



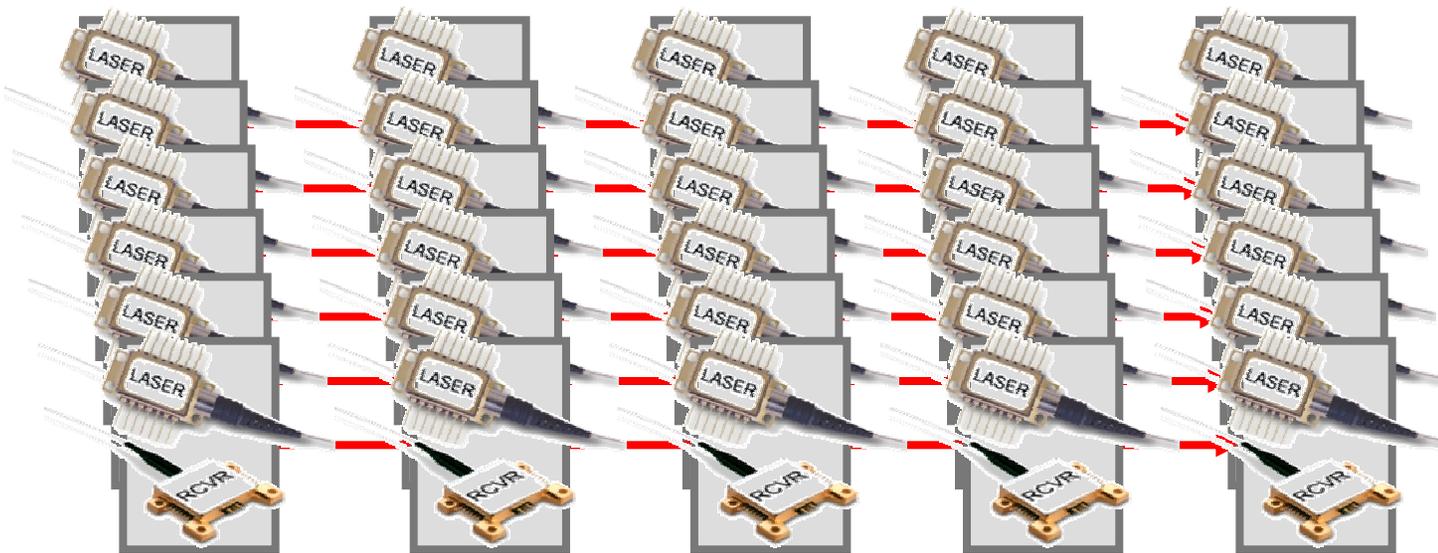
Next-Generation Optical Transport Networks enabled by Large-Scale Photonic Integration

Serge Melle

Vice-President, Network Architecture

A short history ...

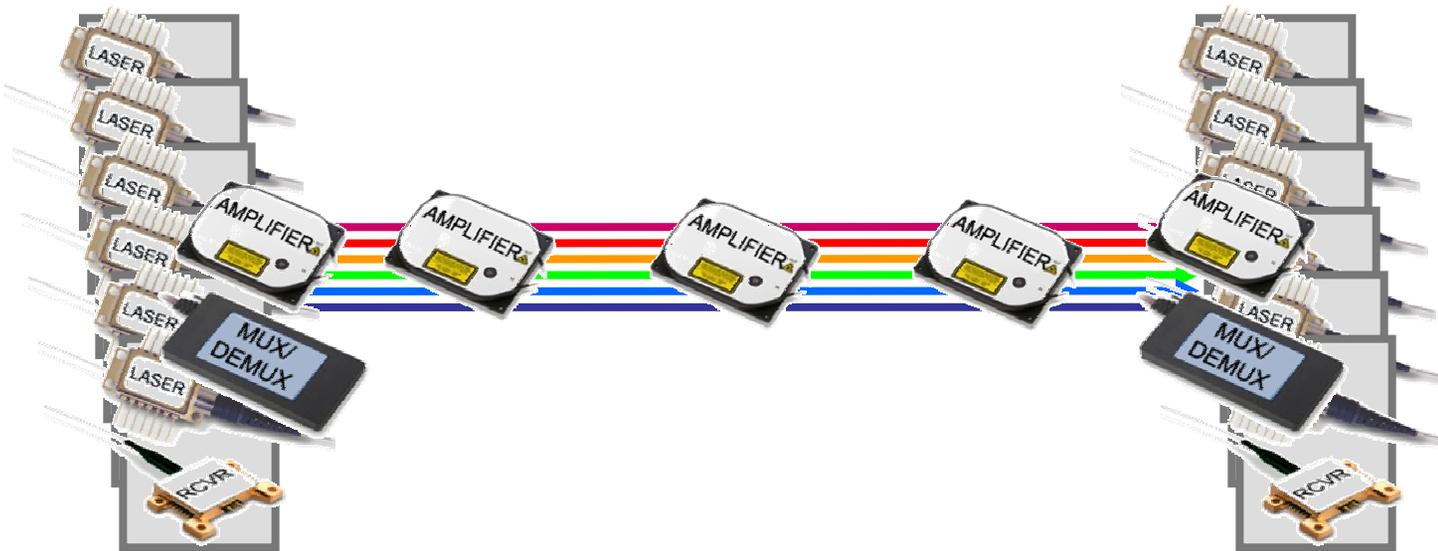
Legacy optical transport



- O-E-O's at each repeater site enabled PM's & add/drop anywhere
- Capacity growth required parallel fibers and opto-electronics
- Created unsustainable economics

