# Delivering 100G per wavelength with today's DWDM infrastructure

## Motivation, Experiments and Standards

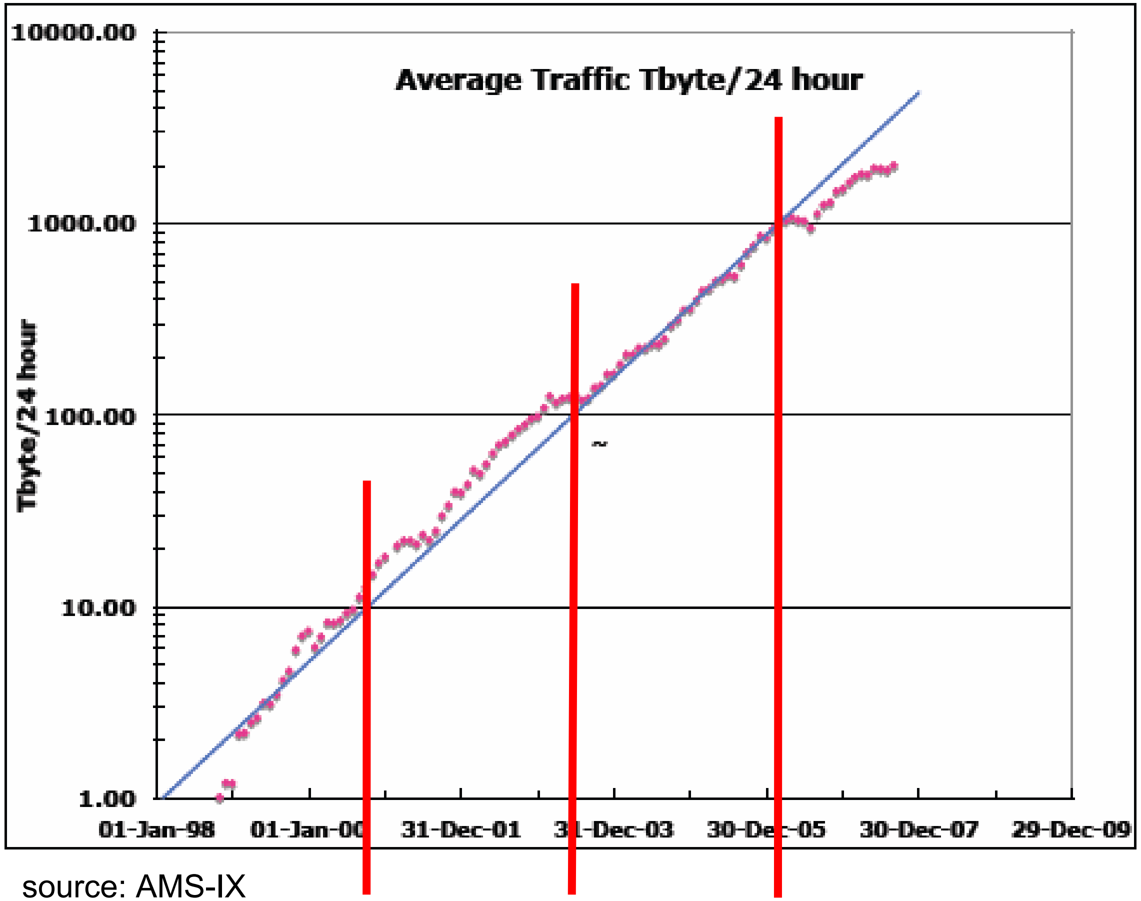
## RIPE 55, Amsterdam

**Michael Finkenzeller, IPT DWDM**

# Agenda

- Motivation and Some Background Information
- 100G transmission: Experiments and Trials
- Standards: 100GbE, Carrier Ethernet Transport
- Conclusion

