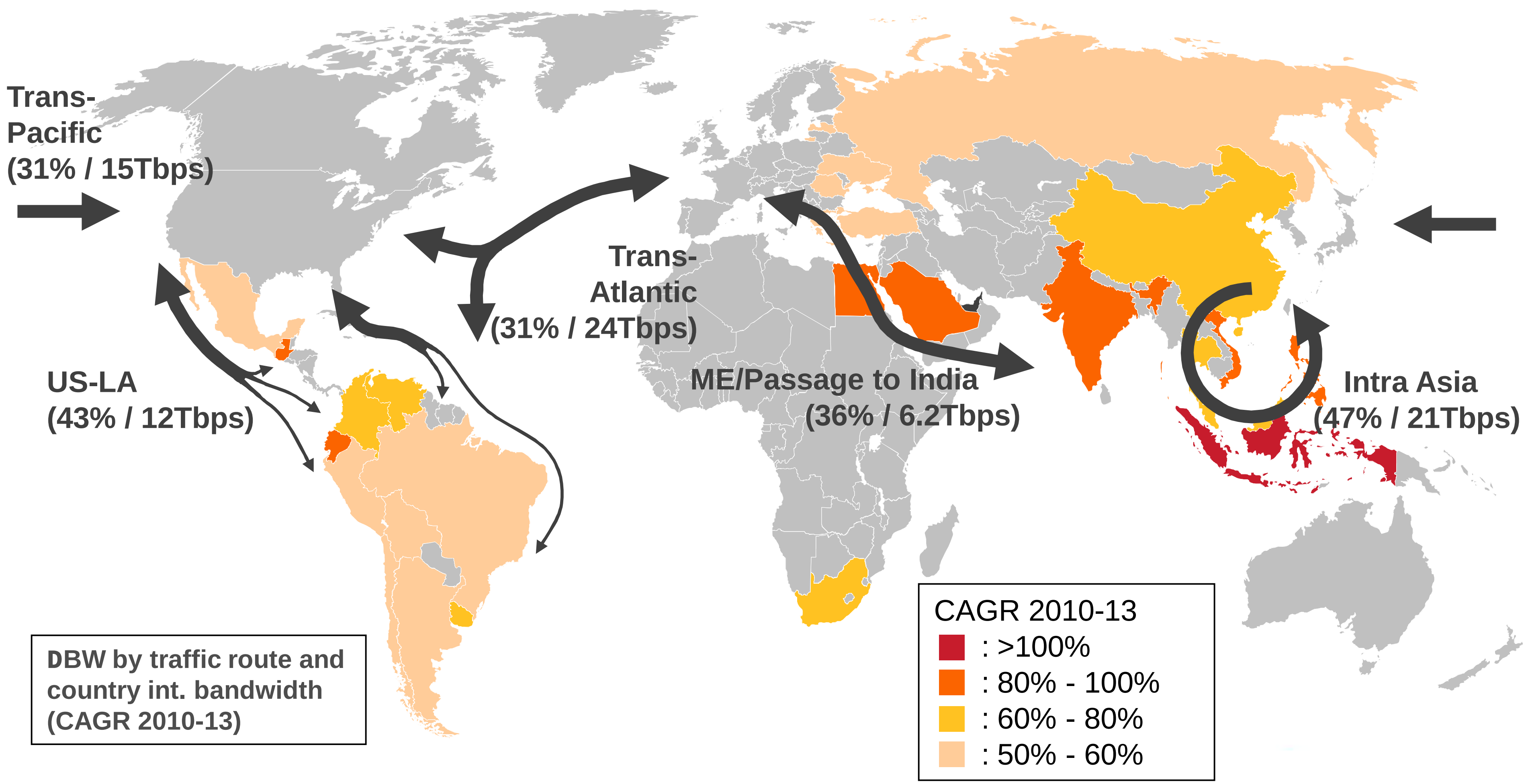
Submarine adopts 40G and 100G

Per Hansen
Sr. Dir. Submarine Solutions

NANOG50, Oct. 5, 2010

Capacity Demand is Voracious

High bandwidth-growth geographic areas



Ref.: Global Bandwidth Forecast Service, Telegeography, 2010

Challenges Scaling TDM to Higher Data Rates

1 **Increased design, component complexity & cost**

- Components need to operate at faster speeds -> Increased system cost
- Limited supply of components -> Yield and Reliability issues