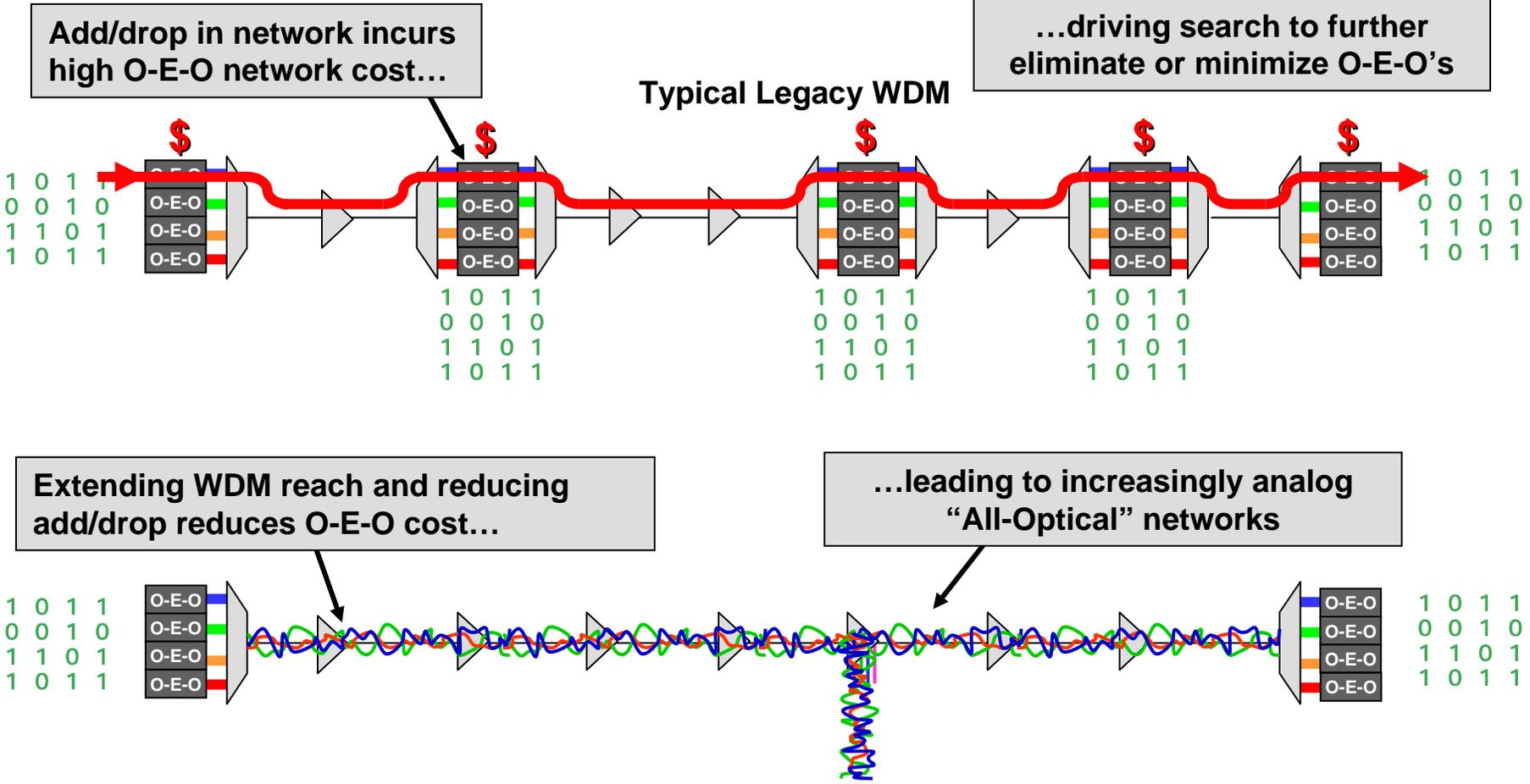
A short history ...

Legacy optical transport



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- Regens displaced by optical amplifier and WDM technology to eliminate OEO cost and enable cost-effective capacity scaling

