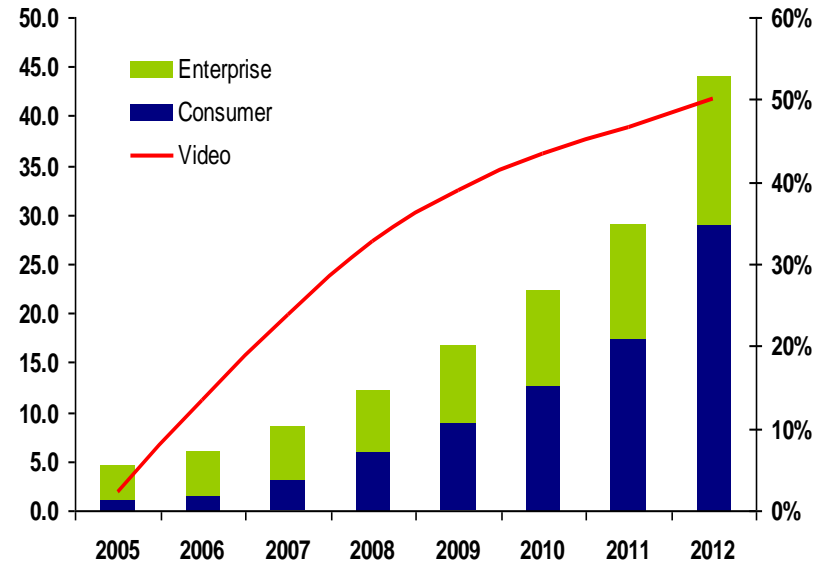
Outline

- Introduction
- 40G DQPSK technology
- Modulator driver technology
- Surface mount packaging technology
- Summary