2 **Inferior performance to 10G**

- 75% reach lost at 40G, 90% lost at 100G
- Addition of RAMAN amplifiers and/or REGENs required (CAPEX)

3 **Cannot operate over existing optimized network**

- Replace some ROADMs with Regens (CAPEX)
- Increase cost and time to upgrade

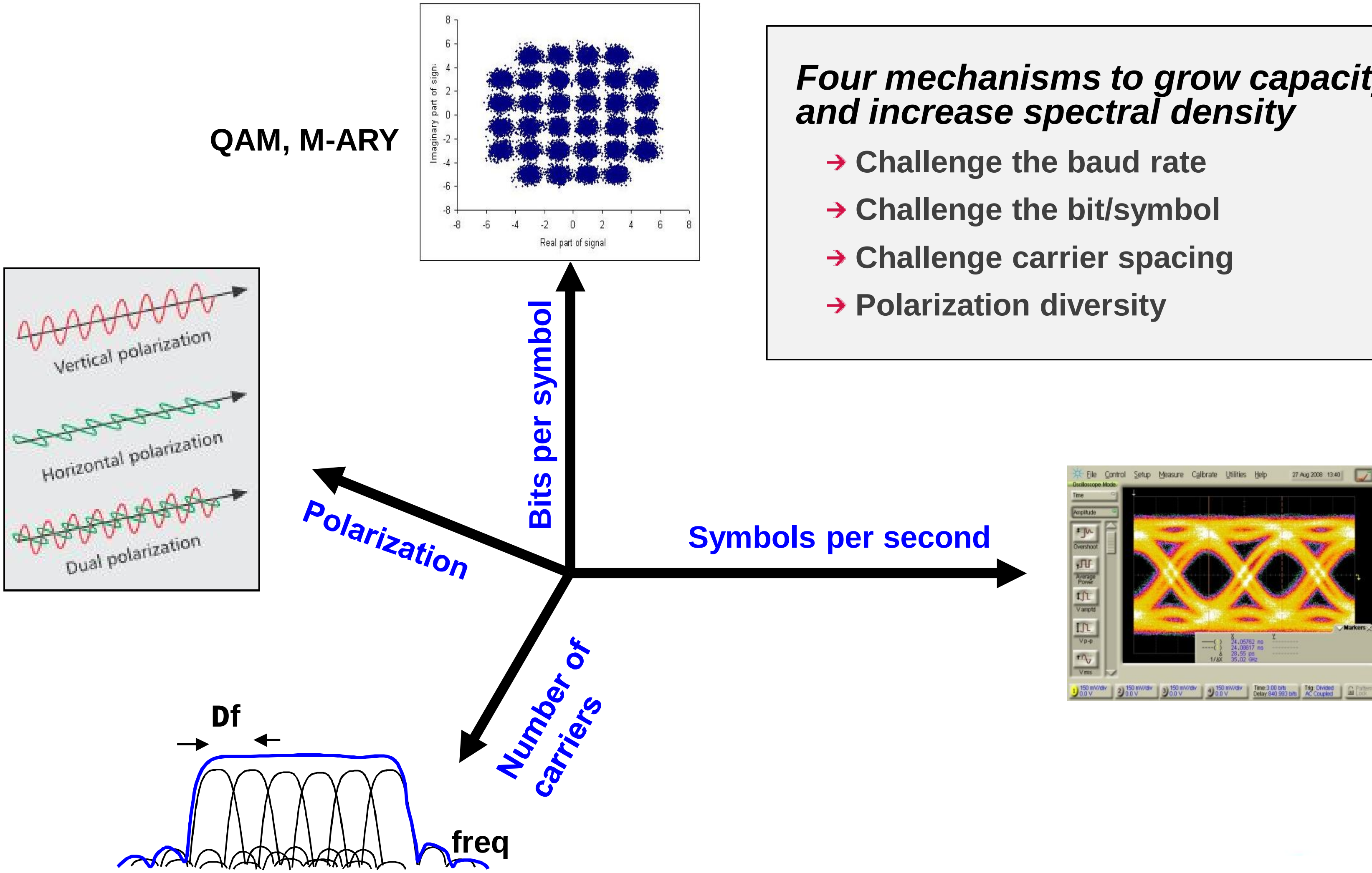
4 **Increased sensitivity to chromatic dispersion**

