



Agile 400G-800G Optical Networking

Global Research Platform Workshop 2019

San Diego

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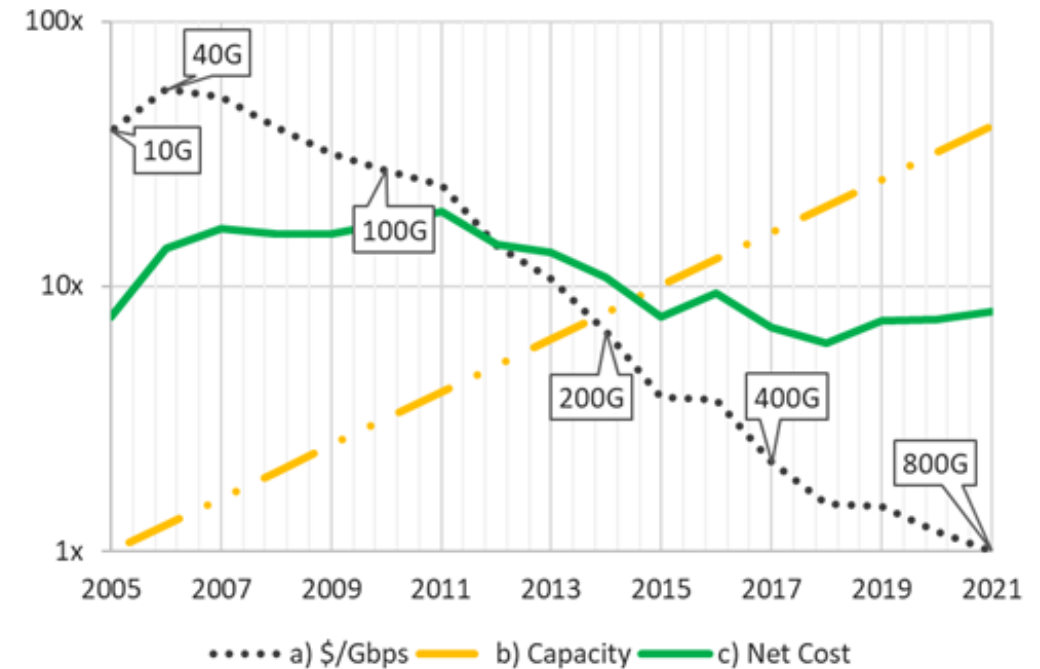
Director of External Research, Office of the CTO

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Factors influencing design of coherent optical solutions

- Equivalent 100G port capacity experiencing double digit growth YoY, no sign of slowing down
- Dependence on coherent technology innovations to drive cost / bit reductions

Coherent Technology Innovations driving transport cost reductions

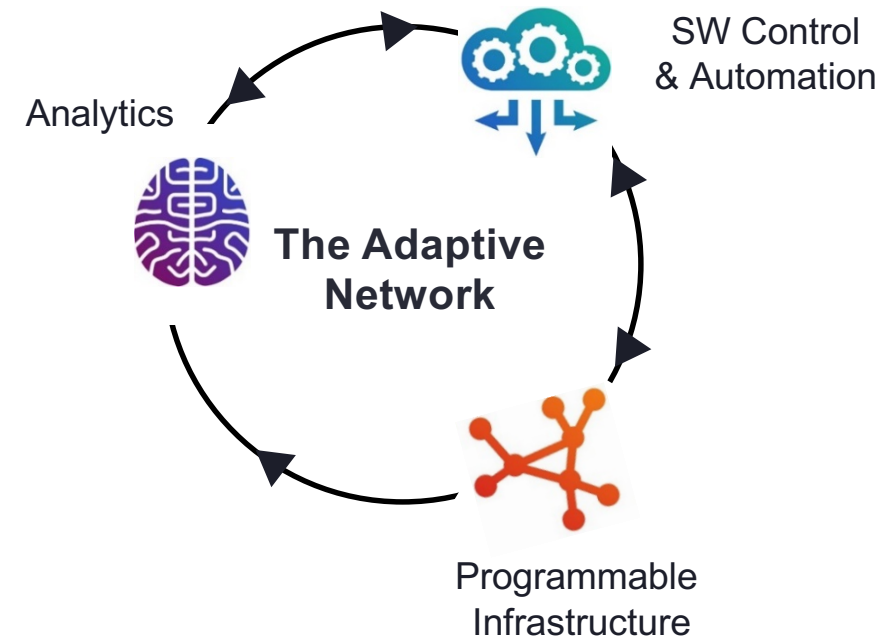


Ovum, Optical Networks Forecast: 2018 – 2023, Jan 2019

Representative cost of optical transport capacity over time and transponder generations based on historical average sales price (ASP) of DWDM line card data from Ovum.