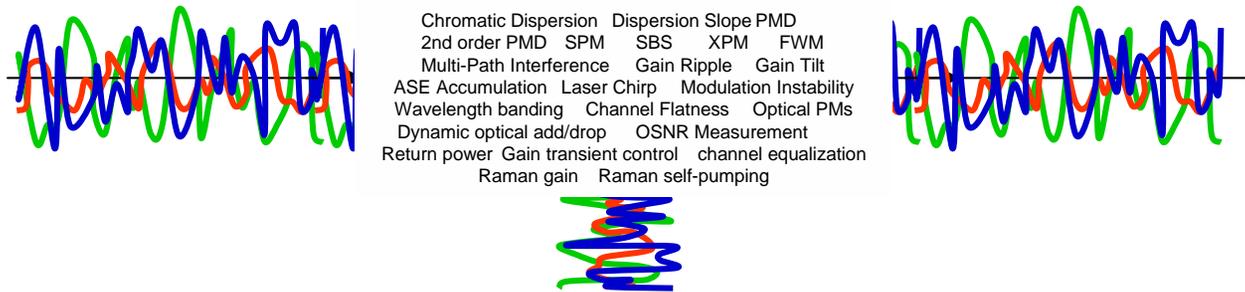
WDM Networks Today



Issues of Analog “All-Optical” Networks

“All-Optical” Networks

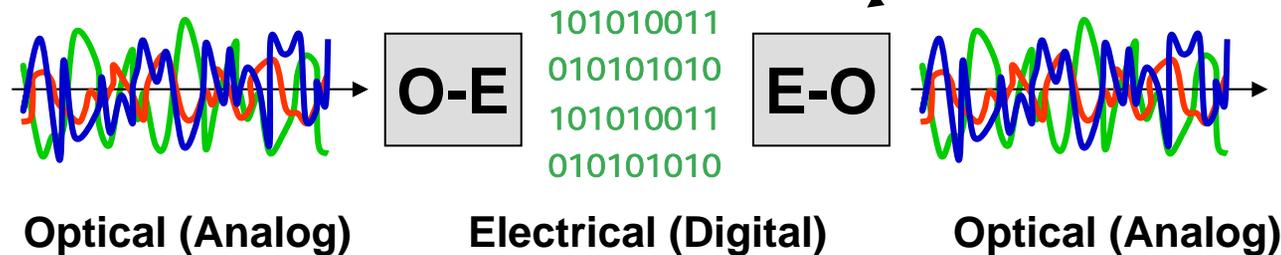
analog transmission of λ 's



- **Forces network operators to compromise between WDM network cost and number of users served**
- **High level of system and engineering complexity**
 - Complex analog optical engineering & compensation of impairments
- **Complex network architectures and operations**
 - No digital statistics, complex fault identification, wavelength planning

Benefits of O-E-O Conversion

But...what are the benefits of accessing digital network data?



Enhance Services & Increase Access

- Maximize "On-Net" locations
- Reduce service costs
- Improve Service SLA's
- Full access to user data

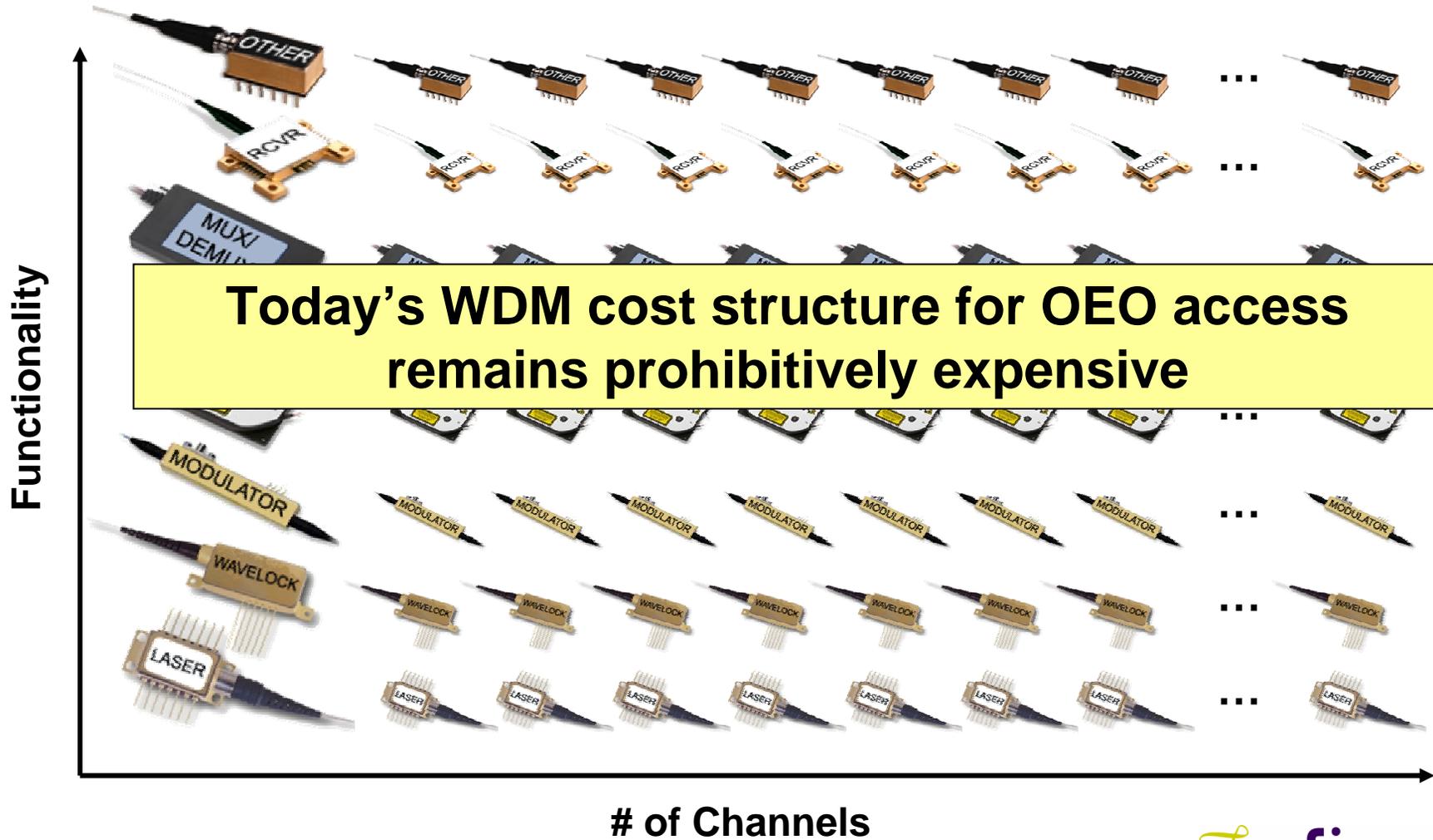
Simplify Network Operations

- Protection/Restoration
- Full Digital statistics
- Easier & Faster Fault Identification

