PATHWAYS TOWARDS 1 Pb/s SUBMARINE CABLE CAPACITY

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Executive Summary

- SDM is required to increase submarine cable capacity
  - Increase in number of fiber pairs is overall more attractive than C+L band
  - Current belief is that 48 fiber count (24 FPs) cables are possible
- Transatlantic:
  - Can *almost* achieve 1 Pb/s with today's technology
  - Improvement in fiber attenuation and cable impedance can enable 1 Pb/s
- Transpacific:
  - Much more difficult to achieve 1 Pb/s - stretch goal
  - Can achieve 1 Pb/s but some disruptions are needed
- >24 FPs will almost inevitably be required to reach 1 Pb/s

Submarine SDM Fiber Technology Outlook

Today

Loss:
0.15-0.17 dB/km

Aeff:
80-150 μm^2

Fiber OD:
250 µm

Fiber Identification:
16 fibers (16 colors)

Next few years

Loss:
≤0.15 dB/km

Aeff:
80-115 μm^2

Fiber OD:
250 and 200 µm

Fiber Identification:
48 fibers (colors + Ring Marking)

5 years +

Loss:
0.14 dB/km or less (?)

Aeff:
Same: 80-115 μm^2

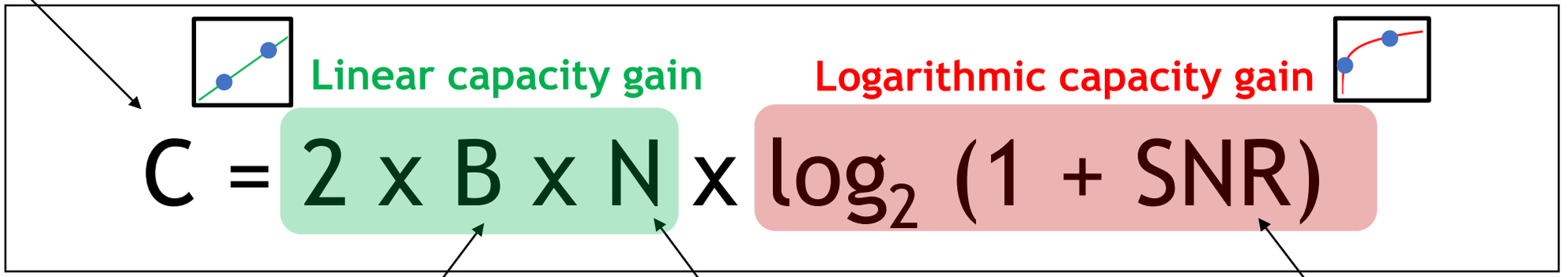
Fiber OD:
200 µm, maybe less (?)

Fiber Identification:
>48 fibers (colors + Ring Marking)

Cable and system innovations must occur in parallel to fiber innovations

Options to Increase Cable Capacity to 1 Pb/s

Cable capacity (Shannon formula)



Bandwidth (THz)
(C + L)

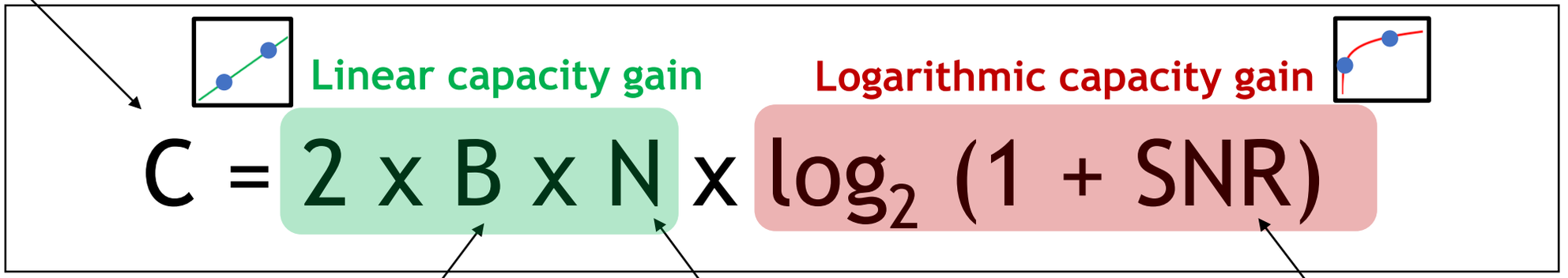
Spatial paths
(More fibers in cable)