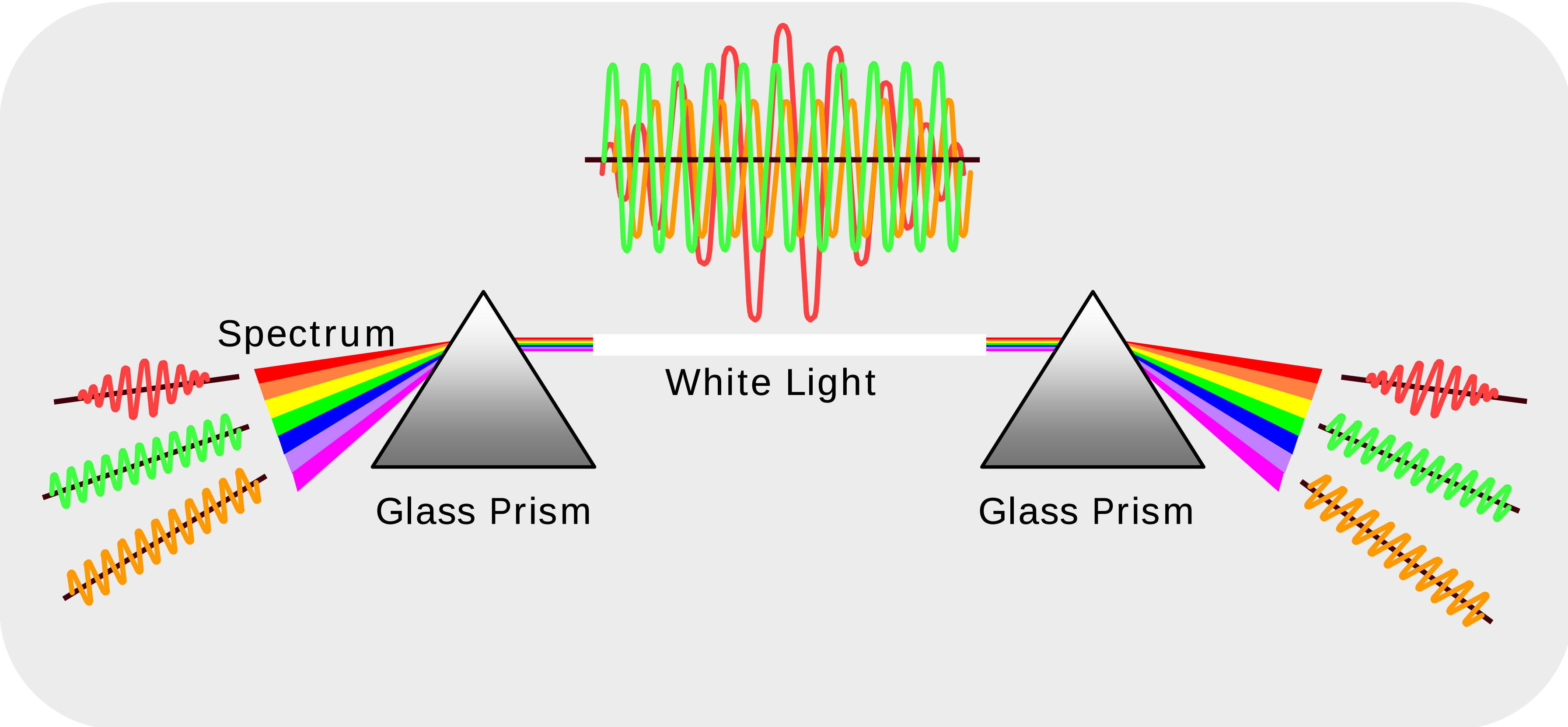
# Historical Volume Growth AMS-IX




source: AMS-IX

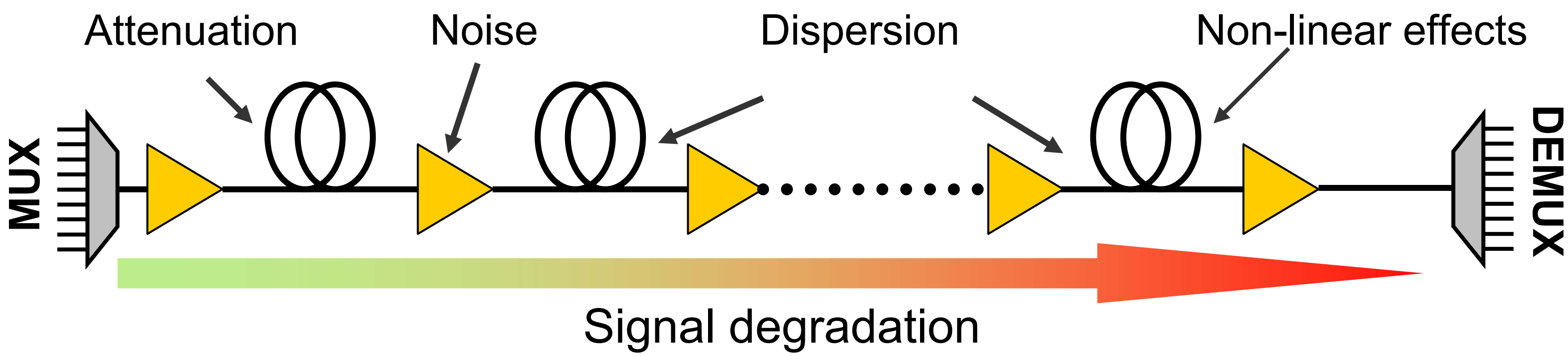
**Every 30 months traffic increased with factor 10.**

# WDM - Wavelength Division Multiplexing




- Each “coloured” wavelength represents one WDM channel
- Multiplexing of separate signals on same fiber

# Signal Quality Degradation in Optical Systems




## Bit rate increase to 100Gb/s

- ☹ Chromatic dispersion tolerance decrease
- ☹ Polarization Mode Dispersion tolerance decrease
- ☹ OSNR tolerance decrease
- ☹ Non Linear Effects

- New transmission techniques
- New optical modulation schemes
- New dispersion management techniques
- New components

