Spectral-Efficient 100G Parallel PHY in Metro/regional Networks

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OUTLINE

- **Why spectral efficient DWDM for 100G?**
- **DWDM spectral efficiency advancement over the last 10 years**
  - 10G/20G/40G Modulation techniques review
- **Optical modem structure and cost implications**
- **Conclusion**

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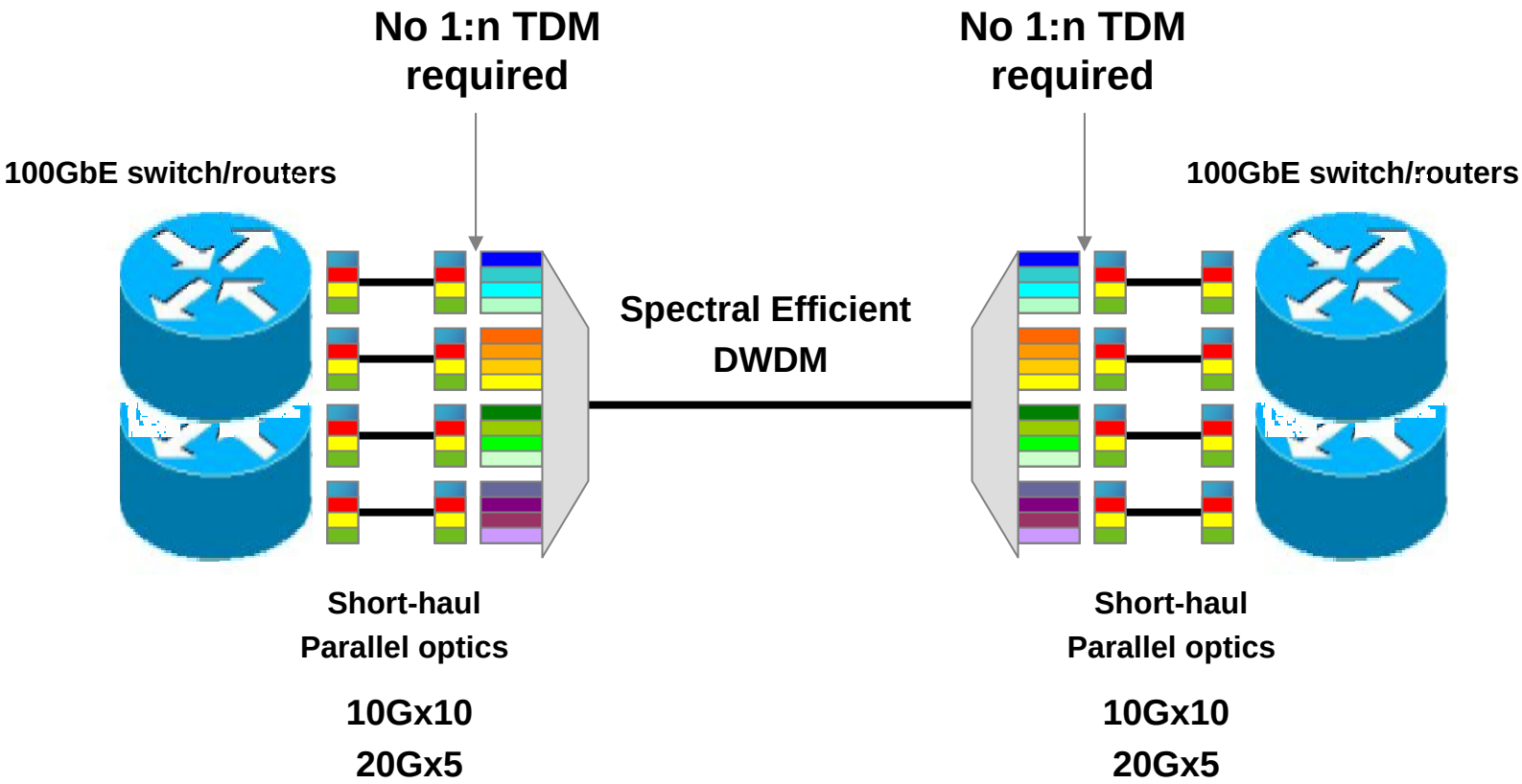
Spectral-efficient parallel PHY lowers cost on both fiber infrastructure and transceivers