Megatrend: Increasing Bandwidth Demand



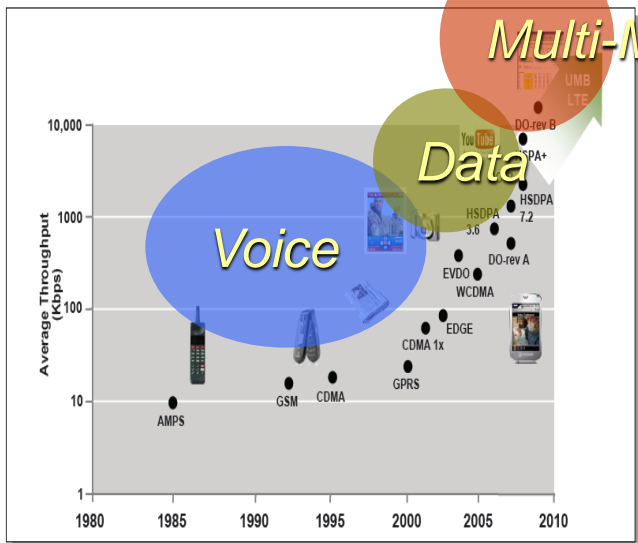
IP Traffic in Exabytes (1e18) per Month



Source; Cisco Systems 2007

Moving Beyond Voice

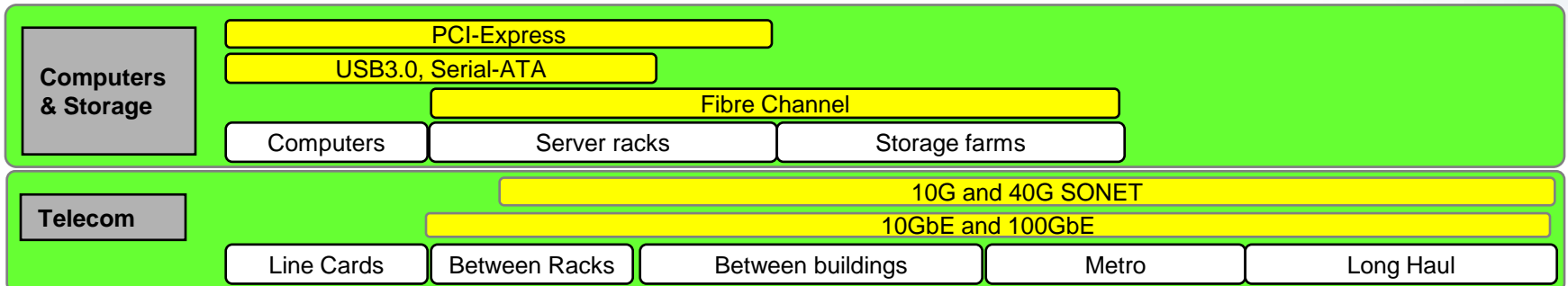
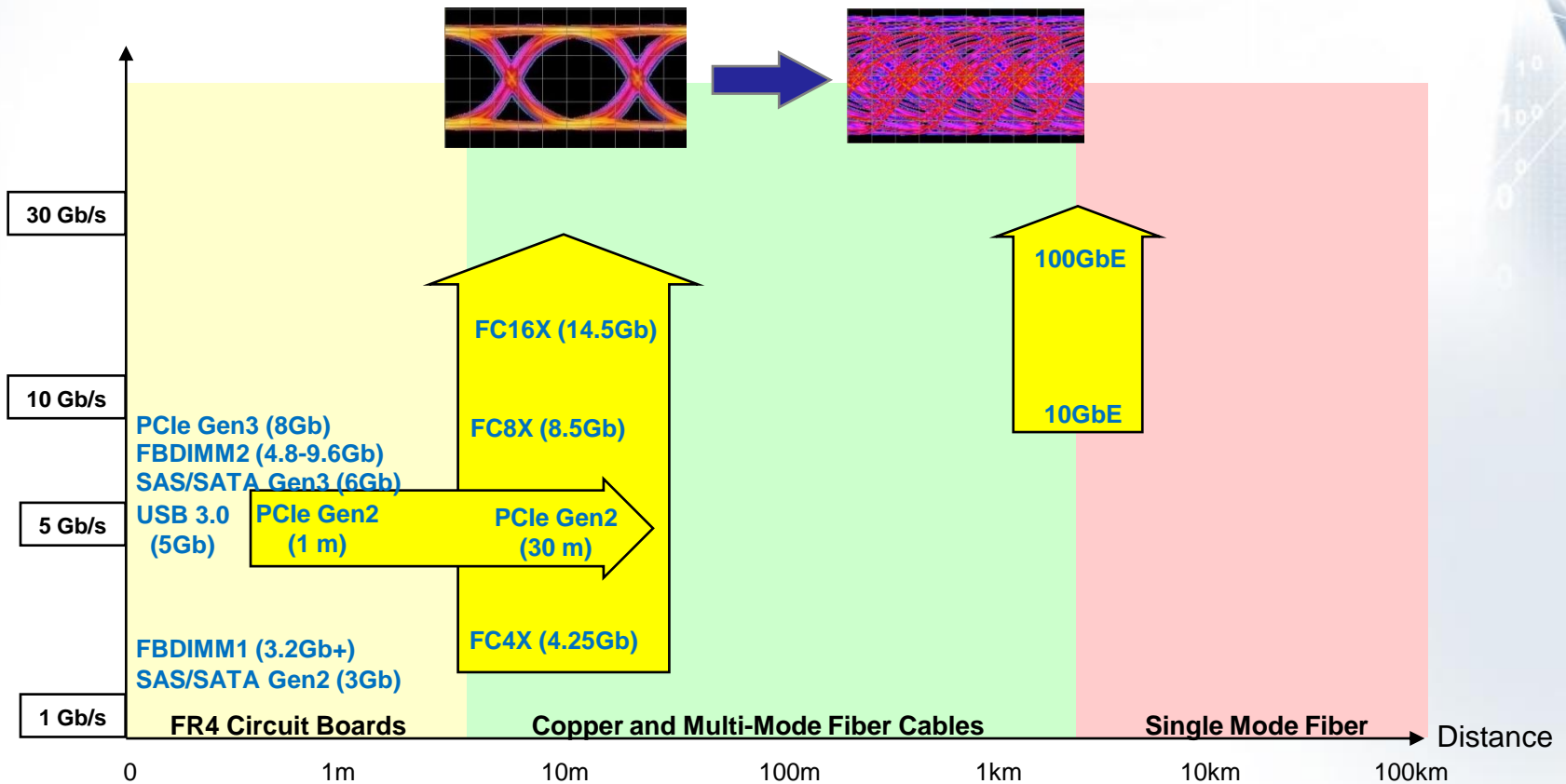
More Bandwidth and More Opportunity for Carrier Revenue Growth



(Source: Qualcomm Jefferies Conference Oct '07)