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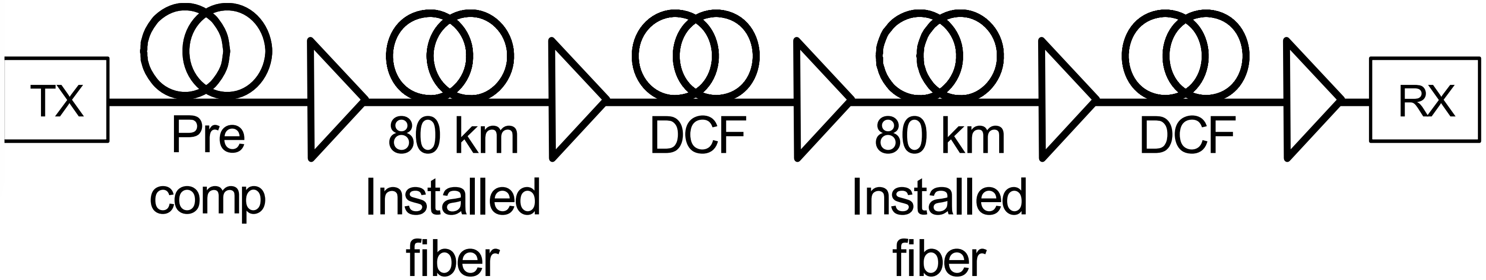
# 2006: 107 Gbit/s transmission over 160km


**Transmission line**:

- 2x80-km field NZDSF, 19.7 dB attenuation per span
- Direct optical 107 Gb/s generation and additional filtering
- Electrical processing of 107 Gb/s in single chip after photo diode
- Q-factor: 10.4dB btb, 9.6dB after 160km



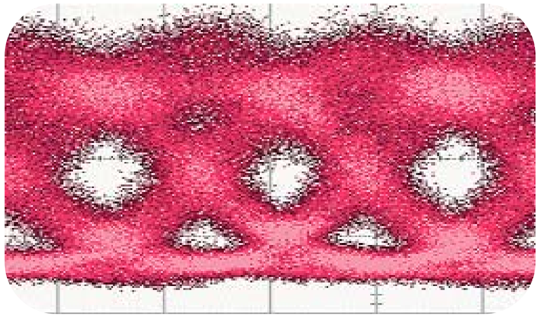
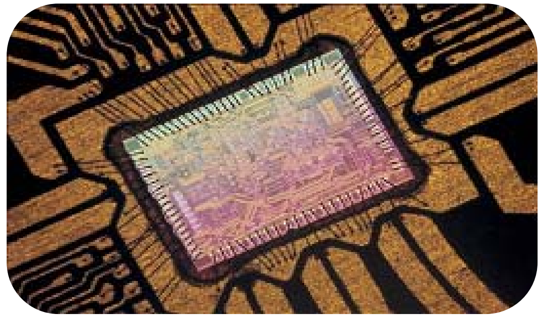



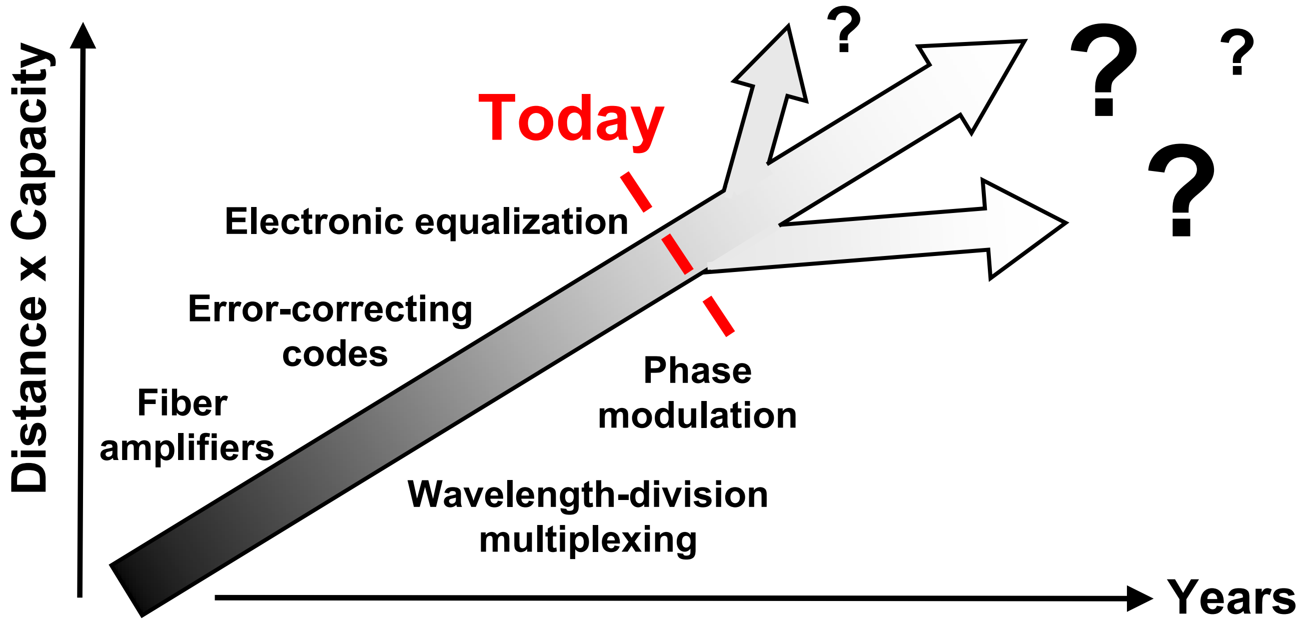
Photo of single chip **clock & data recovery** and **1:2 demux** for 107Gbit/s