Improve System Performance

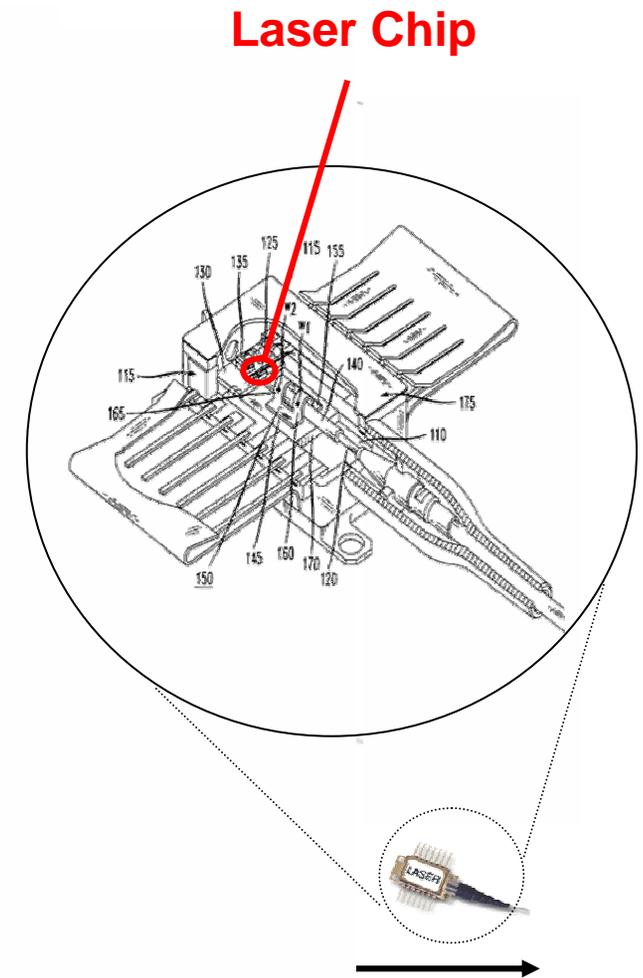
- Leverage Silicon economics
- Bandwidth Management
- Improve BER w/FEC
- Elec. Dispersion Compensation
- Increase reach w/Modulation

WDM Cost Structure



WDM Cost Structure

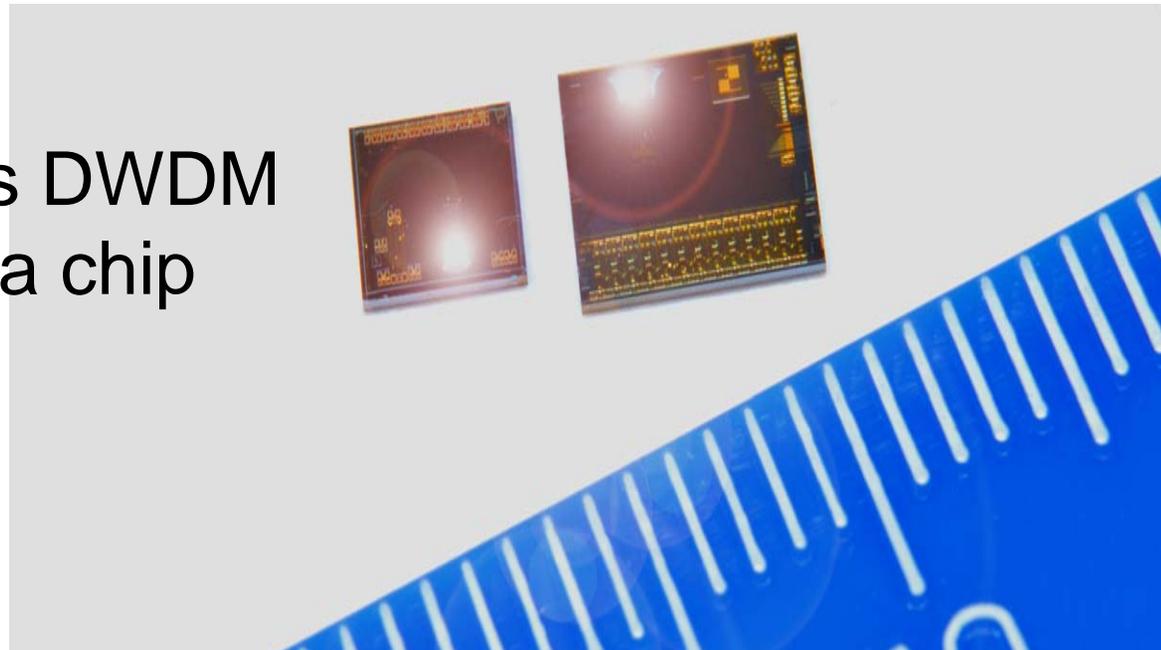
- **Cost of conventional OEO:**
\$10,000 per λ
 - Laser, λ -locker, modulator, mux, demux, photodiode
- **Why so expensive?**
 - Packaging
 - Cost dominated by fiber coupling
 - Discrete components add loss
 - Conventional 80 channel system >560 couplings
 - Too many technologies
 - InP, LiNbO₃, GaAs, Silica, Polymers, MEMS, Fiber-based...