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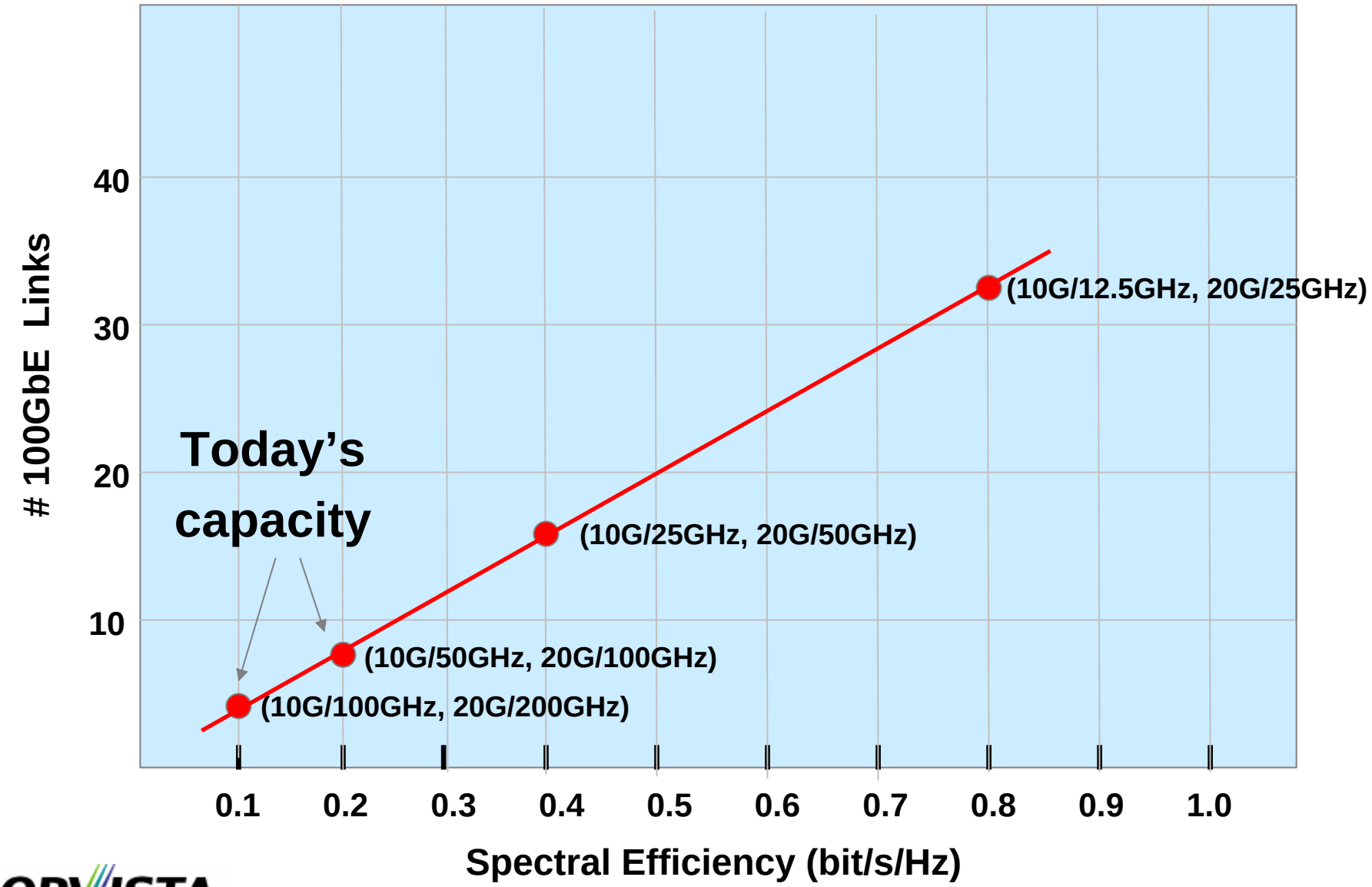
How many 100GbE can a single-mode fiber support (in C-band)?