Optical Eye Diagram of 107Gbit/s signal



**Field trial using ETDM sender and receiver.**

# Technology Trends in 40G/100G



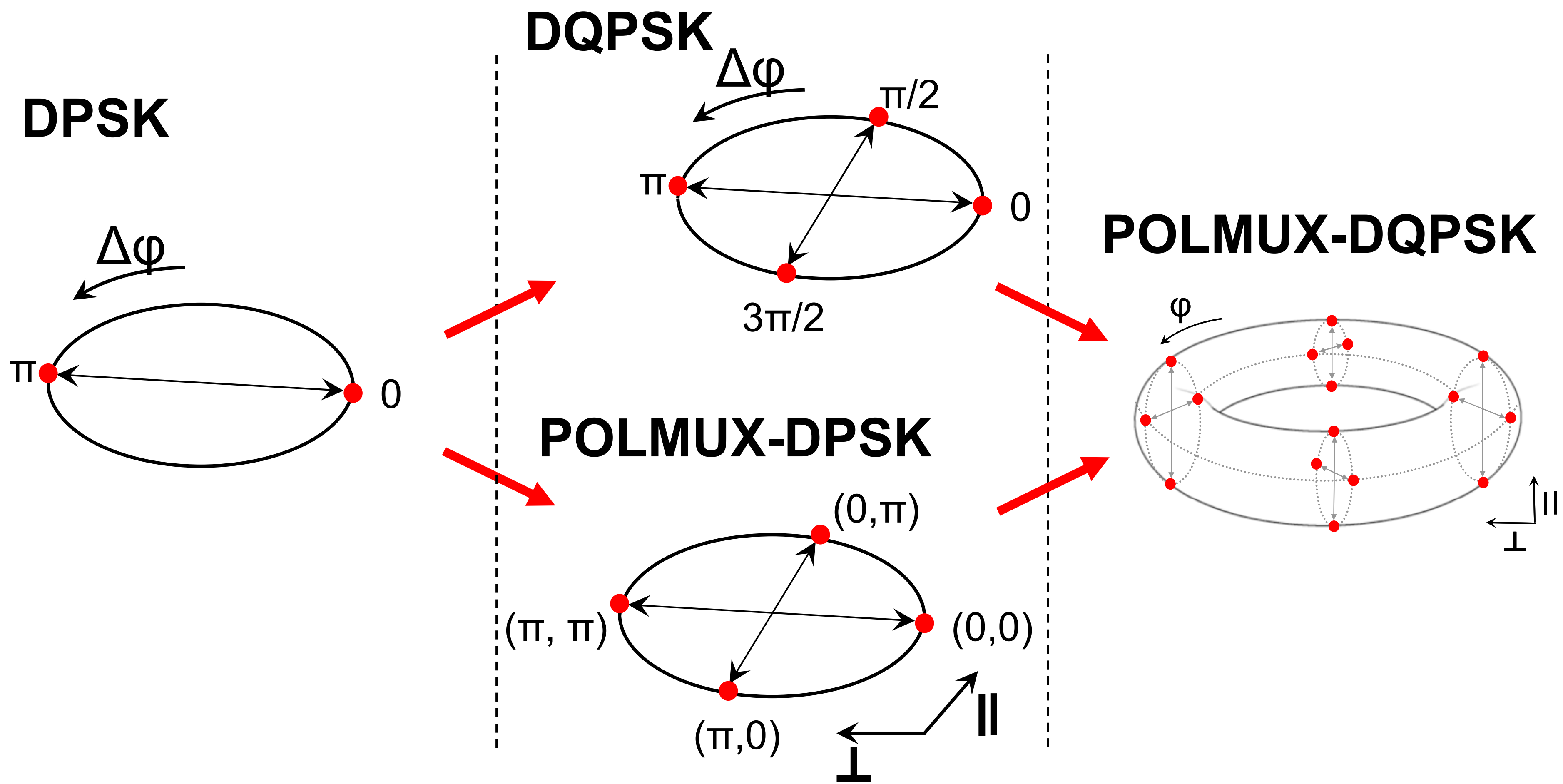

**Enabling technologies:**

**Modulation formats (DPSK, DQPSK)**

**Polarization-Multiplexing (PolMux)**

**Coherent receivers**

# Modulation formats: multiple bits per symbol




***1 bit/symbol*** ***2 bits/symbol*** ***4 bits/symbol***

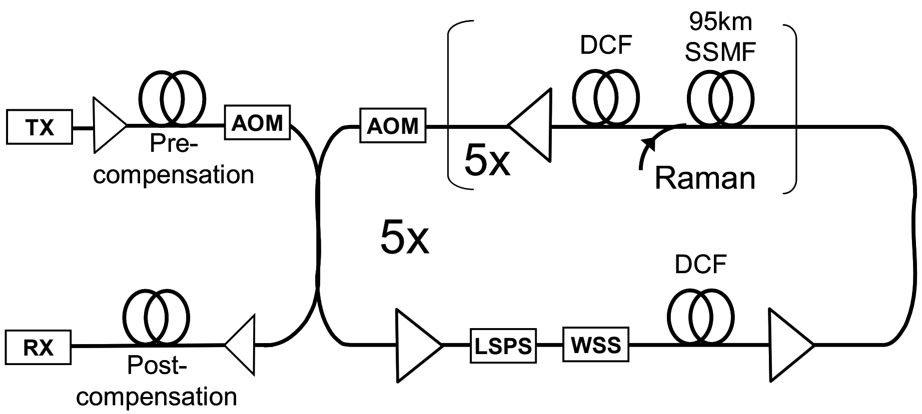
 

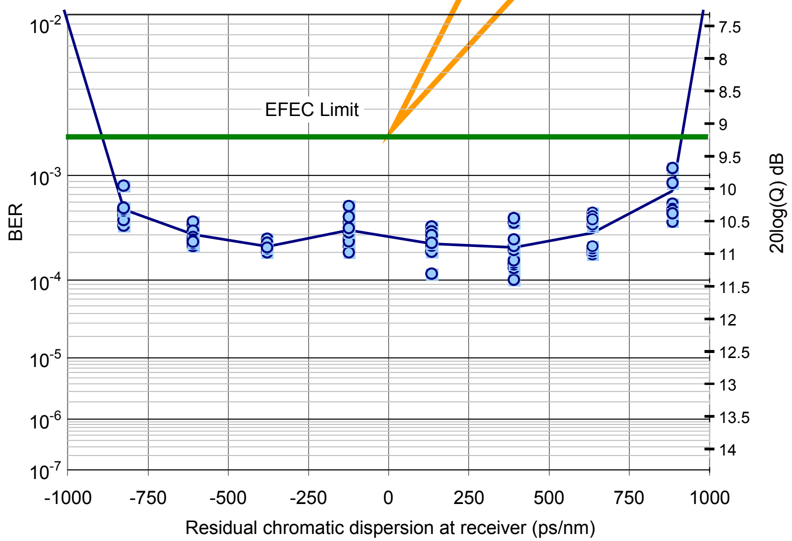
# 2007: 10 x 111 Gbit/s transmission over 2375 km

**Experimental setup**:

- 10 channels with 111Gbit/s each (100GbE + EFEC) on a 50GHz grid
- Alternative modulation format **POLMUX-RZ-DQPSK**
- Completely electronic modulation and demodulation
- 2375km of SSMF and 5 add-drop nodes