Fundamental Innovation

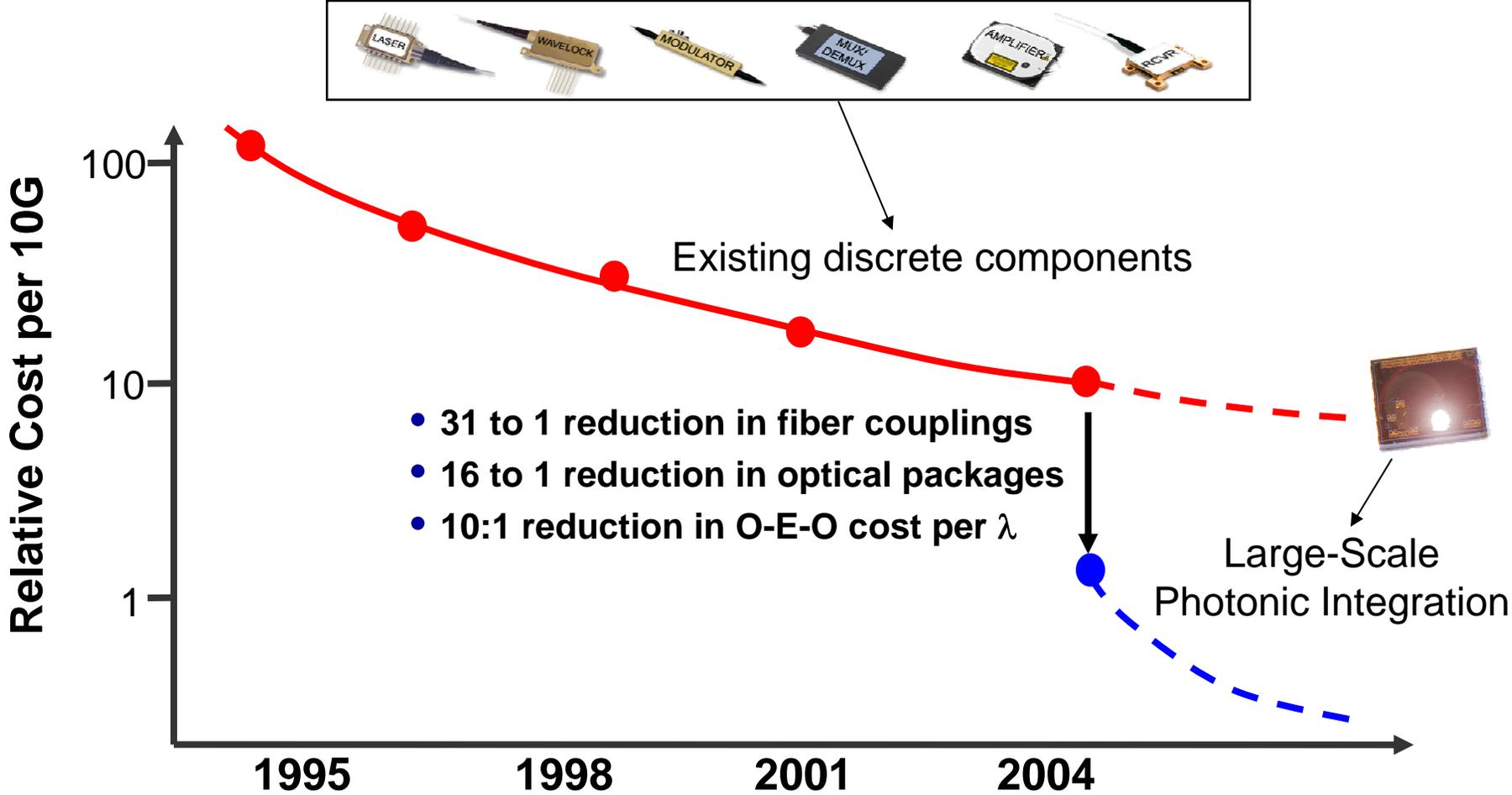
- How can benefits of digital access be realized?
- Reduce OEO cost by factor of 10 times
- Large-Scale Photonic Integration

100Gb/s DWDM
on a chip



Enables Ultra Low-Cost O-E-O's

Introducing a New Cost Structure...