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Two extremes on the spectrum

Need to find an optimum point
in the middle

10Gb/s x10 → ← **100Gb/s x1**

Poor spectral efficiency

Cumbersome fiber management

Lower cost on 10 transceivers

Low cost on fiber infrastructure

Good spectral efficiency

Simple fiber management

Higher cost on 1 transceiver

High cost on fiber infrastructure

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Historical view: 40G upgrade on 10G infrastructure?

- **6 dB more OSNR must be overcome**

  (> 6 dB if dispersion map is not optimized)

  – NRZ→ RZ: 1~2 dB OSNR gain **$**

  – OOK→ DPSK: 3 dB OSNR gain **$**

  – RS FEC→ BCH FEC: 3 dB OSNR gain **$**

- **Accumulated PMD must be low**

  – New fibers with PMD < 0.1~0.2 ps/km$^{1/2}$ must be used **$**

  – Highly reliable PMD compensators needed **$**

- **Chromatic dispersion maps must be compatible (requires pre-compensation and tunable post-compensation) $**

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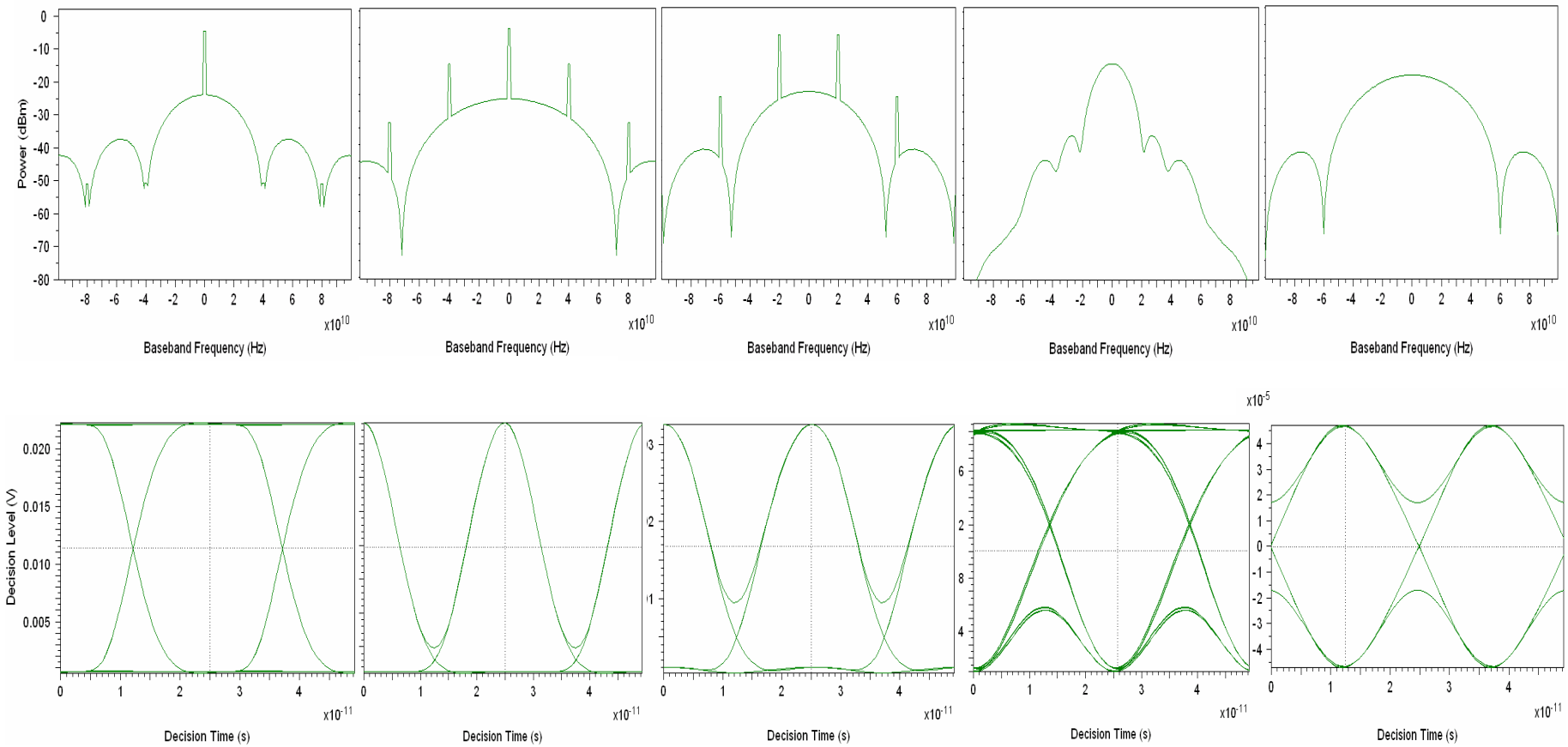
Optical Power Spectra and Pulse Shapes of various modulation formats