- **Coherent detection and equalization** for polarization recovery and high chromatic dispersion tolerance

**As broad as 10G → same infrastructure usable!**



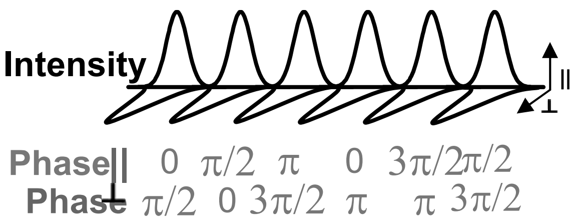



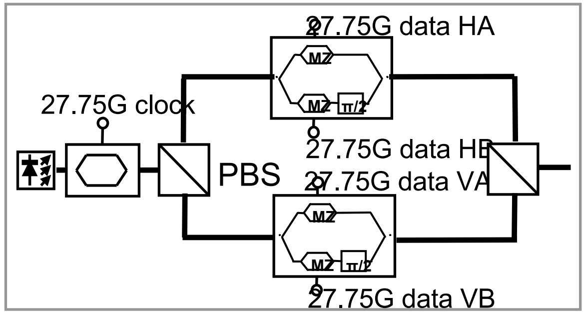

**Possible to use today's 10G infrastructure for 100G/λ transmission**

# COHERENT 111-Gbit/s POLMUX-DQPSK (CP-QPSK)

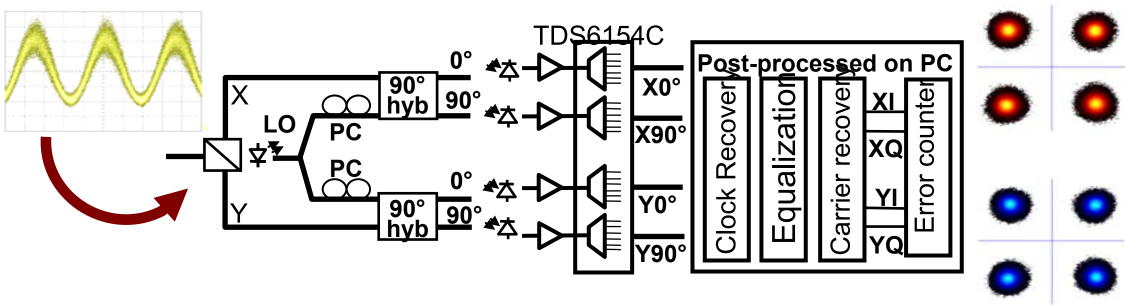
- ✓ Very narrow spectral width => Use of existing 50Ghz grid WDM systems
- ✓ High spectral efficiency 4 bits per symbol (27,75Gbaud)
- ✓ Use of low spec 40-G electrical components
- ✓ Chromatic dispersion and PMD are compensated electrically (1st time for 100Gb/s)
- ✓ Coherent detection allows electrical polarization de-multiplexing