Spectrally-efficient modulation
(optimized for given reach)

Increase in "N" is a Preferred Pathway for SDM

C+L Might be Needed Occasionally (Good to Keep in a Design Toolkit)

Cable capacity (Shannon formula)



	Transmission Performance	Power Efficiency	Capacity Scalability	Fiber Price	Cable design + fiber ID
C+L band					
More fibers					

Decision Making Criteria for SDM Systems

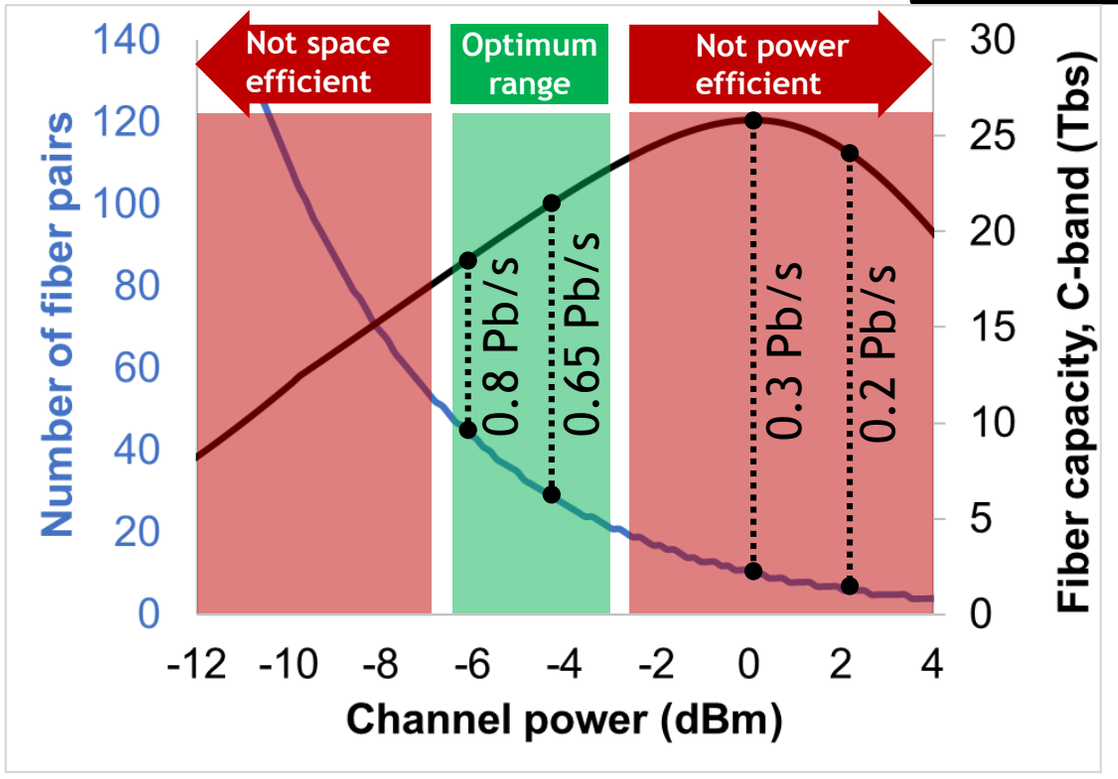
Achievable Cable Capacity Falls Short of 1 Pb/s

Additional Improvements are Needed (Easier for Transatlantic)