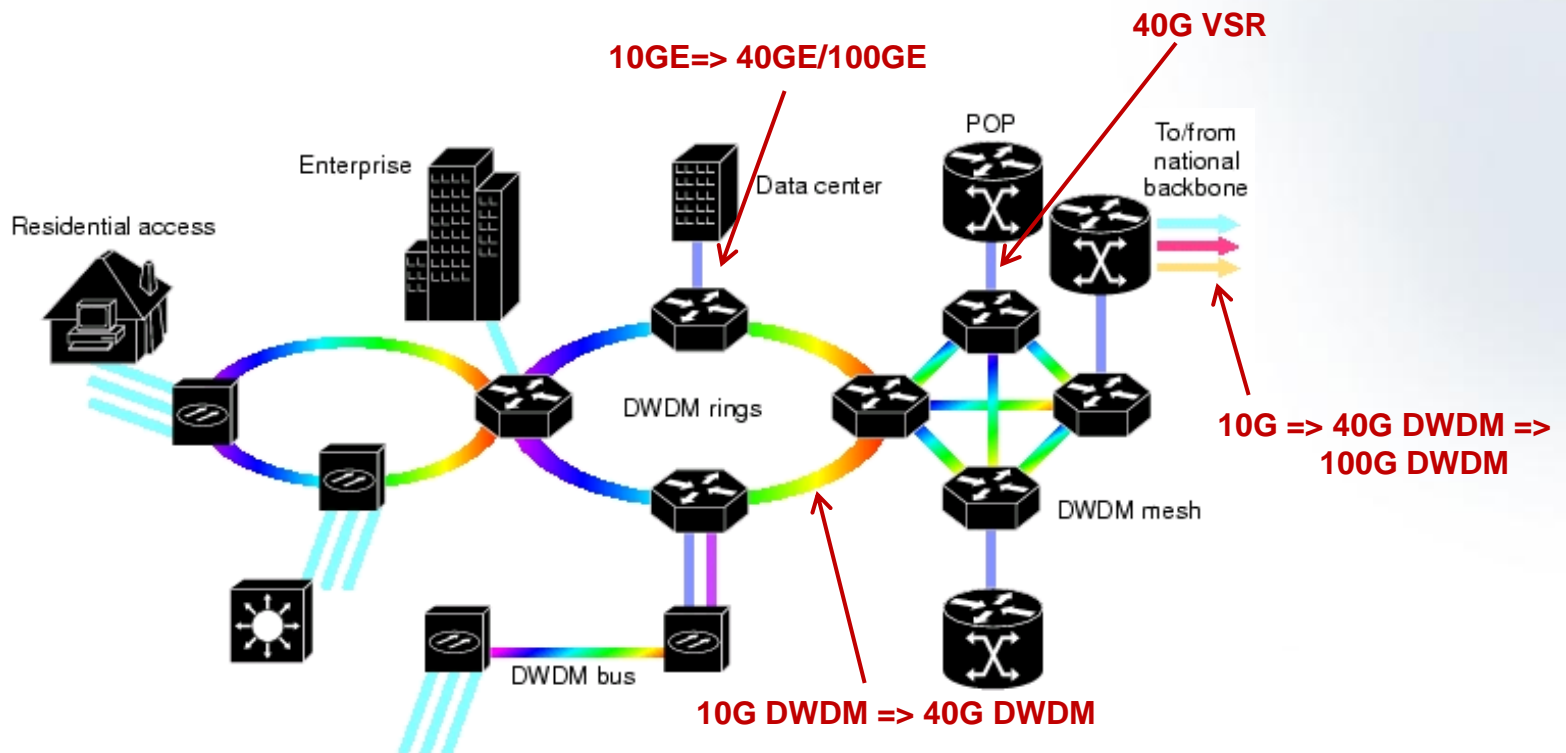
- More contents from more sources
- Consumers expect higher quality of experience
- Video will be 50% of IP traffic by 2012
- Explosion in bandwidth demand puts severe pressure on network infrastructures