111-Gbit/s POLMUX-(N)RZ-DQPSK transmitter:
**Polarization multiplexing**




POLMUX-(N)RZ-DQPSK receiver:
**Coherent detection**



# Native transport versus concatenated within DWDM layer

**Native 40/100G (serial)**

- ☺ optimal use of network capacity
- ☺ easy service routing
- ☺ easy to implement services in meshed network

- ☹ high reach might be available later
- ☹ potentially more regeneration points

**Concatenated nx10G (parallel)**

- ☺ less optical impairments
- ☺ more easy to obtain higher reach

- ☹ routing as bundle of wavelengths necessary
- ☹ congests network (especially cumbersome in partially filled meshed network)
- ☹ latency cannot be avoided
- ☹ doesn't scale in OpEx/CapEx

**Native transport is the better choice.**
**Better scalability and simple maintenance: "One service, one port"**

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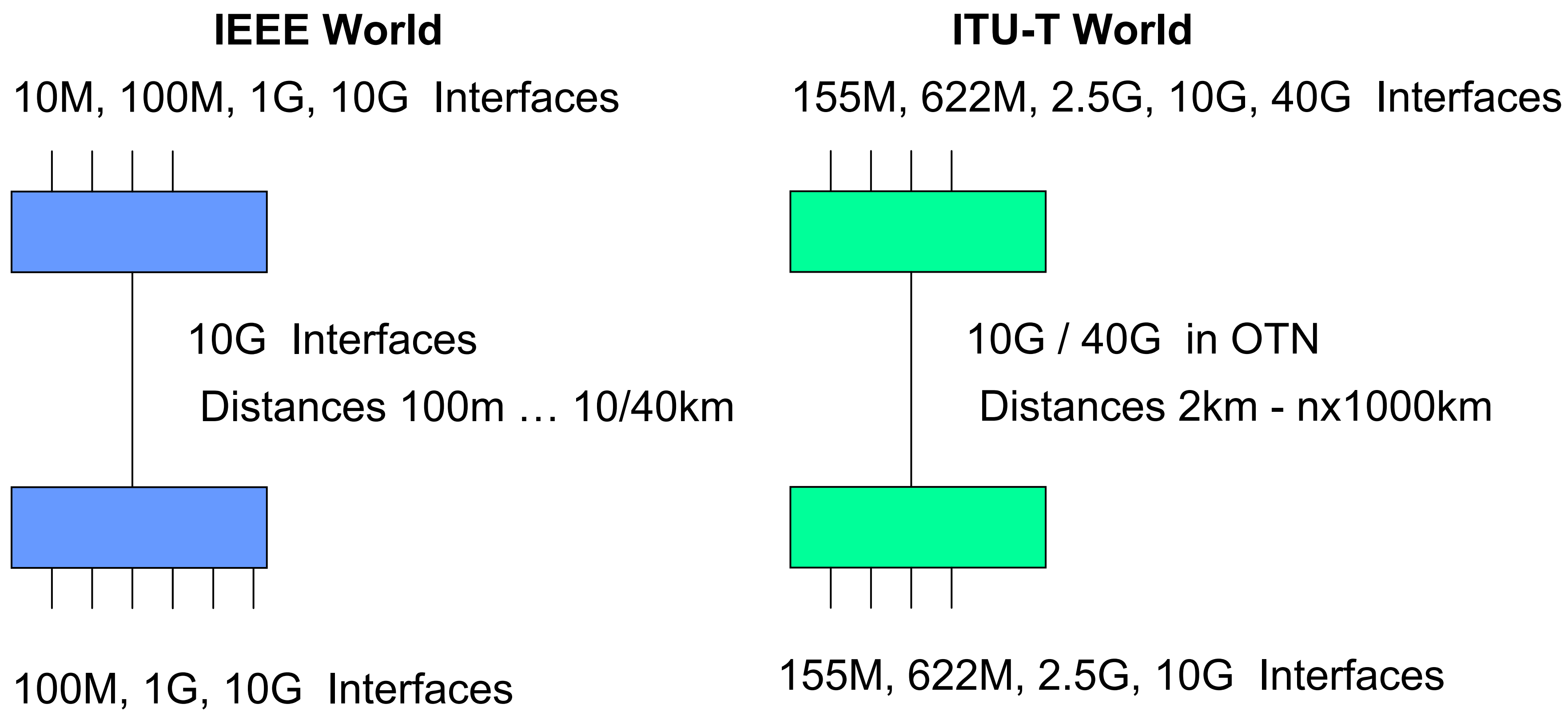
# 100GbE: IEEE and ITU-T are different worlds.