Factors influencing design of coherent optical solutions

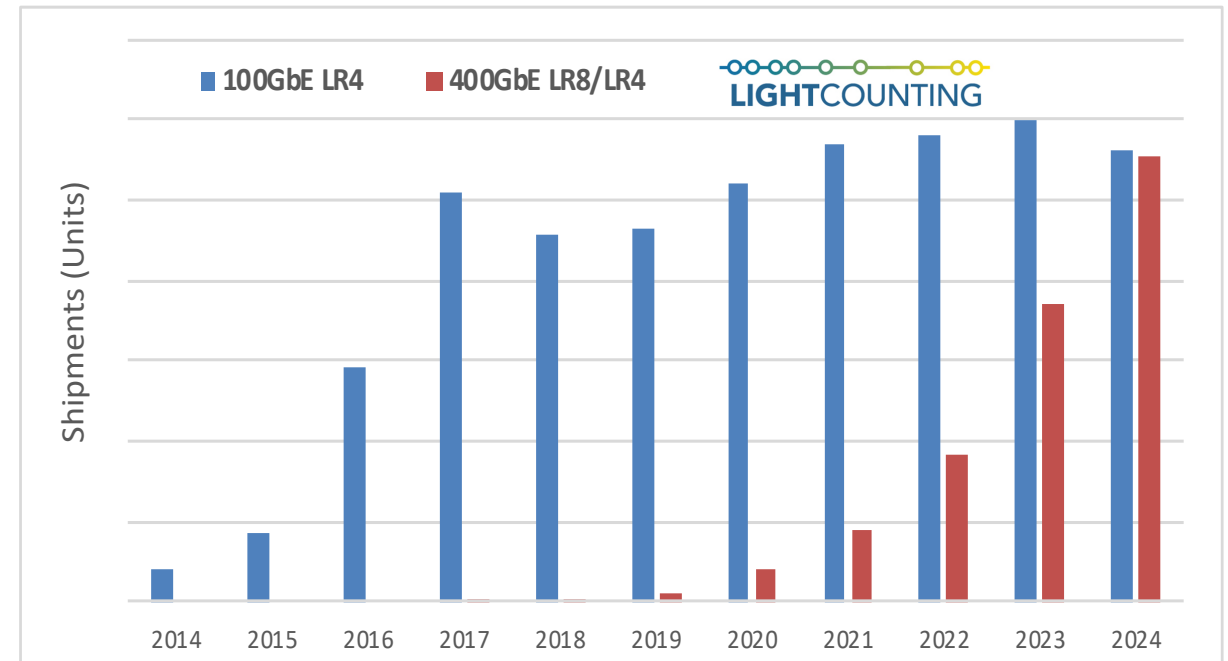
- Equivalent 100G port capacity experiencing double digit growth YoY, no sign of slowing down
- Dependence on coherent technology innovations to drive cost / bit reductions, increase competitiveness
- Dependence on software and automation for successful network evolution



Factors influencing design of coherent optical solutions

- Equivalent 100G port capacity experiencing double digit growth YoY, no sign of slowing down
- Dependence on coherent technology innovations to drive cost / bit reductions, increase competitiveness
- Dependence on software and automation for successful network evolution
- Client rates evolving from 100GbE to 400GbE

Expected introduction and growth of 400GbE LR8/RL4 clients

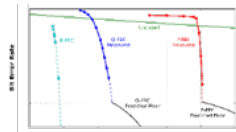
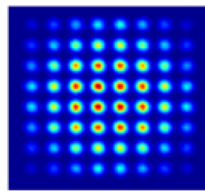


LightCounting Optical Components Market Forecast, April 2019

Two Types of Solutions Emerging for Transmission Cost Reduction

PERFORMANCE - OPTIMIZED

- Lowest \$/bit per km
- Maximum fiber capacity using least # of modems
- Ability to maximize optical layer automation



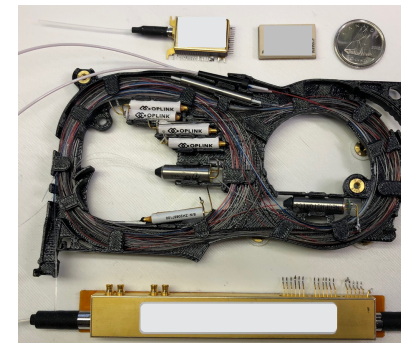
$$\frac{SNR_{ASE}}{SPM} = \frac{S(\Delta f)}{N(\Delta f)}$$