Megatrend: Serial Data Faster and Farther

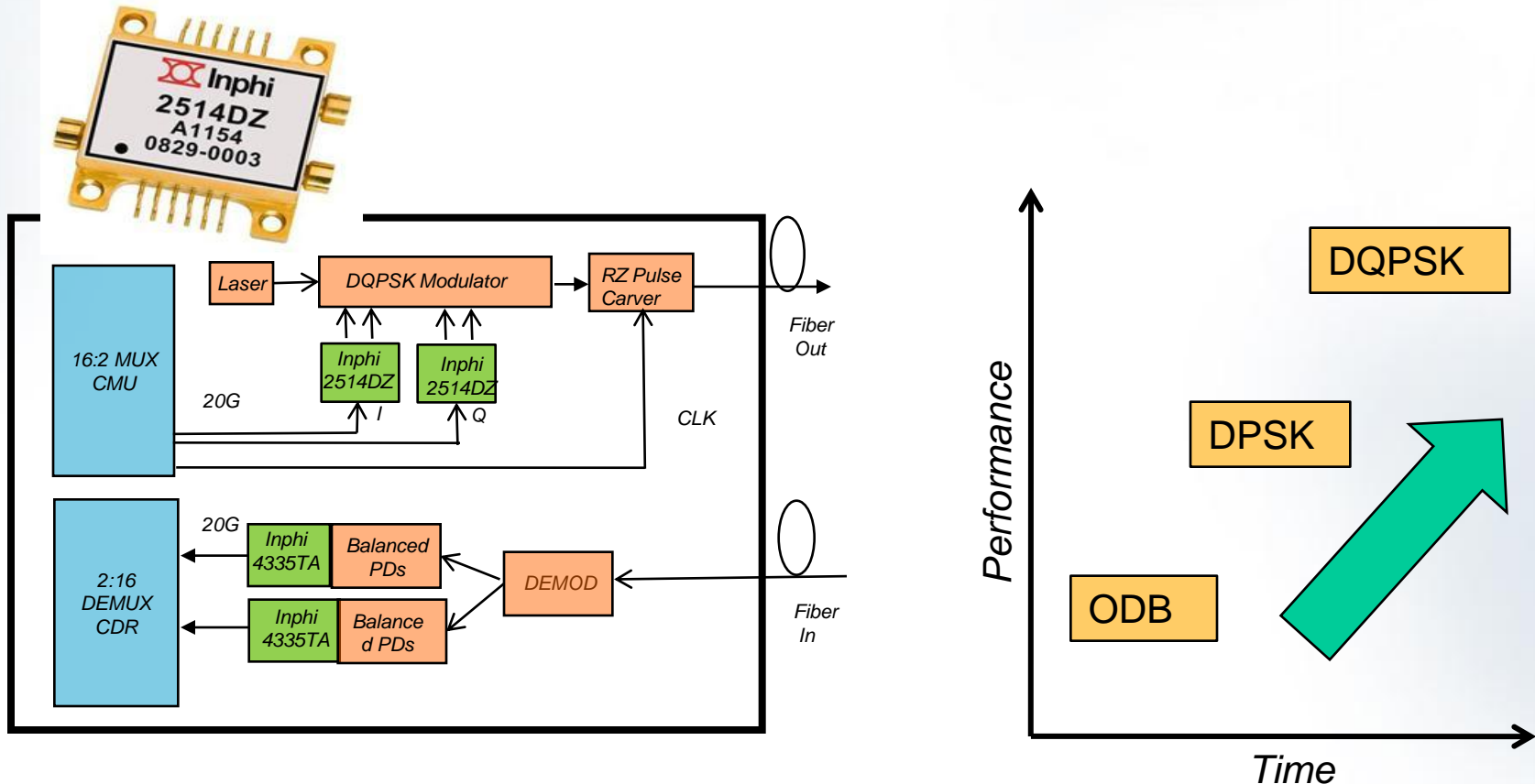


40G/100G Optical Networking

- 40G deployment began in 2006, 100G deployment is expected by 2011
- “Client side” uses 40G VSR to interface with routers
- “Line side” uses 40G DWDM to increase national backbone network capacity, typically with reach > 1,000 km
- 40G DWDM requires external Mach-Zehnder modulators and drivers

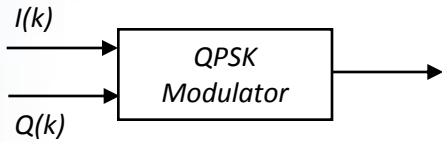


40G DWDM Modulation Formats

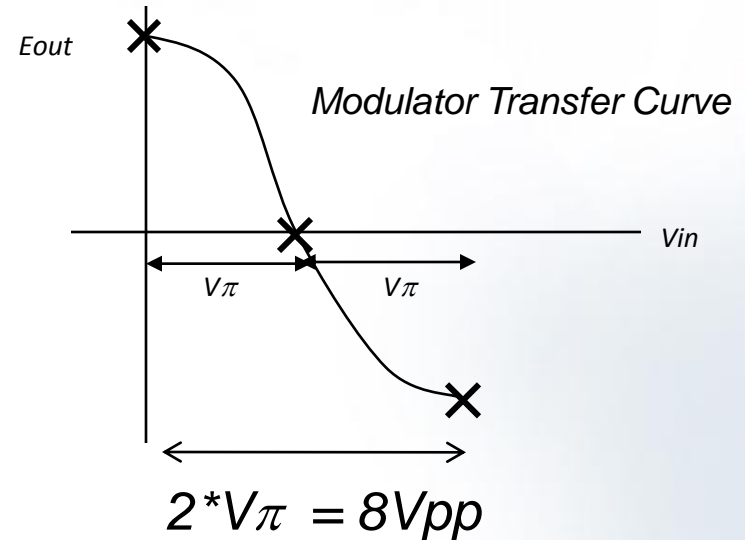
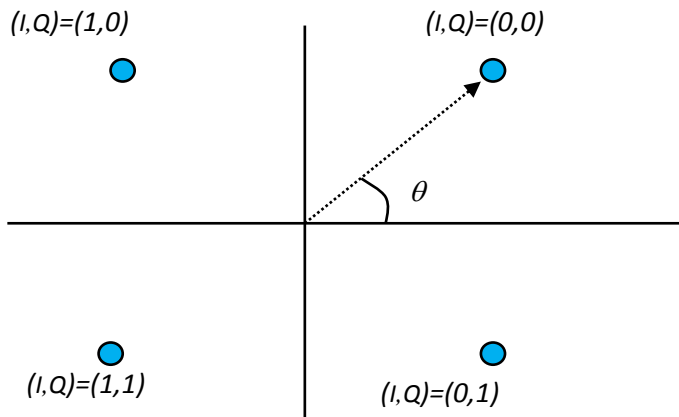


- 40G DQPSK is the latest and most advanced modulation format
- Most spectral efficient
- Most resilient to PMD and OADM filtering tolerance
- Ramping to production now!

40G QPSK Signal Mapping



$$\theta(k) = \begin{cases} \pi/4 & \text{if } (I(k), Q(k)) = (0,0) \\ 3\pi/4 & \text{if } (I(k), Q(k)) = (1,0) \\ 5\pi/4 & \text{if } (I(k), Q(k)) = (1,1) \\ 7\pi/4 & \text{if } (I(k), Q(k)) = (0,1) \end{cases}$$