- 16 x worse at 40G, 100 x worse at 100G
- Addition of compensator equipment, amplifiers (CAPEX) and more complex engineering (OPEX)

5 **Increased sensitivity to Polarization Mode Dispersion**

- 4 x worse at 40G, 10 x worse at 100G
- Rip and replace bad fiber, addition of compensator equipment (CAPEX), and complex eng. (OPEX)

Spectral Optimization



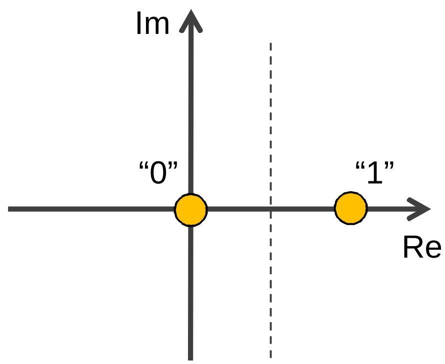
Four mechanisms to grow capacity and increase spectral density

- → **Challenge the baud rate**
- → **Challenge the bit/symbol**
- → **Challenge carrier spacing**
- → **Polarization diversity**

Encoding Schemes

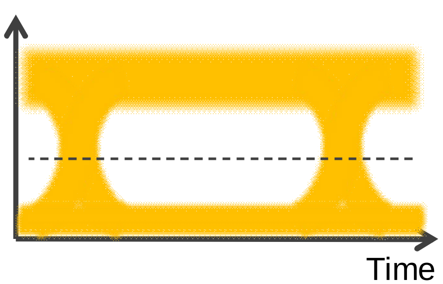
OOK

Electrical Field



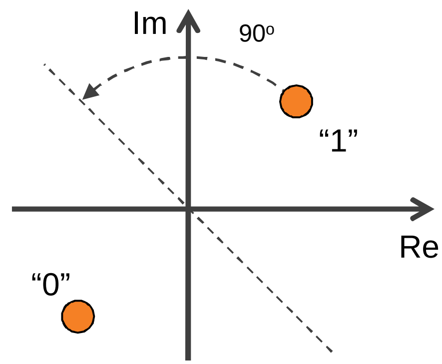
1 bit/symbol

Intensity



BPSK

Electrical Field

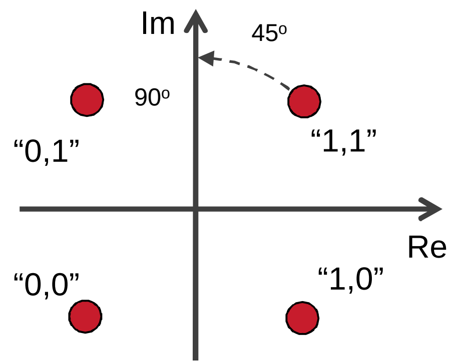


1 bit/symbol

Intensity

QPSK

Electrical Field



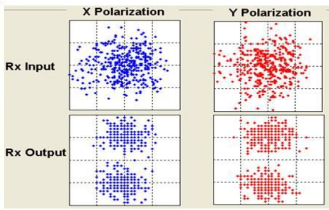
2 bits/symbol

Intensity

Enhancing Spectral Density
while retaining propagation characteristics

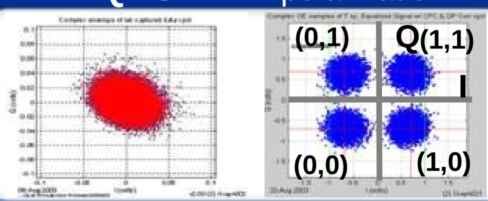
Modulation Format

BPSK

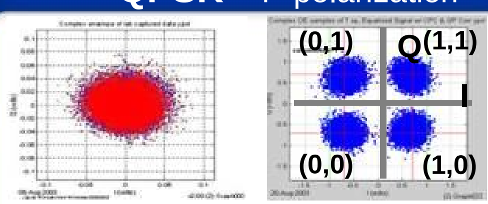


- Rx Data before DSP
- Rx Data after DSP

QPSK X - polarization