A New Direction

~~Underlying Assumption:
"OEOs are Expensive"~~



~~Action:~~

~~Eliminate OEOs and
replace with analog
functions~~



~~End Game:~~

~~All Optical
(and Analog)
Networking~~



**New Reality:
Photonic Integration**

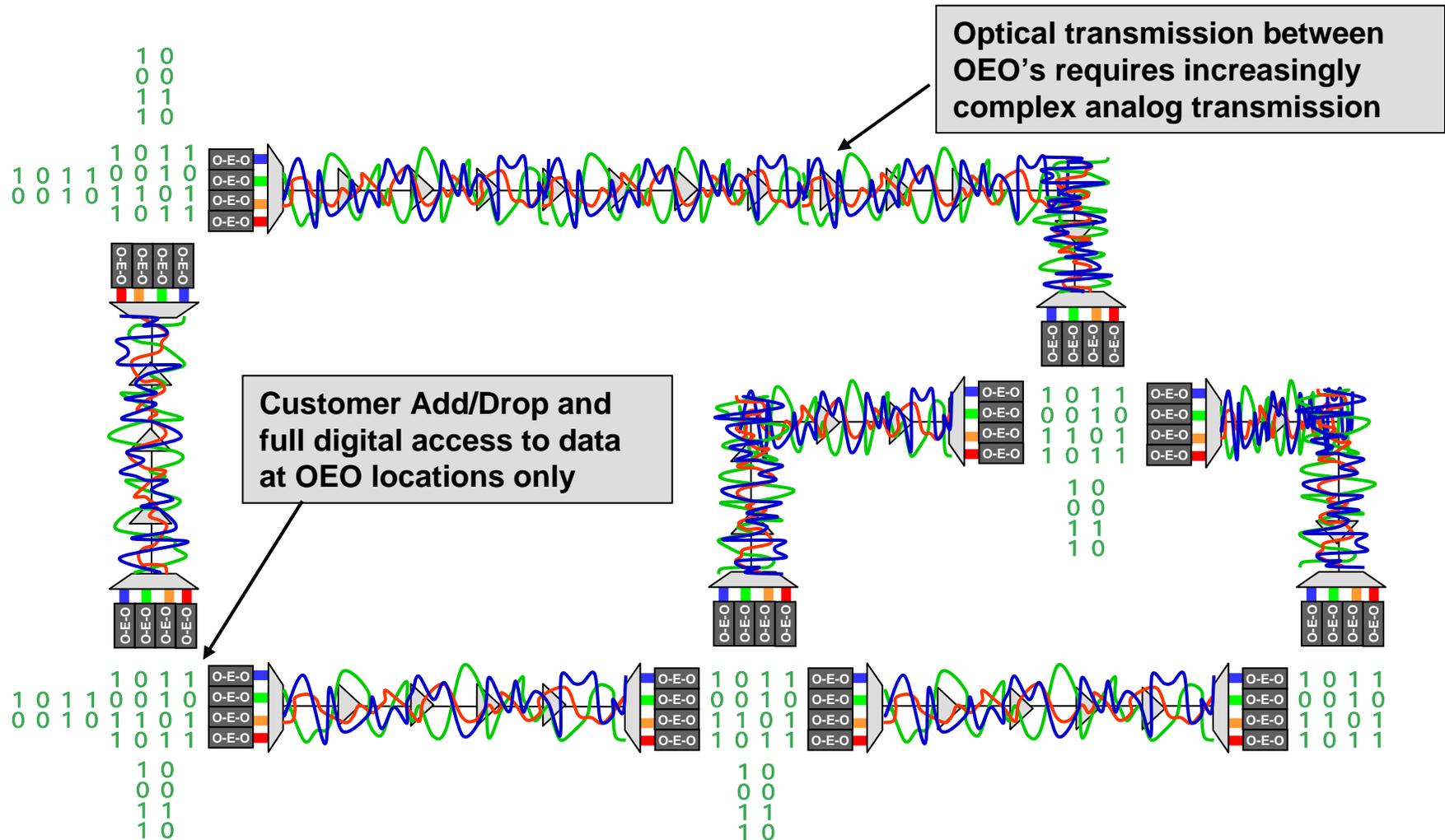


**Action:
Embrace OEOs and
the benefits of
digital functions**

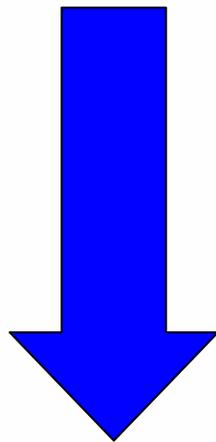


**End Game:
Digital Optical Networking**

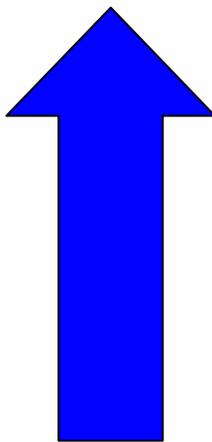
Evolving from today's Analog WDM Network