Most important element: DSP

But you also need
high bandwidth
E/O

FOOTPRINT - OPTIMIZED

- Designed to fit within specific power envelope
- Opportunity for packet-optical integration efficiencies
- Brings coherent to access applications

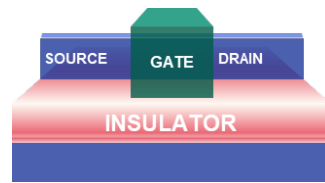


Most important element: photonic integration

But you also need
small footprint DSP

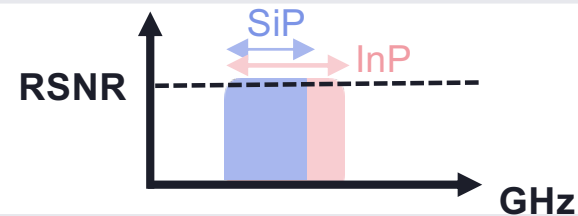
Design Choices

CMOS – Technology Node



- 7nm FinFET
- Maturity – full production
- **Benefits:**
 - Higher transistor density
 - Smaller die
 - More functions for less power
- **Considerations:**
 - Significant cost for mask tooling
 - Challenging high performance analog design

SiP or InP Photonic Integration



- **Silicon Photonics**
 - Volume # dies/wafer
 - Non-hermetic packaging
 - Cost reduction
- **Indium Phosphide**
 - Required for performance at high baud (>70Gbd)
- Moving forward:
 - “Integration” of SiP and InP provide best of both material systems

System Requirements



- **Enabling SW Automation**
 - Variable capacity rate
 - Variable baud
 - Real-time link Monitoring
- **Encryption**
- **Low-latency FEC** for time-sensitive applications

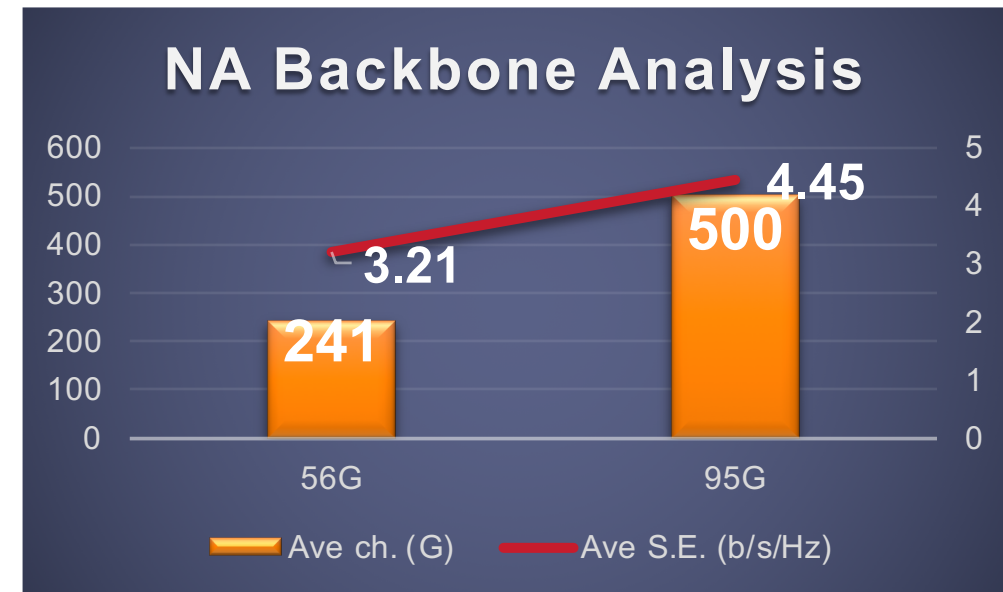
Holistic design approach provides optimized system performance

Design choices - baud

- **Baud Selection:**
 - Based on throughput objective and achievable distance for throughput based on representative network characteristics
 - Throughput selected based on expected client rates
 - Ex. 90-100Gbd for 100GE/400GE rates
 - 800G at 100km, 400G at >1,500km
- **Considerations:**
 - High-speed DAC/ADC operating at appropriate sampling rate
 - High-bandwidth electro-optics
 - FEC algorithm and coding will dictate spectral efficiency, performance
 - **Time to market will depend on control over all aspects of the solution**

- **System implications:**
 - At single wave 400G and above, >50GHz spectrum is required → flex grid WSS
 - Higher baud → more channel spectrum
 - **Appropriate software applications for spectral assignment / routing critical moving forward**