QPSK Y- polarization



Rx Data Before DSP | Rx Data After DSP

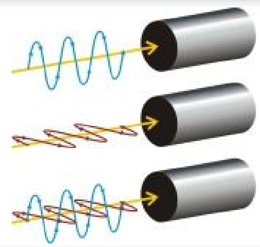
Polarization Mux.

Dual Polarization

Vertical Polarization

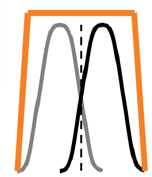
Horizontal Polarization

Dual Polarization



Sub-Carrier Mux.

CoFDM



- Two subcarriers @ ~20 GHz spacing
- 50 GHz channel spacing

Key requirements:

→ Grid compatibility

→ Propagation characteristics like 10G

→ Cost efficient hardware

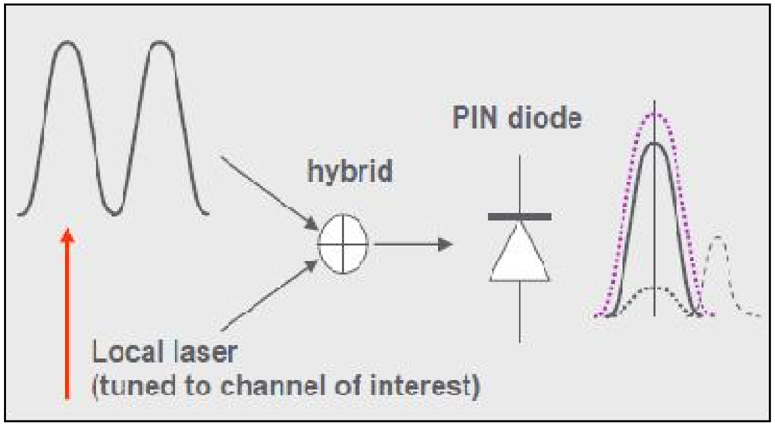
→ Operational simplicity

Benefits of Coherent Detection

Linear frequency translation *from optical to baseband*

Correction of impairments

- Allows DSP to process received signal, correcting:
  - Electrical transfer functions and path delays
  - Optical filtering
  - Chromatic dispersion
  - Polarization state
  - Polarization mode dispersion (PMD)
  - Polarization dependent loss (PDL)
  - Transients



Channel monitoring

- Access to amplitude, phase & polarization information

Spectral selectivity

- Co-FDM; colorless optical network egress

Optical gain

- Receiver sensitivity

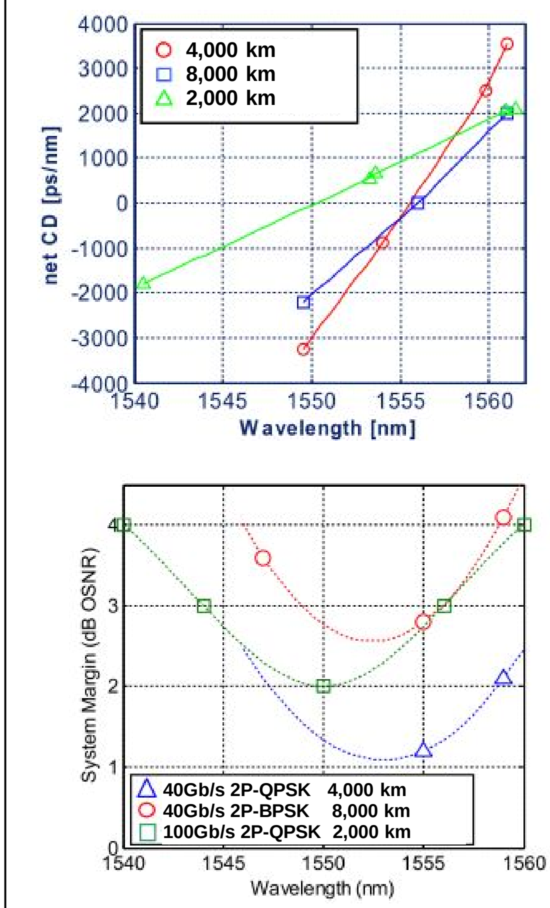
Transmission Properties
Transmitter and wet plant