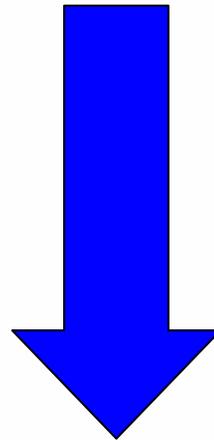
Implementing Digital Optical Networks



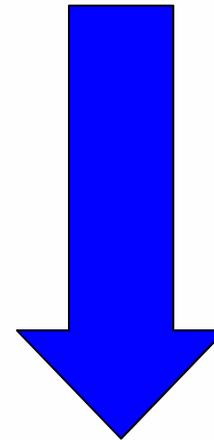
***Reduce
CapEx***



***Increase
Access***

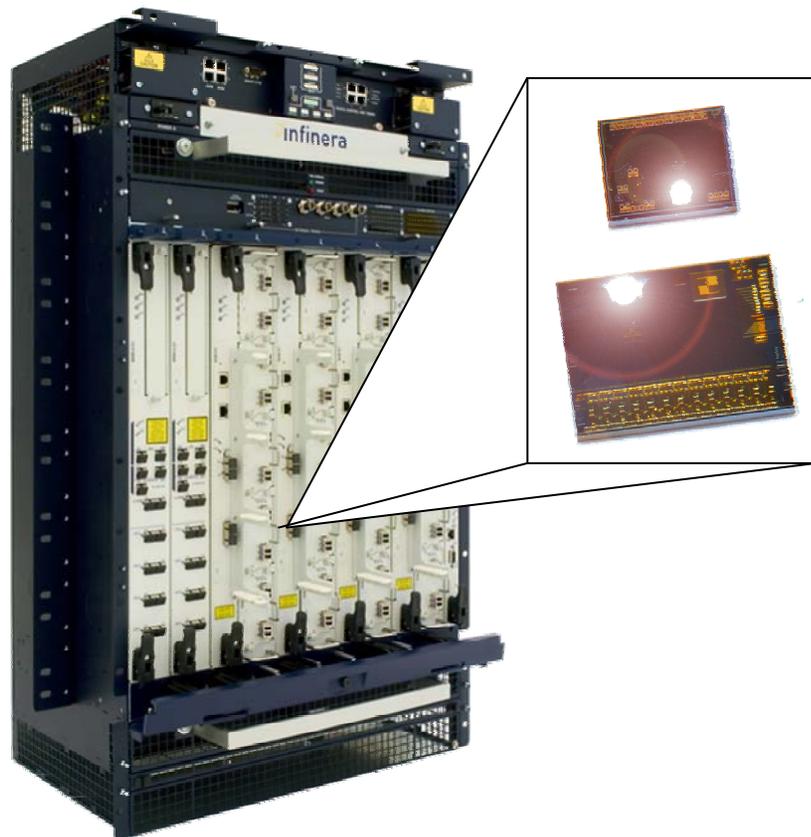


***Reduce
OpEx***



***Reduce
Complexity***

Infinera Summary



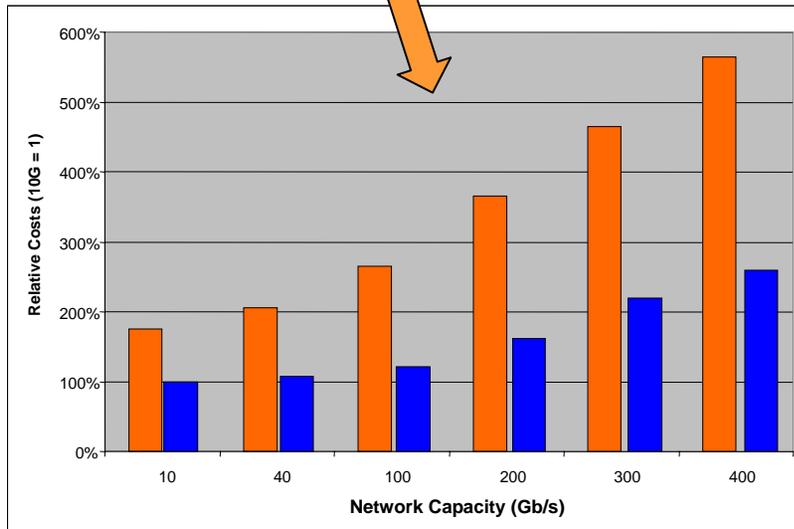
- **Optical Transport Systems**
 - Serve Long-Haul, Regional and Metro core applications
- **Key technology:**
“Photonic Integrated Circuits”
- **Enables Digital Optical Networks**
 - Dramatic cost reductions
 - Service flexibility: Add/drop any service anywhere
 - Simplify network architecture
 - Simplify engineering and operations