NRZ RZ (50%) RZ(67%)=CSRZ Duobinary RZ-DPSK



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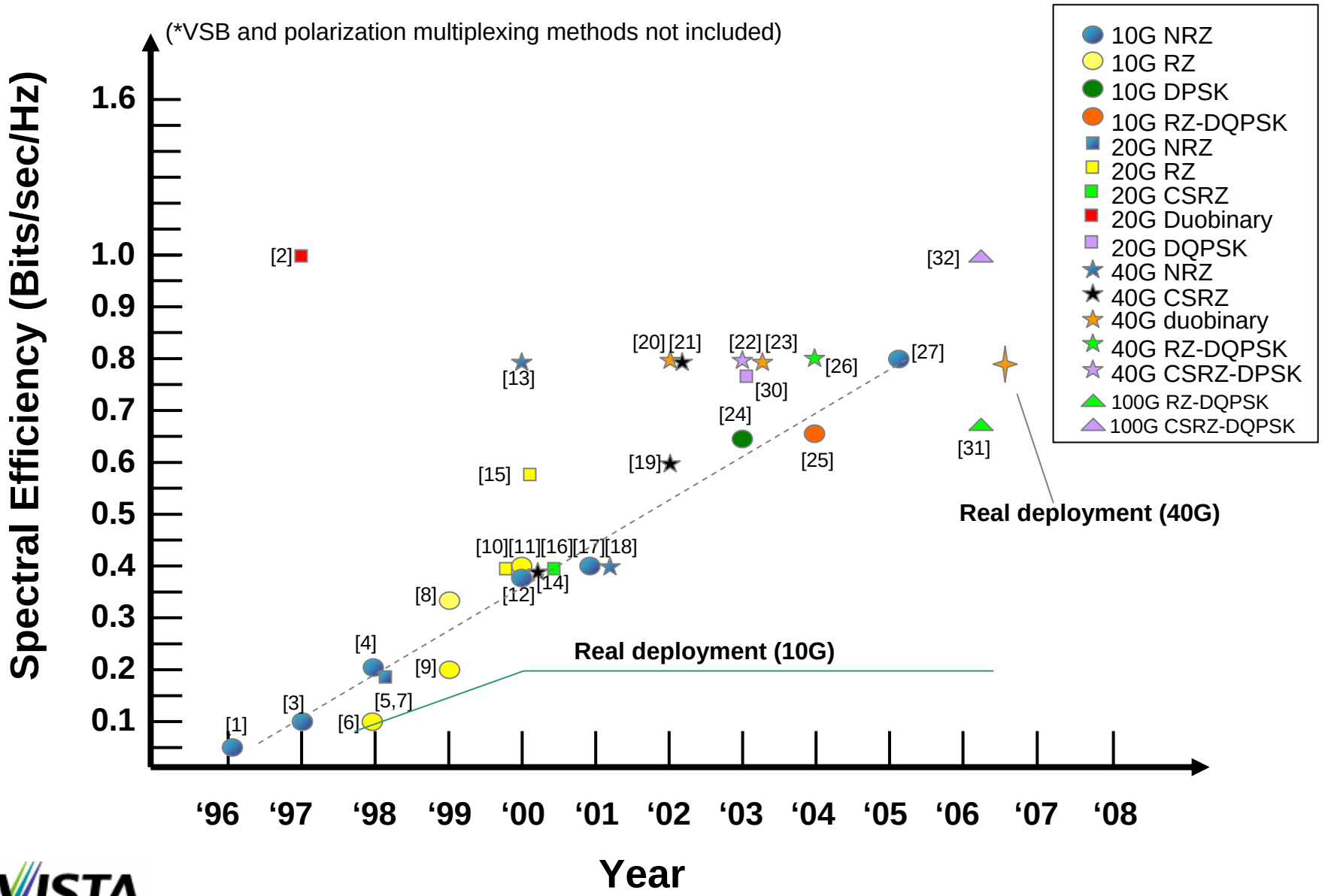
10, 20, 40 & 100 Gb/s DWDM Spectral Efficiency Trend