Low optical launch power

- Accommodates high number of channels
- Minimal deleterious effects on other channels (new and old)
- Allows addition via monitor ports

Dispersion maps

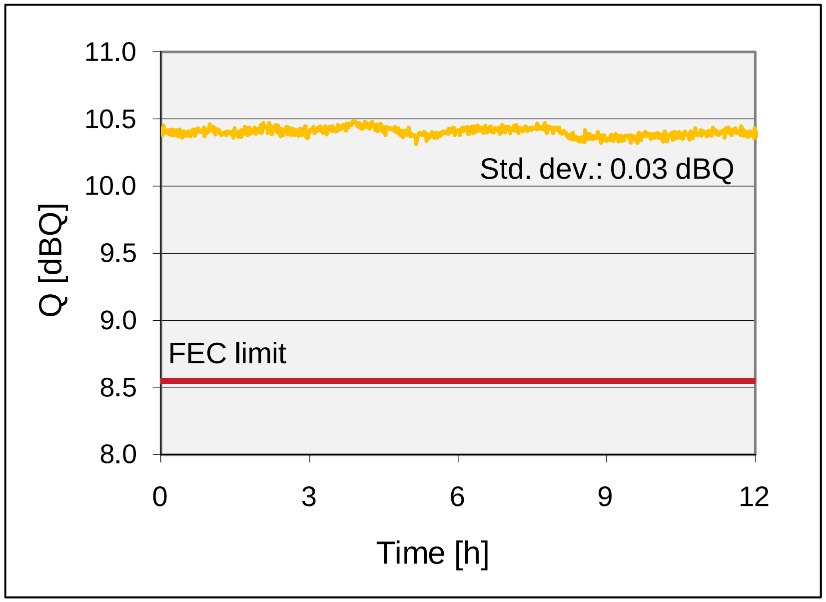
- Tolerates poor maps relatively well
- Typical maps with zero-dispersion near center of band has most challenged channel where noise performance in usually very good providing better usage of total spectrum
- Optimal map has high dispersion across band letting the receiver compensate for a high amount of dispersion at end