Infinera Network economics

“Sparse” and “Dense” Networks

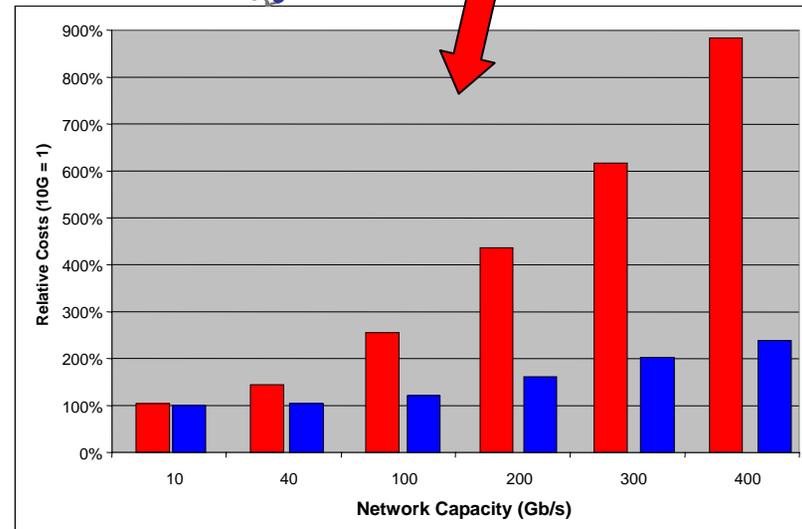
Sparse Network

- Add/Drop in 22 cities
- Maximize cost efficiency for high-capacity LD circuits

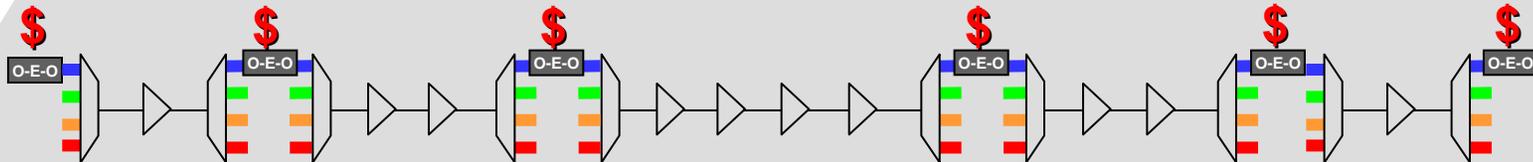


Dense Network

- Add/Drop at 98 cities
- Maximize revenue

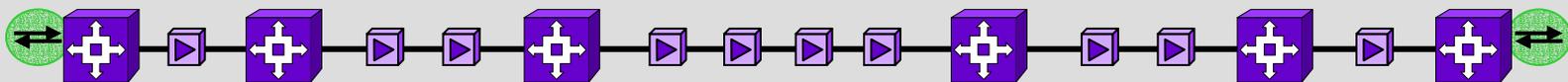


Lower CapEx: Incremental Cost for New Channels



Traditional DWDM:

Many, and costly, transponders required at every back-to-back WDM terminal



Infinera Digital Optical Network:

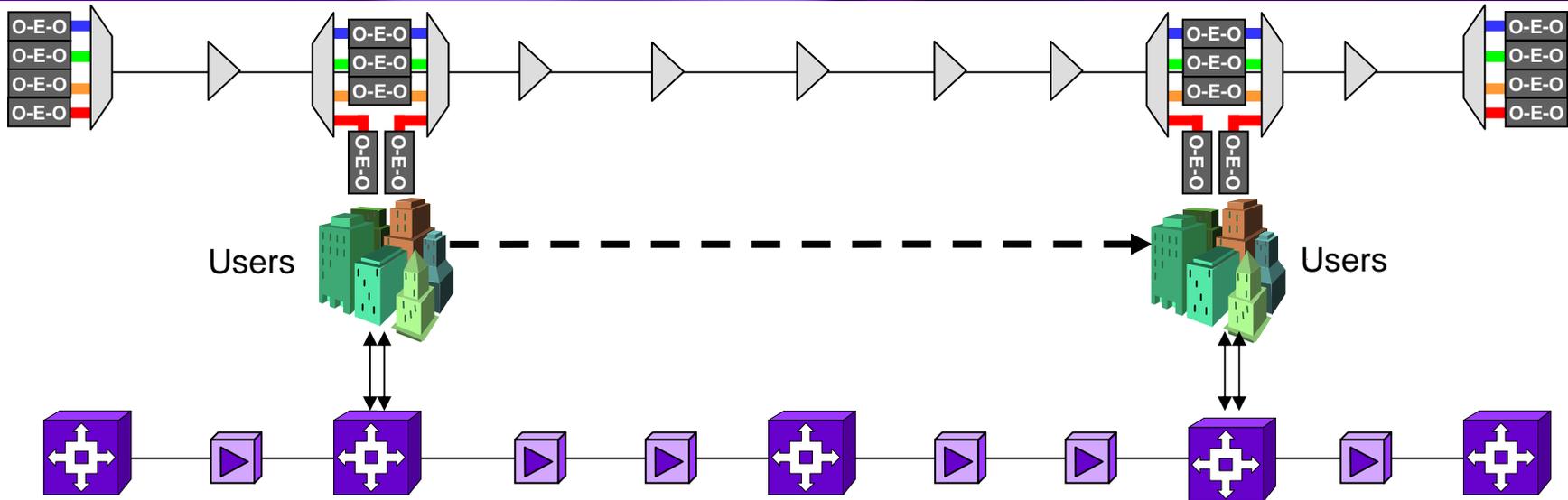
Ultra-low cost OEO for pass-through, client optics only at end points

Incremental CapEx costs for single new 10G end-end circuit:

- 225km – **68% savings**
- 480km – **78% savings**
- 940km – **81% savings**
- 1410km – **84% savings**

**Minimize service
costs to connect
new users**

Increase User Access



Option 1: Legacy

- Forgo serving location
- Minimize user access
- Reduces ROI and network value to users

Option 2: Legacy

- Lease "Off-Net" back-haul tail circuit
- Ongoing monthly costs
- More complicated planning & provisioning

Option 3: Legacy

- Convert OLA site to WDM terminal
- High CapEx cost
- Disruptive to existing users

Option 4: Infinera

- Deploy Infinera low-cost "add/drop anywhere"
- Maximize user access
- Ease of adding new users to network

Maximize network reach and value to users

Summary

A Digital Optical Network....

- Brings network to more users
- Simplifies network architecture
- Lowers CapEx – new builds & incremental channel adds
- Lowers OpEx – simplifies all aspects of operations, design & engineering
- ***Re-defines optical transport***



Thank you