**The IEEE world is short range and used factor 10 in the past.**
**The ITU-T world is long range and used factor 4 in the past.**

# Status 100GbE Standardization

- **Status IEEE 802.3 Higher-Speed Study Group (HSSG)**
  - Attendance predominantly interested in cost-efficient, mature transceiver alternatives for short-reach applications, transport networking vendors / service providers represent a minority. New: data center and server operators.
  - Description of standard is scheduled for 2008, finalization for 2009/2010.
  - Data rate and de-skewing procedure are defined in study groups today.
- **Status ITU SG15 Q6 / Q11:**
  - Several OTU-4 proposals in G.709 are under discussion (111 - 112 Gb/s or 130Gb/s), new revision of G.709 including 100GbE transport capability planned for Feb 2008.

| Line Data Rate | Client Interface | Line Interface |
|---|---|---|
| 111-112Gb/s | 100GbE (9-10 x 10Gb) | 1λ, 2λ |
| 130Gb/s | 100GbE<br>3 x 40Gb/s (9 ..12 x10Gb/s) | (1λ), 2λ, 3λ |

**Data rate 130G would delay 100GbE products availability for 2 years. Close coordination is needed for 100G and 40G.**



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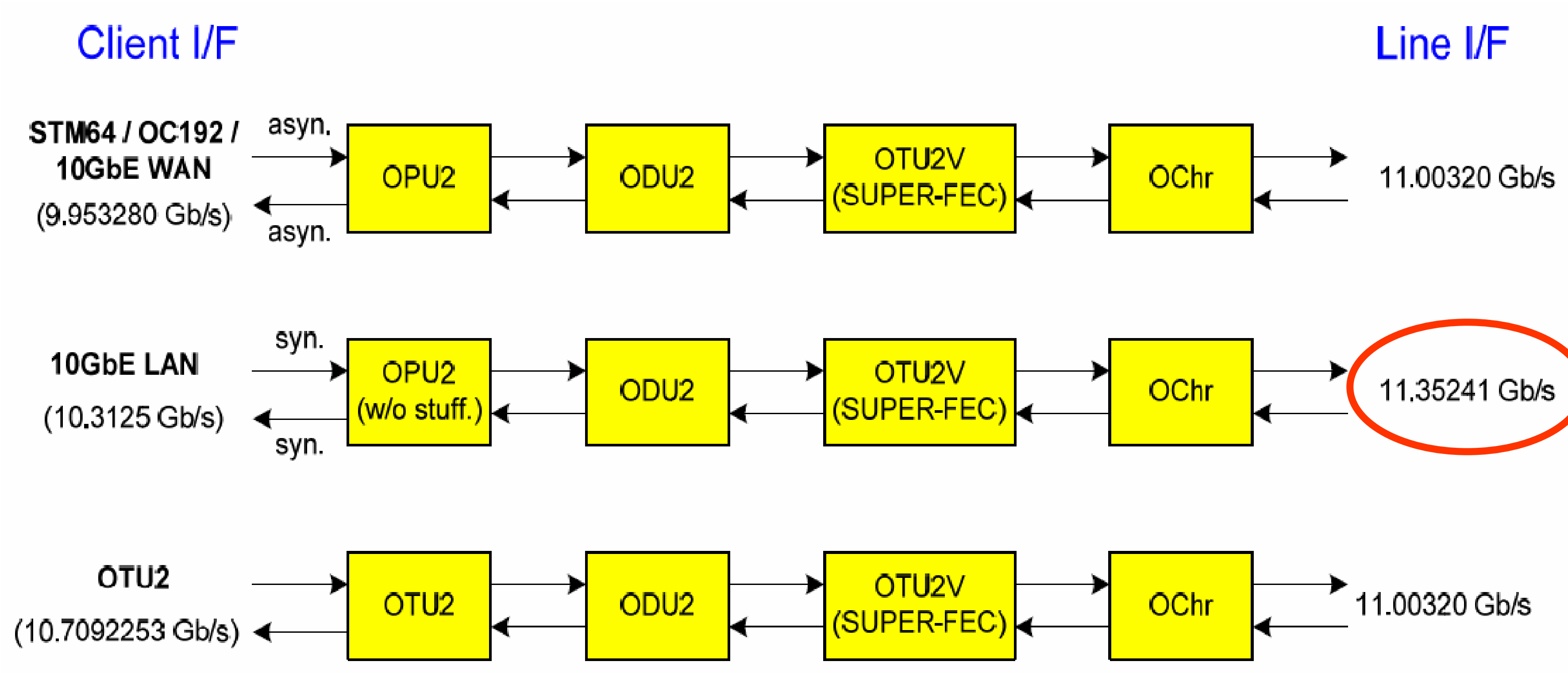
# Mapping of 10GbE: Example where standard didn't much help …




**For 10GbE two different line interfaces (over-clocking).**

# Pre-Standard 100G?

**AT&T, Verizon Have Optical Wishes**

JUNE 08, 2007

… In a keynote on Wednesday, AT&T's Peter Magill said his company would need 100 Gig sooner rather than later.