Transmission properties
Receiver

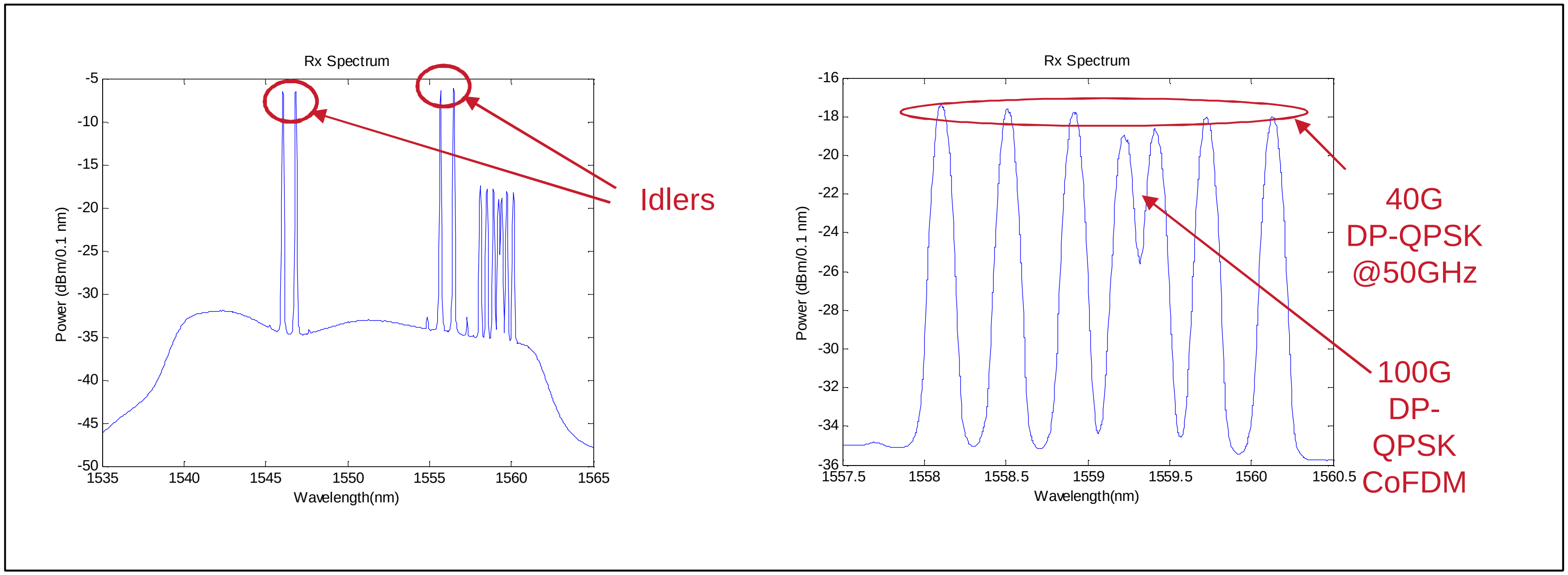
Adaptive receiver

- Lower performance variation → reduced margin requirements (tracking polarization, residual dispersion, and received power)
- Continuous monitoring and reporting of optical layer metrics (e.g. actual chromatic dispersion and PMD)
- Easy card installation and operational simplicity



100G CoFDM DP-QPSK Submarine Trial

Un-announced trial partner/cable (Gen 1): 2,100 km



Maximum channel count: 48

Full-fill capacity with 100G: 4.8 Tb/s

Deployment and Trial Milestones

2008

N x 40G WDM upgrade on repeatered submarine cable
- 50 GHz spacing augmenting existing 10G wavelengths
- Commercial operation

2009

100G WDM upgrade trial on repeatered submarine cable
- 50 GHz spacing augmenting existing 40G wavelengths
- Link distance: ~2,000 km

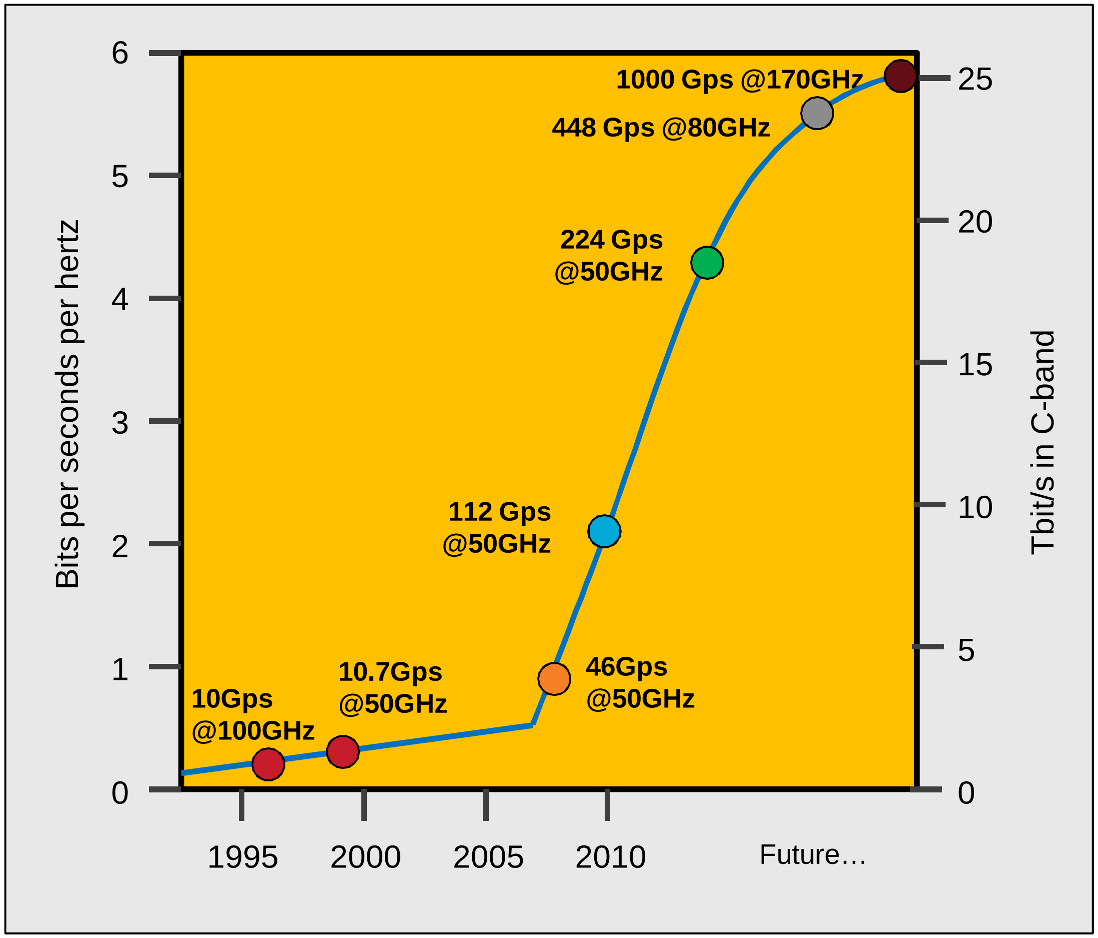
N x 40G WDM deployment unrepeatered submarine cable
- Virgin Media (UK – Ireland: 238 km/58 dB)
- Commercial operation