115 μm² fiber

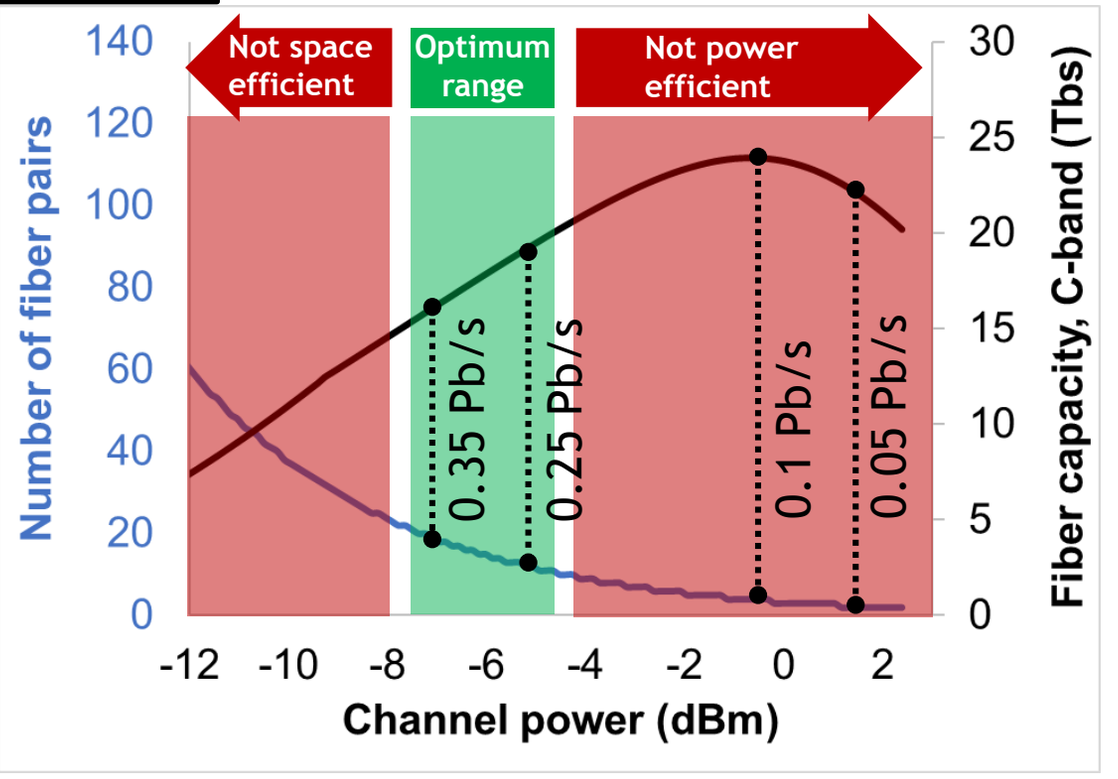
PFE = 15 kV; Cable = 1 Ω/km
EO = 1.5%; Att = 0.150 dB/km