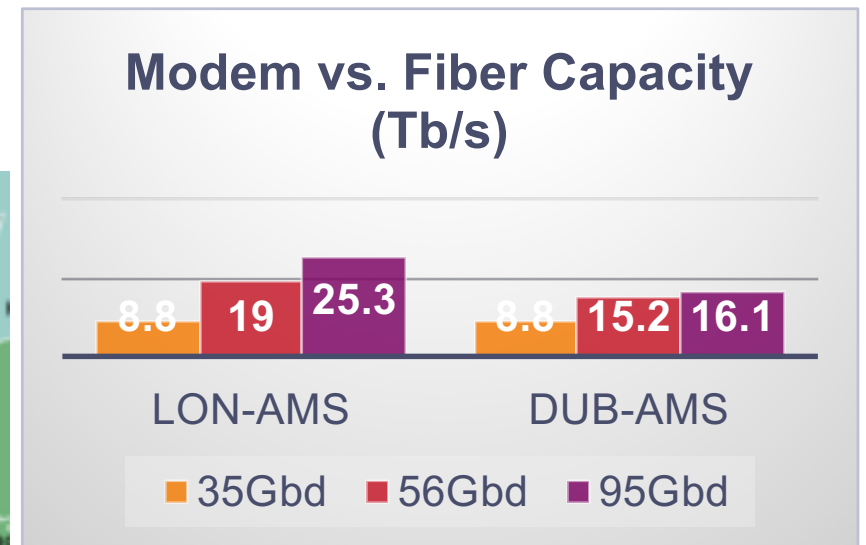
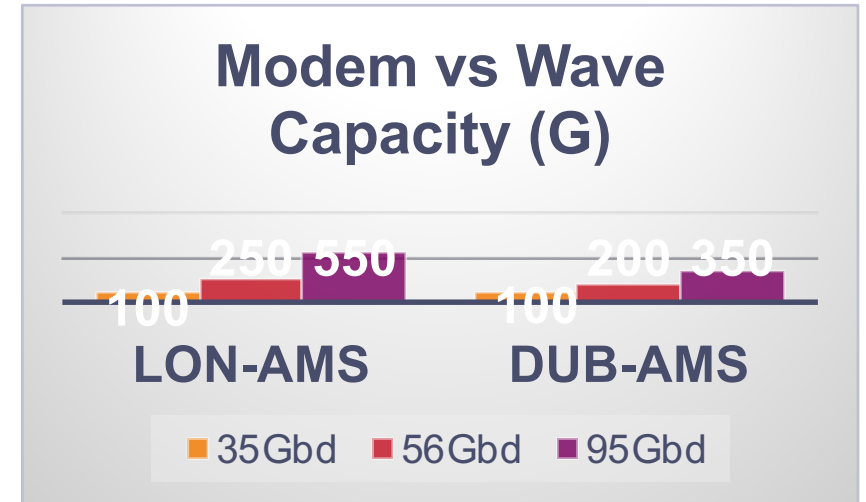
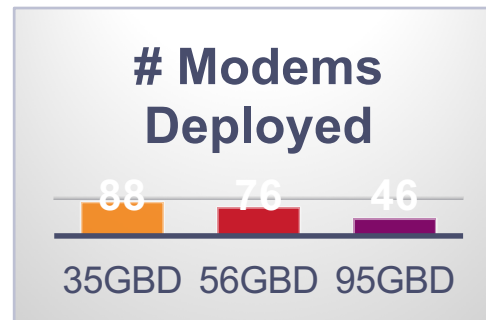
- **Example of networking benefits:**



Network benefits example of next generation coherent technology

Based on Analysis of existing Network

- Analysis completed to determine networking benefits by evolving from 100G fixed grid network to new coherent modem technologies
- Pan Euro network:
 - A: London – Amsterdam (450km)
 - B: Dublin – Amsterdam (1400km)
- Higher baud
 - Fewer wavelengths to deploy/manage
 - Reduced cost/bit
- More fiber capacity – extending life of existing asset



Summary

Key Takeaways

- 1 Upcoming advancements in both DSP and electro-optics will continue to drive down cost/bit: 7nm FinFET, miniaturization of electro-optics with SiP and InP promise significant benefits
- 2 Increasing baud reduces networking costs; design and time-to-market dependent on high speed converters and high bandwidth electro-optics.
- 3 At single wave 400G and above, flexible grid network required. Moving forward, software applications for simple spectral assignment and routing are essential.
- 4 Co-design of both DSP and electro-optics provides advantages in both system performance and time-to-market



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Thank You