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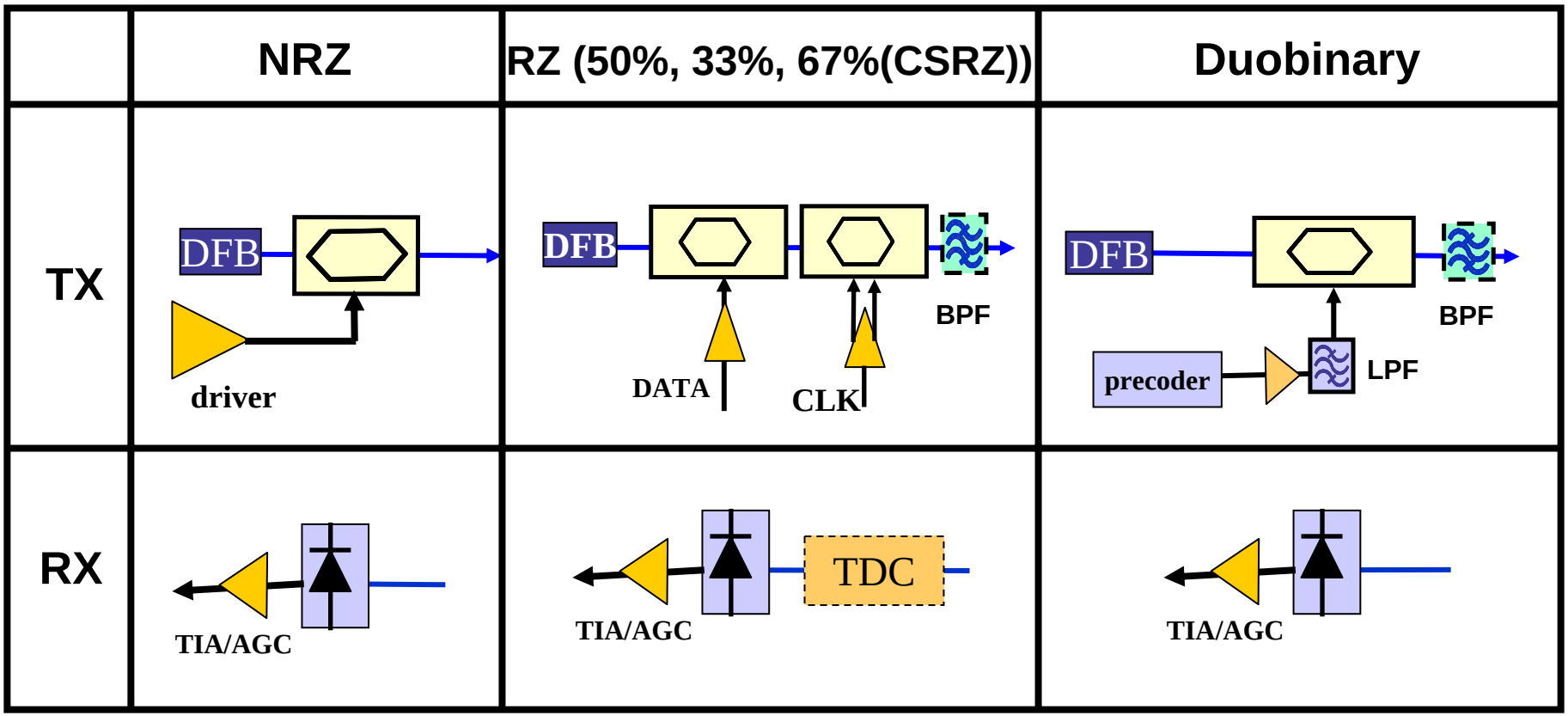
Different System Considerations between Metro/Regional Networks and Long-Haul Systems