Transatlantic



- Can *almost* reach 1 Pb/s
- >24 FPs (>48 FC) likely to be needed

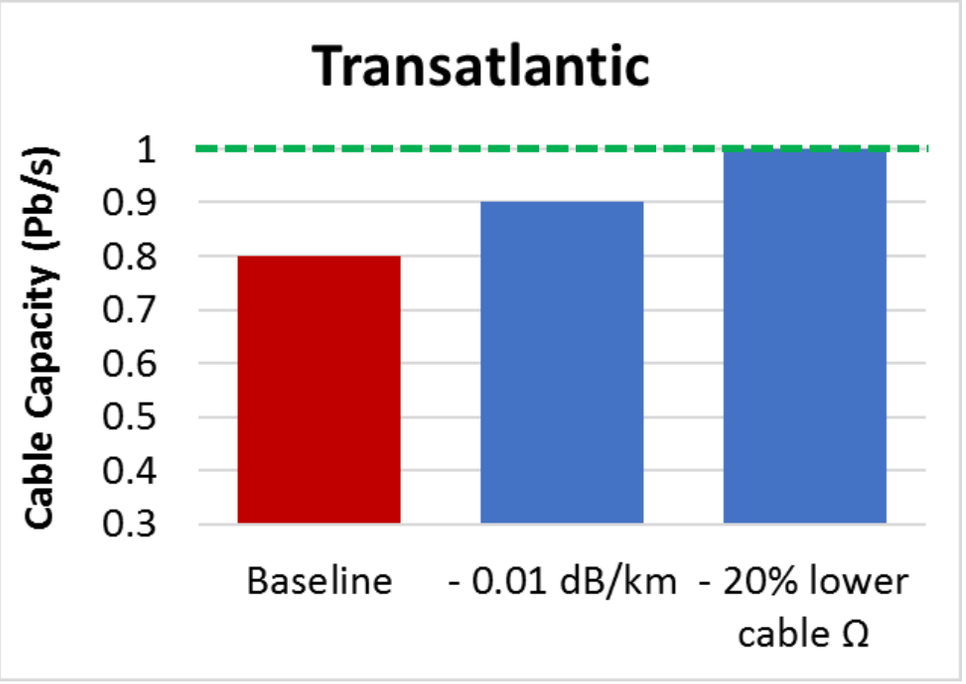
Transpacific



- <24 FPs (<48 FC) may be sufficient
- But significant gap to 1 Pb/s

Can Achieve 1 Pb/s in Transatlantic
With Some *Cumulative* Improvements

115 μm² fiber