…

Magill says that AT&T is committed to meeting bandwidth demands, however, and in an interview after his keynote, he said that **AT&T would deploy pre-standard 100-Gig technology if it had to, as long as it made economic sense**.

**source: Light Reading, October 03, 2007**

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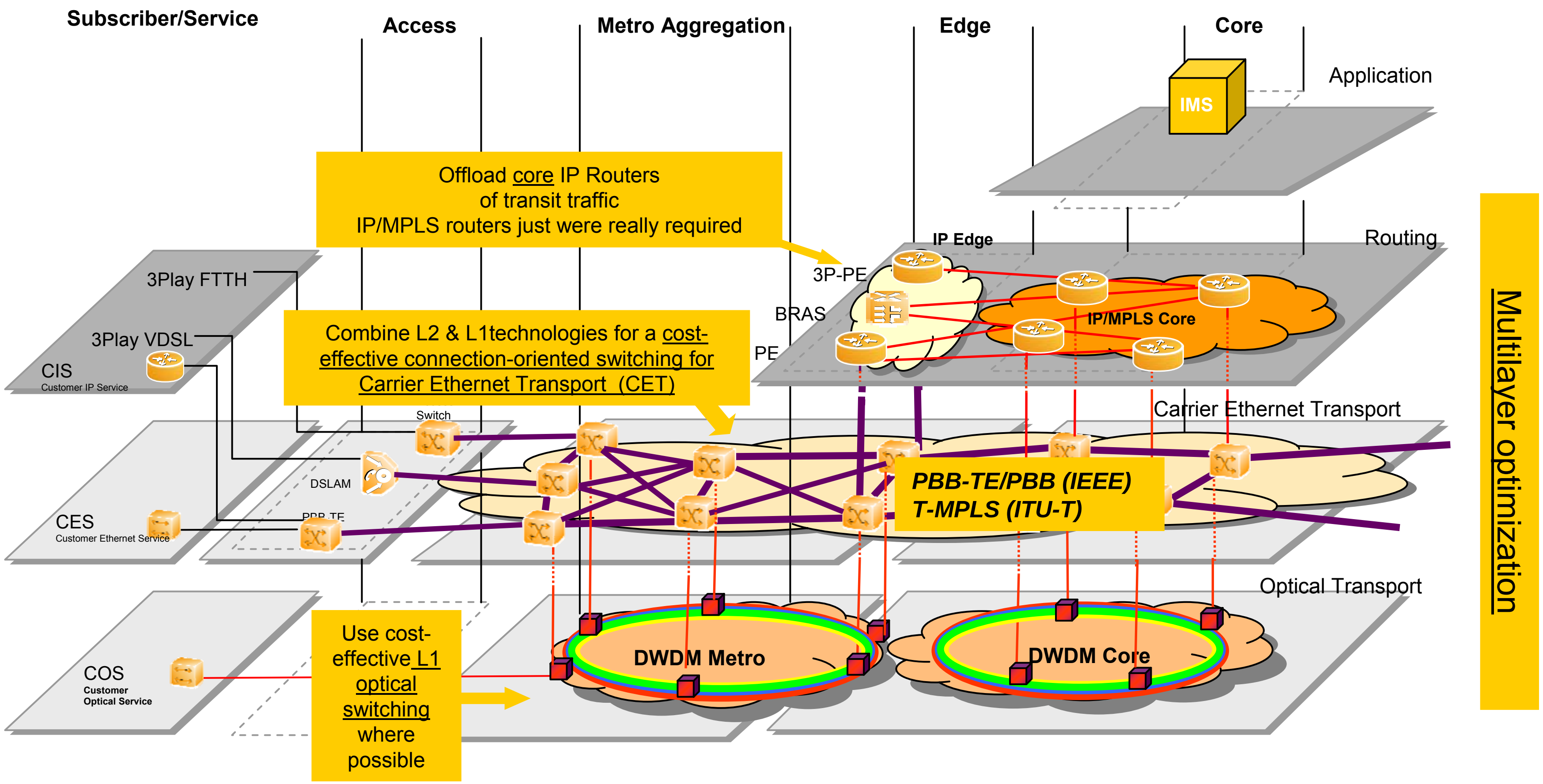
# Provide native End-to-End Ethernet Services

## New 100GbE traffic will require an optimized Carrier Ethernet Transport (CET)




- DWDM infrastructure will transport 100GbE native interfaces
  => New transmission techniques to use existing WDM infrastructure

  } R&D efforts
- Evolve from point-to-point DWDM to an optical meshed network with PXC & ROADM
- Introduce GMPLS control plane in transport layer to optimize operation

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- Demand for 100G is real.
  - IP based applications are main driver.
  - Main payload will be Ethernet based servic
- 100G: Technology is on the right track.
  - Operation of 100G native on 10G infrastructure is feasible.
  - 100GbE standardization is key factor for products in 2010.
- Standardization Issues
  - Transport: client side and line side have to be synchronized
  - Carrier Ethernet Transport (CET) provides simplification and cost savings for future




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# Thank you …

… Questions?