- **Metro/regional networks**
  - Standard (old and new) single-mode fibers dominate
  - Erbium-doped fiber amplifiers dominate
  - A mixture of different data rates and protocols (not just carrying 100GbE)
  - Many dynamic add/drops, ingress and egress nodes often change to cause different accumulated chromatic dispersion and PMD (cannot always be pre-calculated as in LH systems)
  - Transponders are dispersed all over the (ring) network → Cannot use polarization-interleave or –multiplexing techniques to increase spectral efficiency as in LH systems
  - Very cost-sensitive

NRZ, RZ, Duobinary TX/RX



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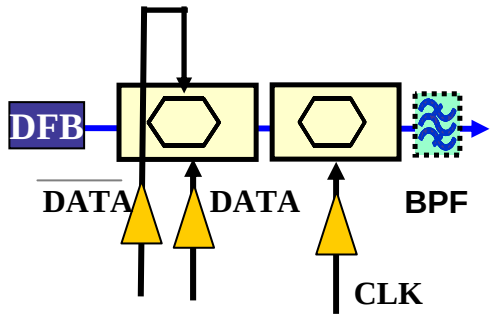
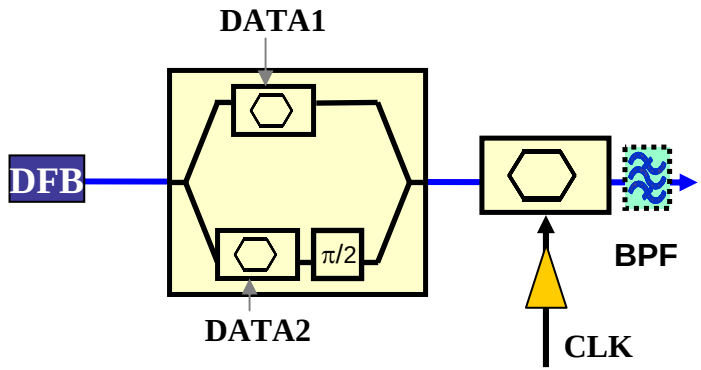
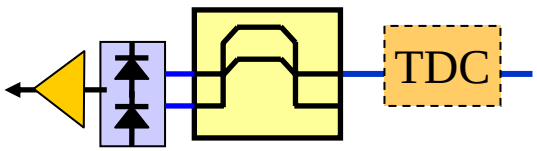
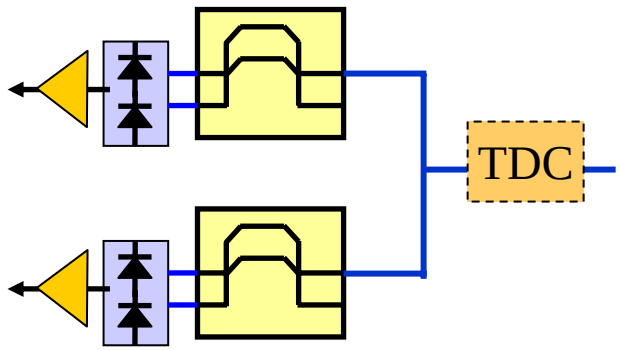
RZ-DPSK, RZ-DQPSK TX/RX