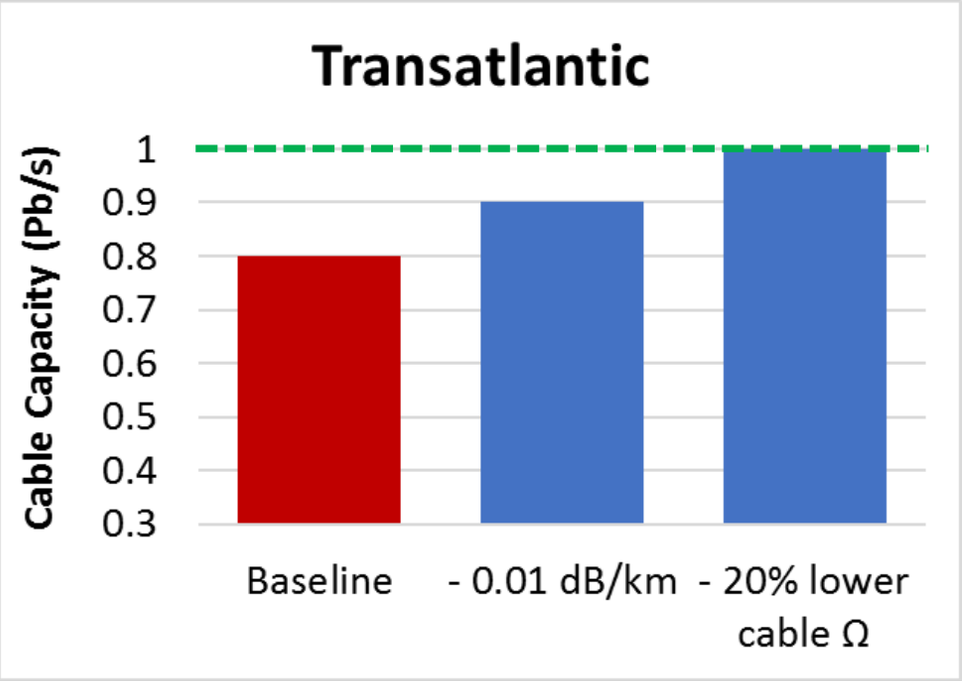


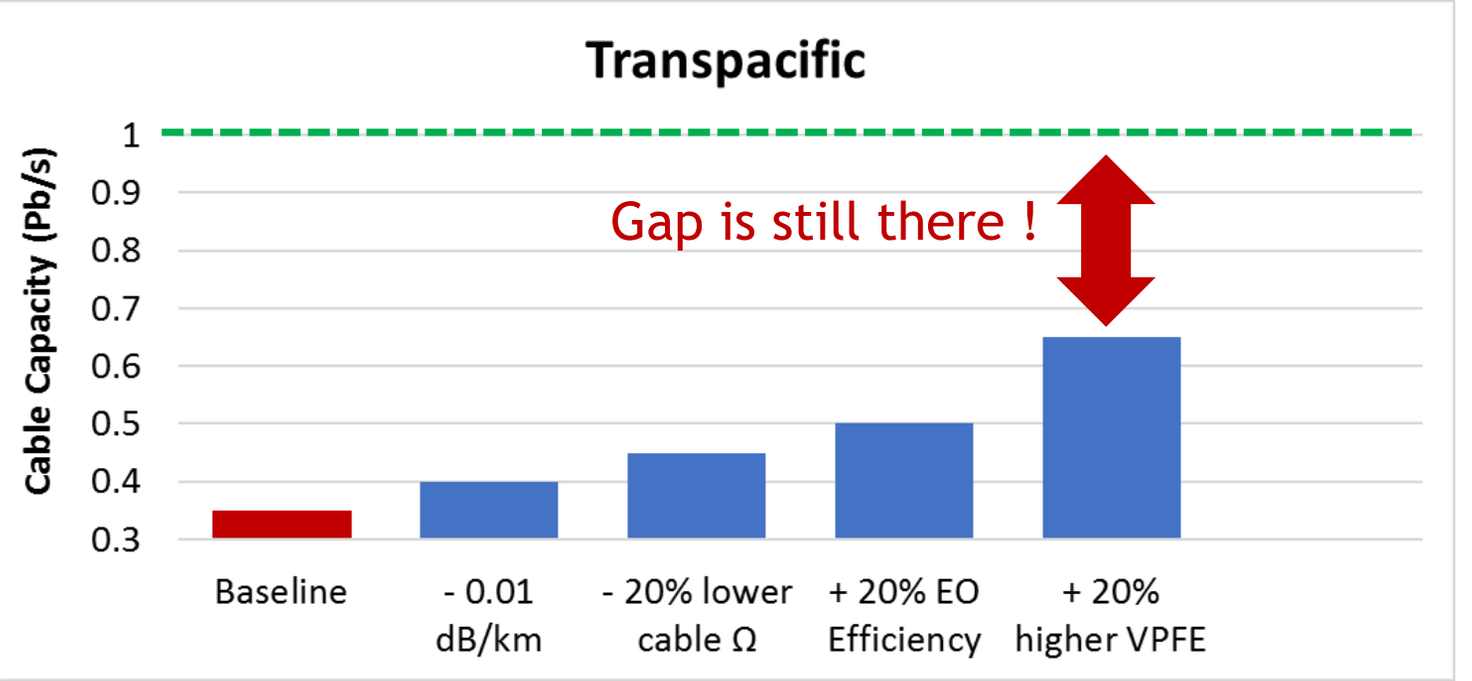
Baseline:

V_{PFE} = 15 kV; Cable = 1 Ω/km; EO Efficiency = 1.5%; Attenuation = 0.150 dB/km

1 Pb/s is Much More Difficult to Achieve in Transpacific
Ambitious Improvement Are Needed

115 μm² fiber





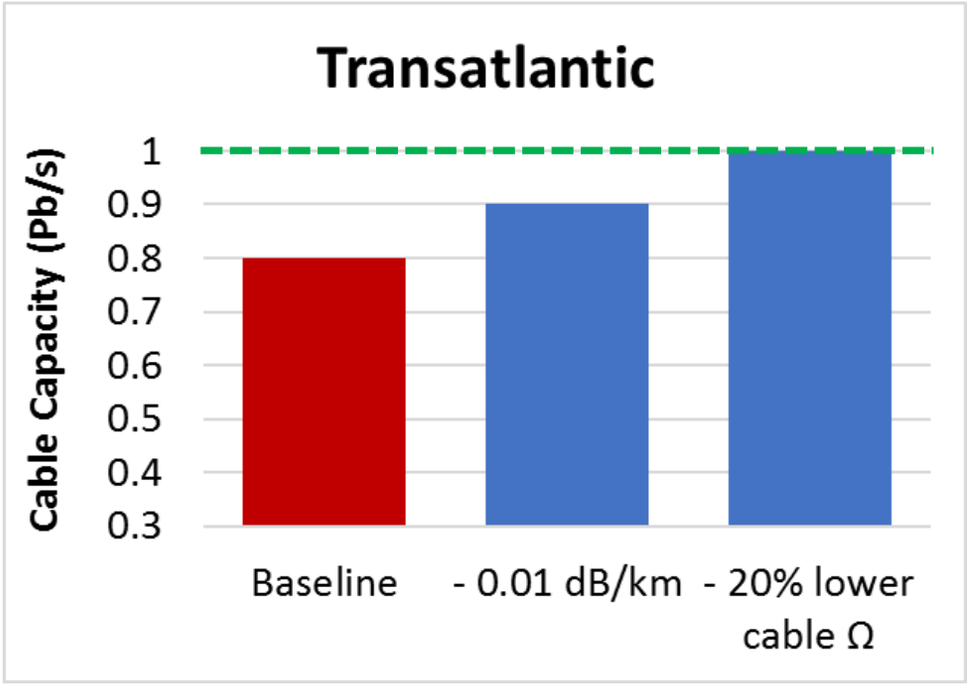
Baseline:

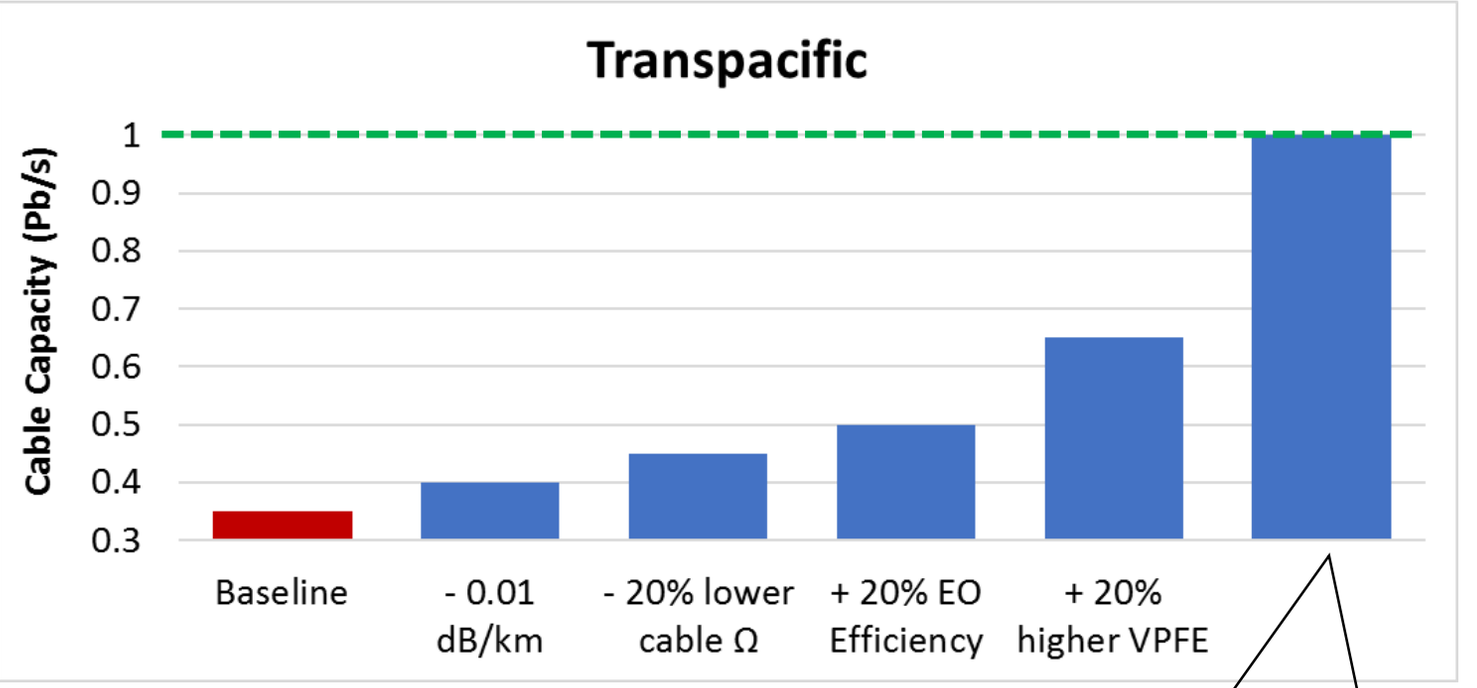
V_{PFE} = 15 kV; Cable = 1 Ω/km; EO Efficiency = 1.5%; Attenuation = 0.150 dB/km

Further Innovations are Needed (Some are Disruptive)

Innovations Must Comply with Low Cost Per Bit SDM Paradigm

115 μm^2 fiber





Baseline:

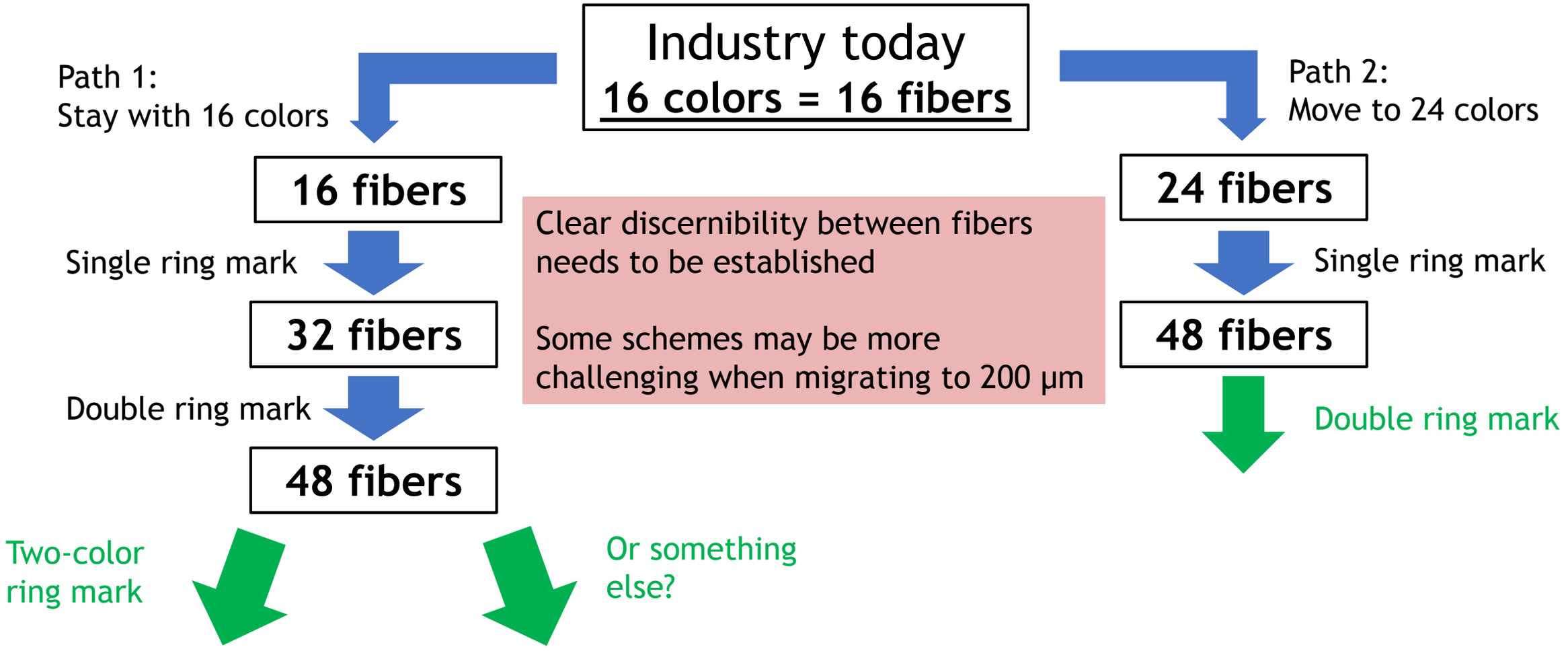
V_{PFE} = 15 kV; Cable = 1 Ω/km; EO Efficiency = 1.5%; Attenuation = 0.150 dB/km

- 0.02 dB/km !!
- 40% cable Ω
+ 20% EO Efficiency
+ 20% V_{PFE}

Number of FPs must increase (up to 48 FPs !!)

Identification Options For >48 Fibers

Assume That >48 Fibers (e.g. 200 µm) Can Be Inserted in Central Tube With Acceptable Microbend Performance



What About More Exotic Fiber Options for The Future

200 um is likely next step. Challenges remain for RCF and MCF

250 µm SCF
(Baseline)

200 µm SCF

Next logical step

Can leverage experience from terrestrial

165 µm RCF
(80 µm cladding)

Potentially higher microbend loss

Mechanical reliability must be evaluated

250 µm MCF
(4 cores)

Ecosystem not ready

Cost per bit likely higher than for SCF

QUESTIONS?