100G deployment on unregenerated terrestrial cable
- Verizon network between Frankfurt and Paris (900 km)
- 50 GHz channel spacing with existing 10Gs on link with ROADMs
- Commercial operation

2010

N x 40G WDM upgrade on repeatered submarine cable
- 50 GHz spacing augmenting existing 10G wavelengths
- Commercial operation
- Certified N x 100G as future upgrade w/o reengineering on ~2,300 km

A Look to the Future – Maximizing Spectral Utility



Source: "100G and Beyond with Digital Coherent Signal Processing", K. Roberts et.al., IEEE Communications Magazine, July 2010

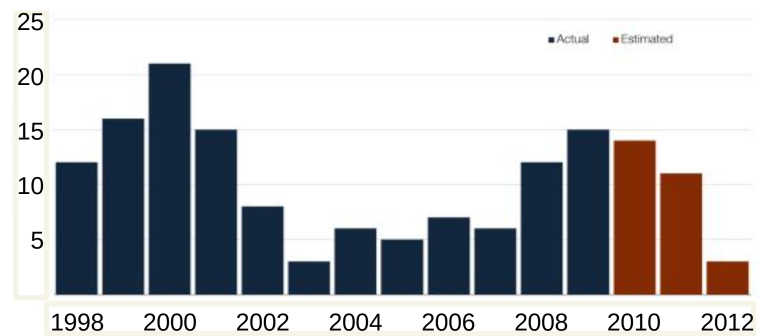
Submarine Deployment Trends

Upgrades take center Stage

Lower marginal cost of bandwidth

- Lower hardware and deployment cost
- Lower operational cost
- Maximize utilization of cable assets

Number of cables entering service 1998 – 2012
Capacity upgrades diminish new cable deployments