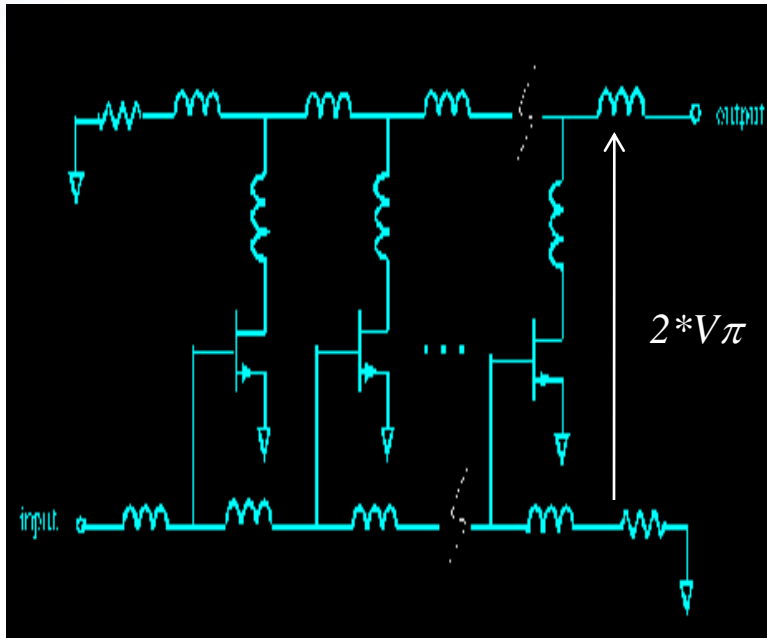


40G DQPSK modulators require drivers with 8Vpp output swing

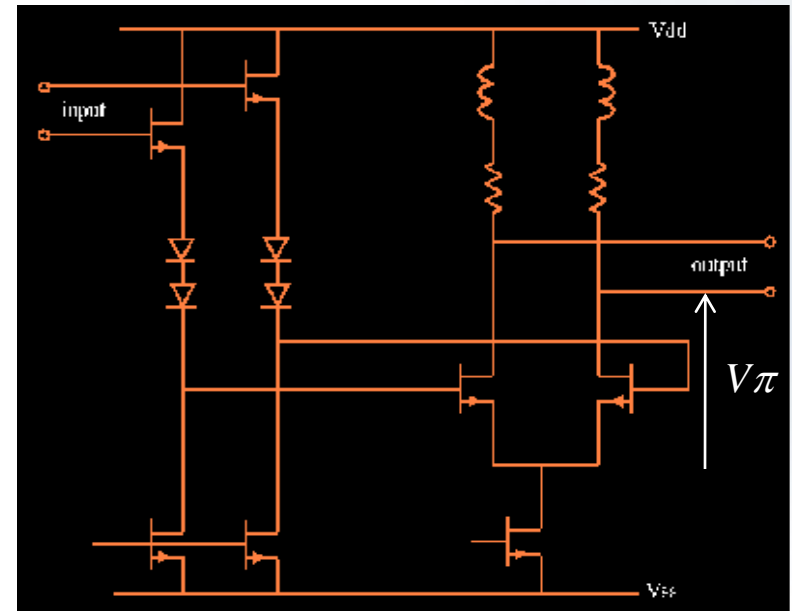
Key Considerations for Modulator Drivers

Two major architectures

- “Microwave” distributed / traveling wave amplifiers (TWAs)
- Switching drivers based on differential pair circuits



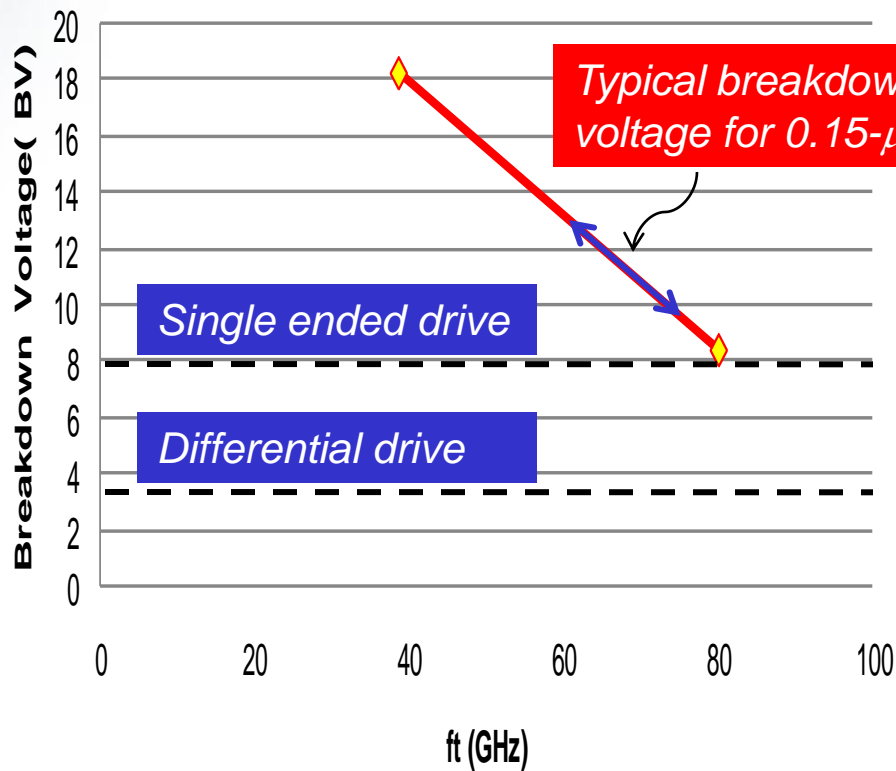
Commonly used for single ended design, output transistors need to deliver $2 * V_{\pi}$ output swing



Commonly used for differential design, output transistors need to deliver V_{π} output swing only

Reliability Consideration

GaAs Breakdown Voltage vs. Cutoff Frequency



- Fundamental tradeoffs between breakdown voltage and speed
- High speed Si and SiGe cannot be used due to low breakdown voltages ($< 4V$)
- GaAs PHEMT with 0.15-μm gate is the preferred technology with breakdown voltage from 10 to 14V
- Single-ended drive operates close to breakdown voltage
- Differential drive solves this problem by operating in push-pull configuration, resulting in significantly more margin