	RZ-DPSK	RZ-DQPSK
TX		
RX		

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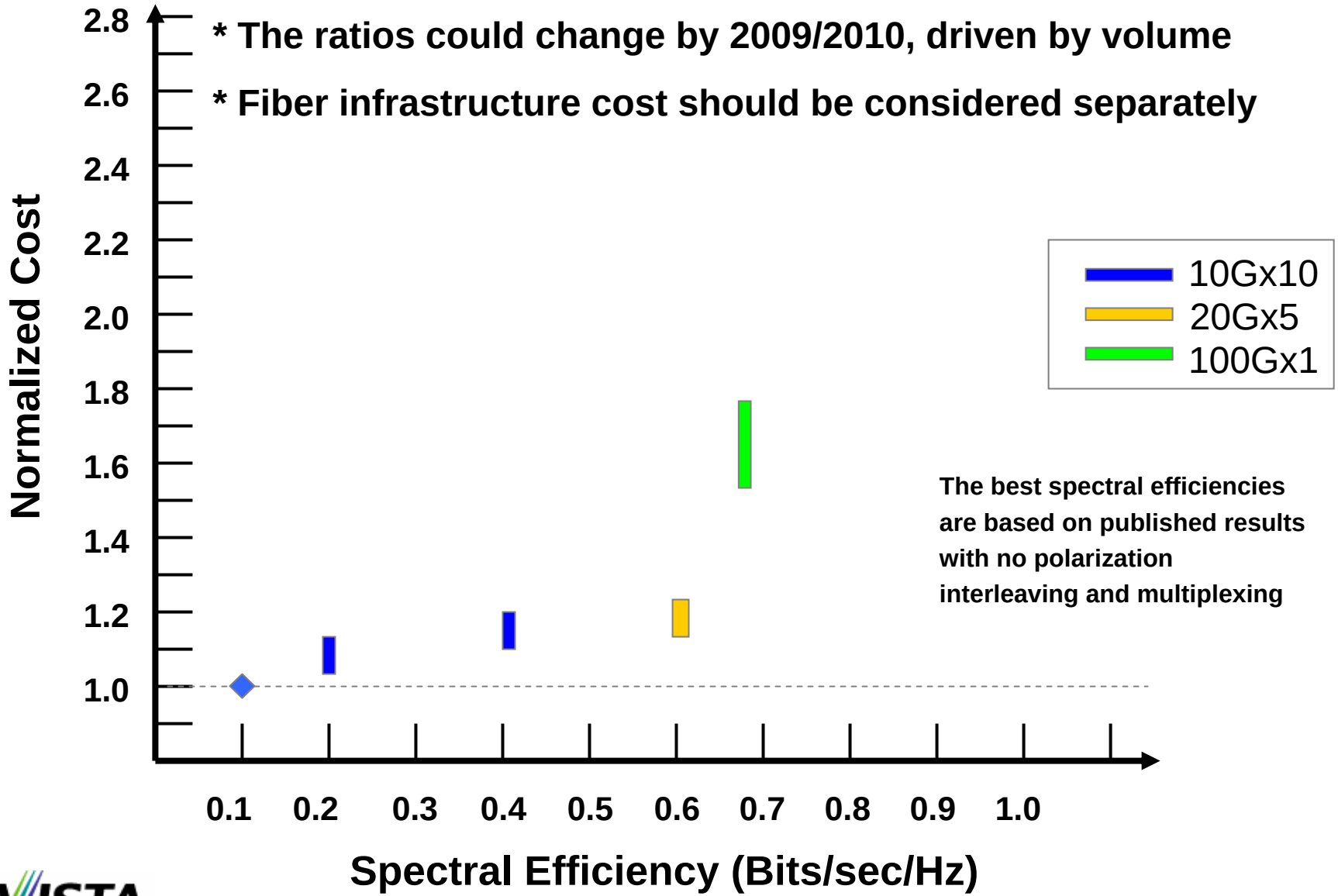
Today's Relative Transceiver Cost Comparison



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Conclusion

- **Today's 10G DWDM spectral efficiency can only support 4~8 100GbE links, and must be improved**
- **Parallel PHY allows 100GbE to be transported in an incumbent fiber plant**
- **For both 10Gx10 and 20Gx5**
  - Fiber infrastructure cost is far lower than that for serial PHY
  - Transceiver cost has the advantage of much higher volume than that of serial PHY
  - Today's **discrete** technology can comfortably improve the spectral efficiency to 0.4~0.6 bit/sec/Hz
  - By 2009/2010, it is feasible to reach a spectral efficiency of 0.8~1 bit/sec/Hz (with binary modulation)

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