Source:Telegeography

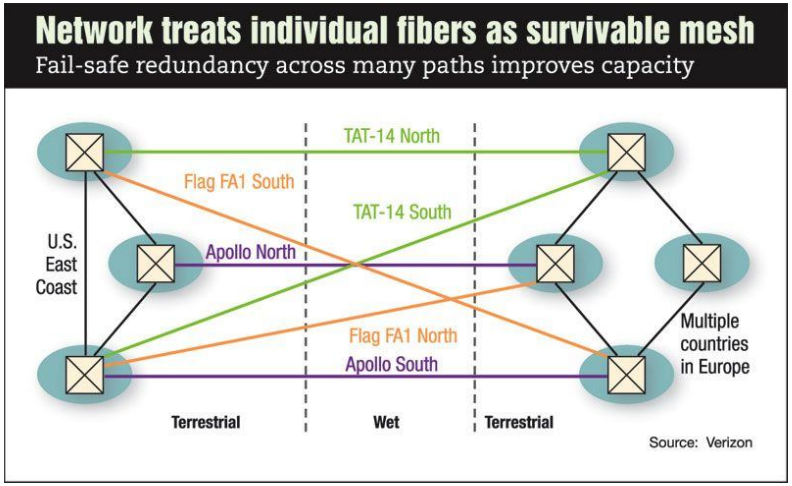
Cable	RFS Year	Capacity Increase
Atlantic Crossing-1	1998	700%
Australia-Japan Cable	2001	297%
Americas-II	2000	863%
Pacific Crossing-1	1999	150%
Southern Cross	2000	733%

Source: Global Capacity Demand Drivers & Network Deployment Trends, A. Mauldin (Telegeography), SubOptic, May 2010

Meshing the Submarine cables

Lower marginal cost of bandwidth

- Maximize utilization of cable bandwidth (shared protection across cables)
- Lower maintenance cost and cost of downtime



Enhance value of services

- Compete on Quality of Services (QoS)
- Expand the Classes of Service (CoS)
- Higher-value application-specific offerings (e.g. international data center connectivity with latency SLAs)

The Global Network

Architecture evolution

Traditional Architecture

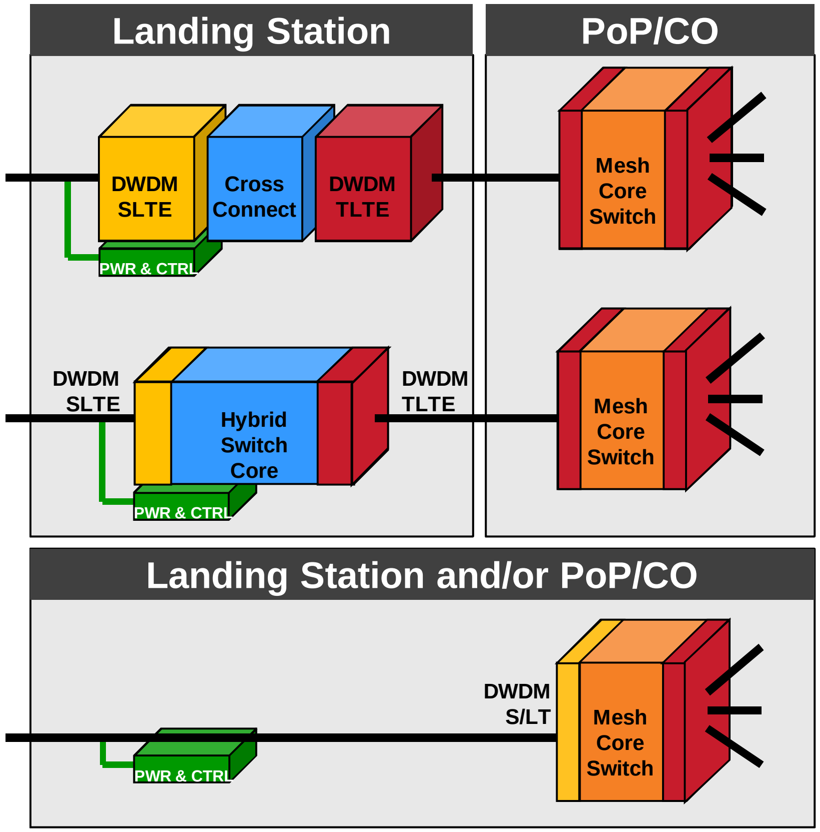
- Discrete network components

Integrated Architecture

- Submarine/terrestrial WDM integration
- Simplified management
- Space and cost reduction

Global Mesh Architecture

- Universal ULH Packet/TDM-OTS
- End-to-end provisioning & management
- Global mesh protection & restoration
- Disassociation of wet plant



Thank you…

Contact info:

Per Hansen
phansen@ciena.com