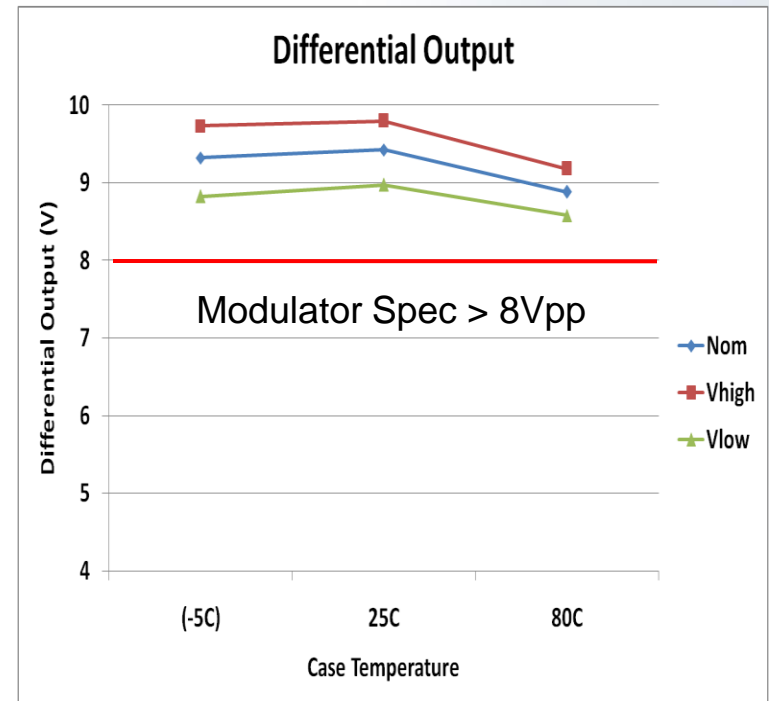
Differential vs. Single Ended

	Single Ended	Differential	Comments
Modulator	In development	In mass production with multiple sources, requires 8Vpp min over all conditions	Differential drive dominates
Modulator Driver Output Swing	7.5 Vpp typical, difficult to achieve >8Vpp over all conditions	Operating in push-pull, 9.5Vpp typical, > 8Vpp over all conditions	Differential drive dominates
GPPO Package	Fewer GPPO connectors required	Need 2X the number of GPPO connectors	Single ended has advantage
SMT Package	Difficult to run high speed traces on board	Best for high speed traces on board at >20 Gbps	30Gbps operation on Roger boards is proven by Inphi

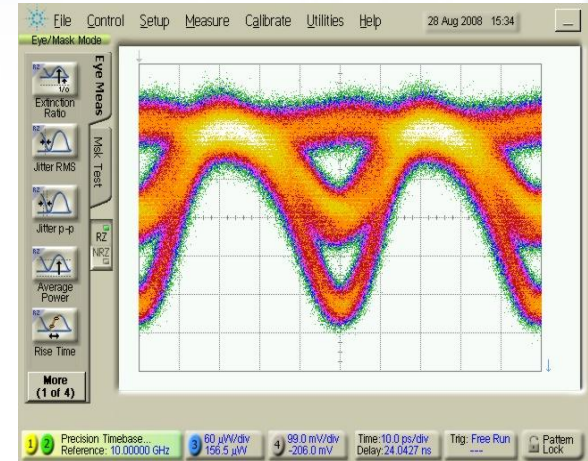
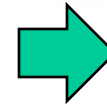
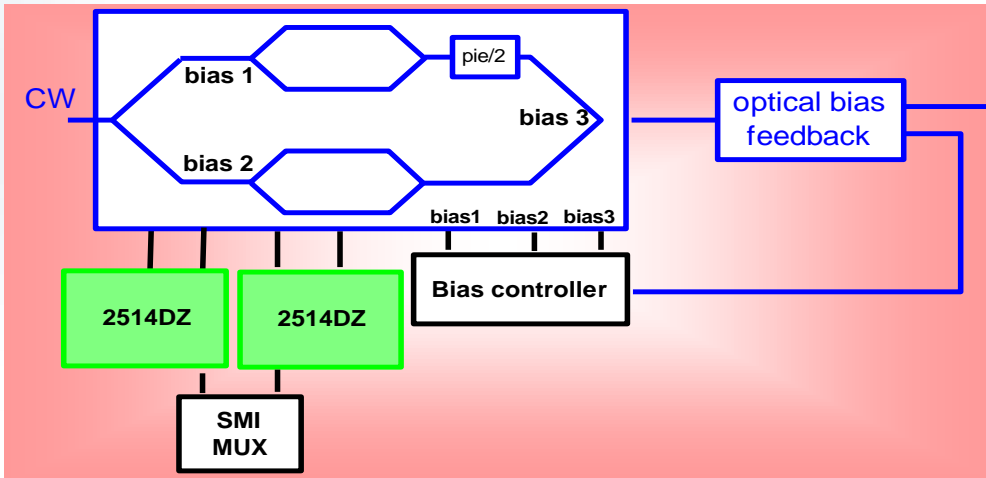
2514DZ: Differential Output Swing



- 40G DQPSK modulators require 8Vpp over temp and voltage
- To meet this requirement, drivers need to deliver >9Vpp typical
- Difficult to achieve in single-ended design without compromising long term reliability
- Differential drivers solve this problem by operating in push-pull configuration



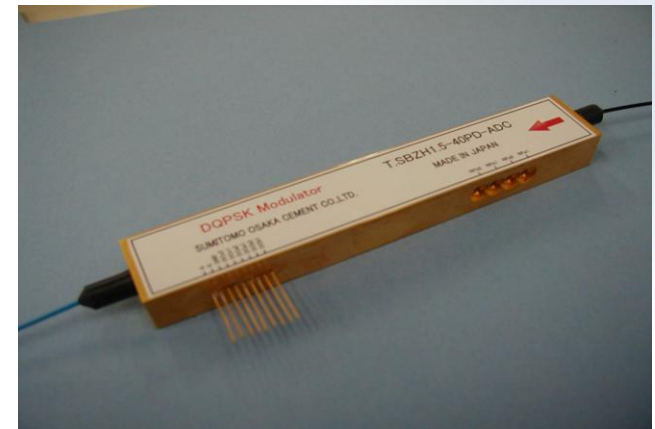
40G DQPSK Optical Transmitter



40G DQPSK optical eye

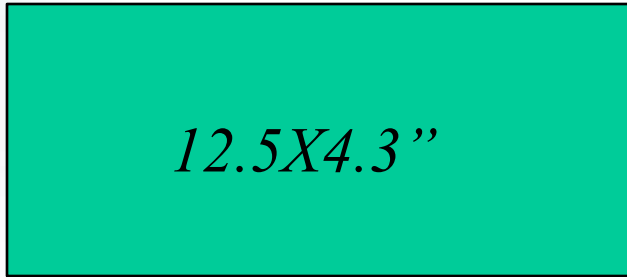


40G DQPSK MUX, Courtesy of SMI



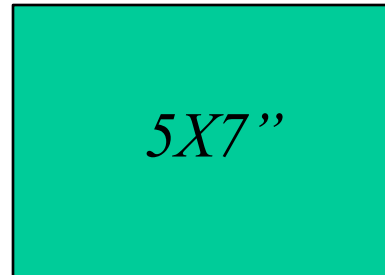
40G DQPSK Modulator, Courtesy of SOCC

40G DQPSK Transponder Evolution



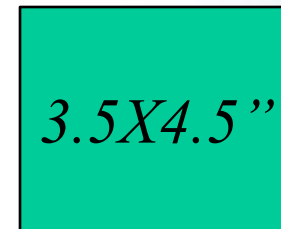
2007

*Metal package with GPPO
discrete components*



Now

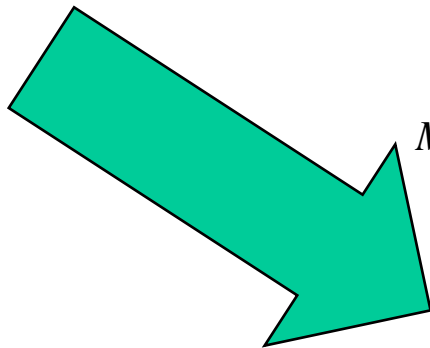
*Metal package with GPPO
More integrated components*



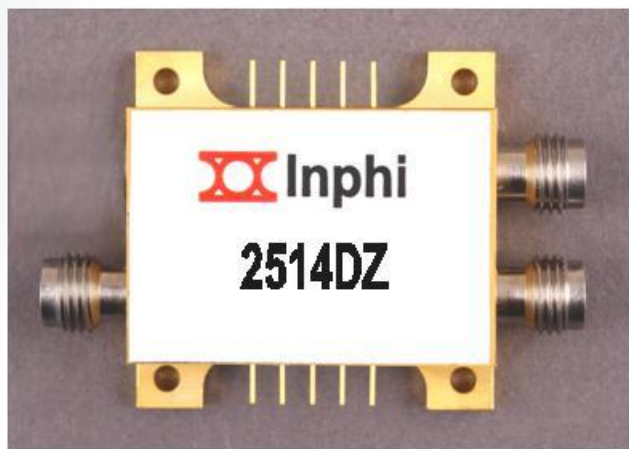
Near Future

*Surface Mount Technology
Highly integrated components*

- Smaller Size
- Lower Power
- Lower Cost



40G/100G Differential Modulator Driver Roadmap

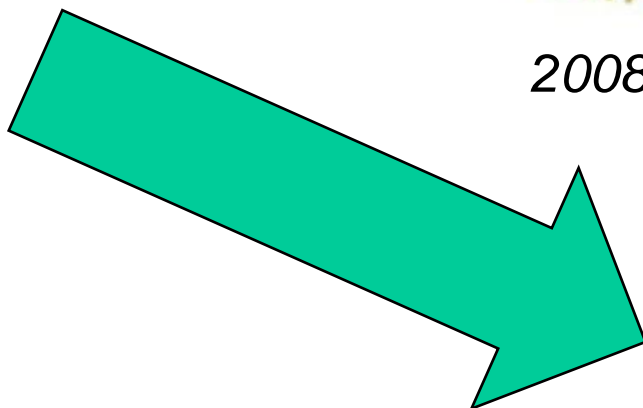


2006



2008

- Largest Output Swing
- High Reliability
- Smaller Size
- Lower Cost



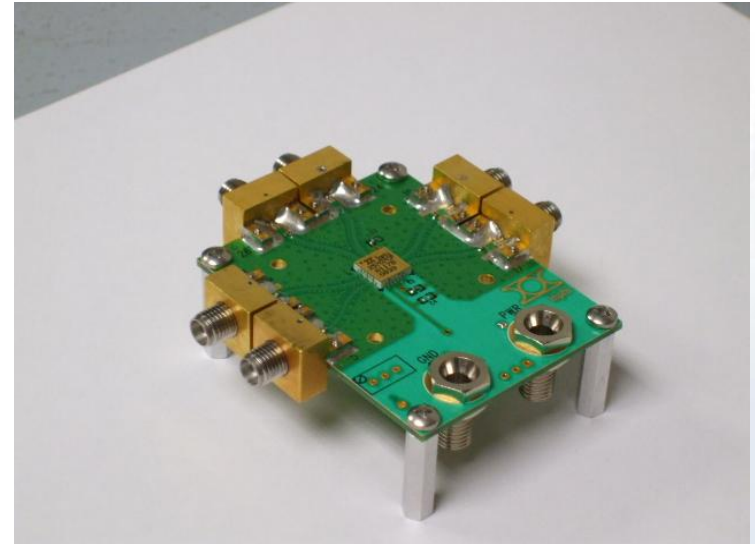
ES Sampling Now

Benefits of Inphi Modulator Driver Solutions

- Largest output swing
 - Works seamlessly with leading modulators and MUX
- High performance
 - Field proven for both 40G DQPSK and 100G Dual Polarization QPSK applications
- High reliability
 - Differential solution results in $\frac{1}{2}$ voltage stress on individual transistors relative to competing single-ended solutions
- Small size
 - SMT package, 7X7mm², 90% reduction in footprint relative to current GPPO package

Inphi 25G SMT Packaging Technology

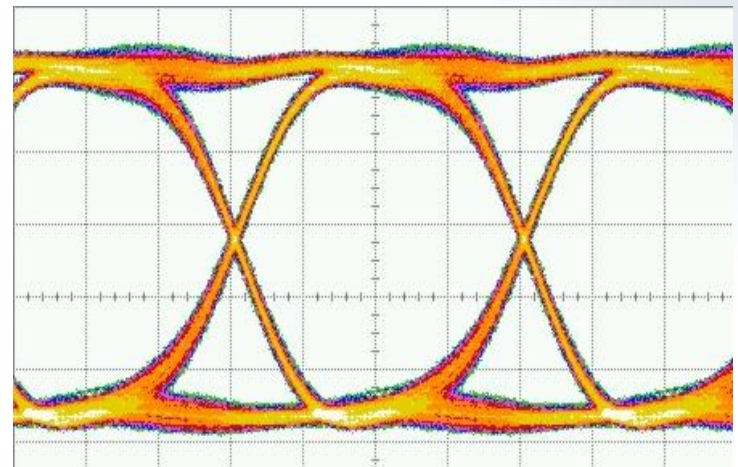
- Field proven, in mass production since 2002
- Fast rise/fall times, 12 ps typical
- Low jitter, 2 ps typical
- Well suited for 40G DQPSK and 100G DP-QPSK applications



25G Eye Diagram on PC Board



25G D Flip Flop in 7X7 mm² ceramic LGA package



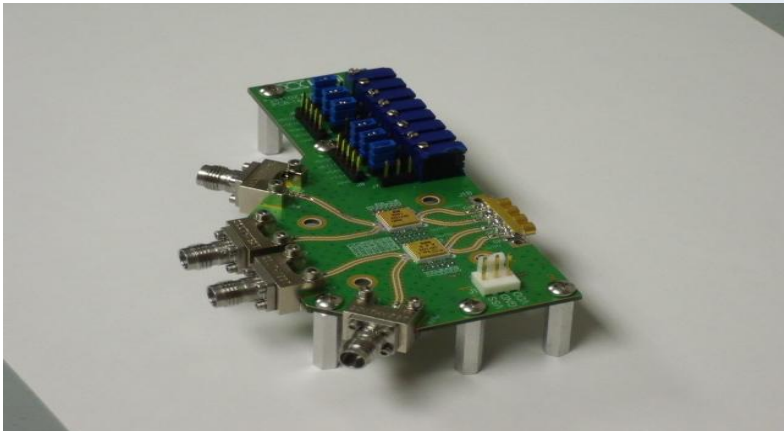
2811DZ: 40G/100G Modulator Driver in SMT Package

- Applications
 - 40G DQPSK
 - 100G DP-QPSK
- Benefits
 - Small size, 90% reduction in footprint
 - Largest output swing, capable of driving all leading MZ modulators
 - Unique, patented true differential architecture => no skews between I & Q
 - Lower cost than current solutions in metal package with GPPO connectors



World First Single Chip 40G/100G MZ driver in 7X7 mm² SMT package

	2514DZ	2811DZ	% Reduction
Package	GPPO	SMT	
Length (mm)	20.3	7.0	66%
Width (mm)	22.3	7.0	69%
Footprint Area (mm ²)	452.7	49.0	89%



Evaluation Board with Dual 2811DZs

Summary

- 40G market is healthy, driven by strong consumer bandwidth demand and IP traffic
- Inphi broadband analog solutions enable 40G/100G broadband connectivity
- Inphi is driving the ecosystem to transition from large and expensive metal package with GPPO to compact, lower cost SMT solutions