AccuCore HCF™ (Hollow-Core Fiber) Low-Latency Amplification and Optical Transmission

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Hollow-Core Fiber can Trim Time by Replacing Glass-Core Fiber

Shaving Fractions of a Second can Deliver Substantive Advantages and Monetary Gains

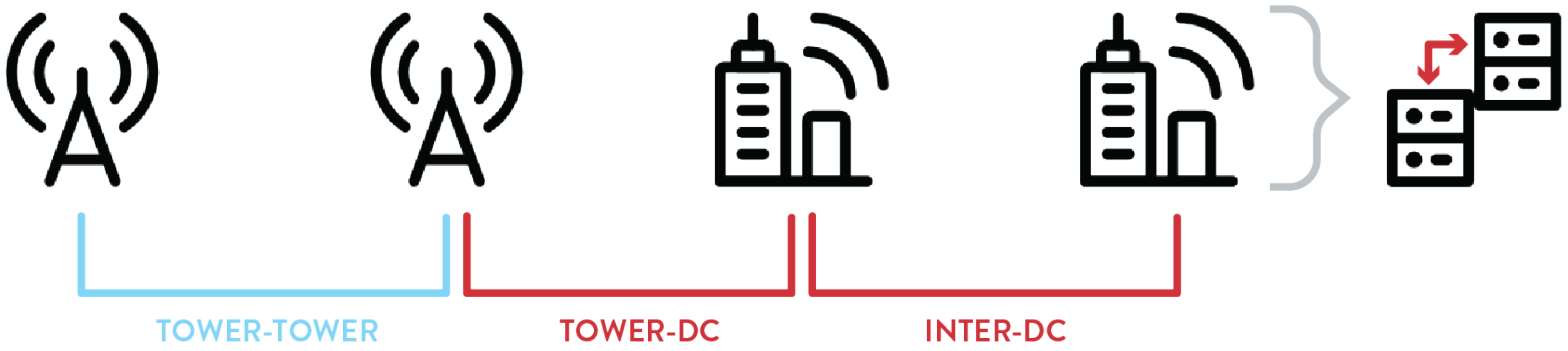
OUTSIDE DATA CENTERS

Use microwave radio links
Compared to optical fiber:

- Shorter distances
- Faster

INSIDE DATA CENTERS

- Specialist hardware (i.e. FPGAs)
- Algorithms in assembly language code



But Tower to DC and Intra-DC use glass-core fiber

Acronyms: DC = data center, FPGA = field-programmable gate array

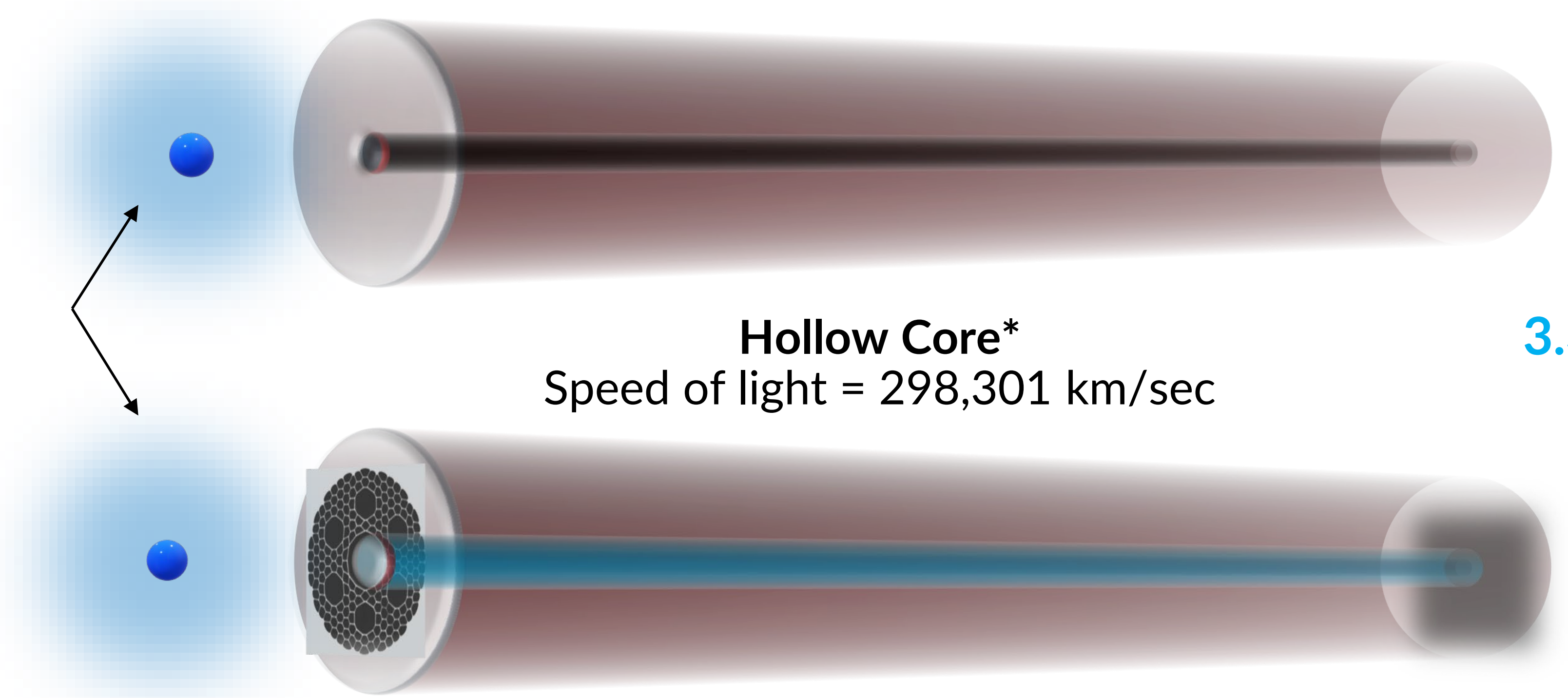
Light Travels Faster in Hollow-Core Fiber than in a Conventional Glass Fiber

1.5 Microseconds per Kilometer (km) Latency Improvement

Glass Core
Speed of light = 204,190 km/sec

Time to travel 1 km
4.897 microseconds

Photons of Light



Hollow Core*
Speed of light = 298,301 km/sec

3.352 microseconds

*Hollow core—transmit light in air core

The Challenge: to realize the latency improvement in field deployed networks because the fiber (i.e., hollow core) is intrinsically sensitive to external stress.

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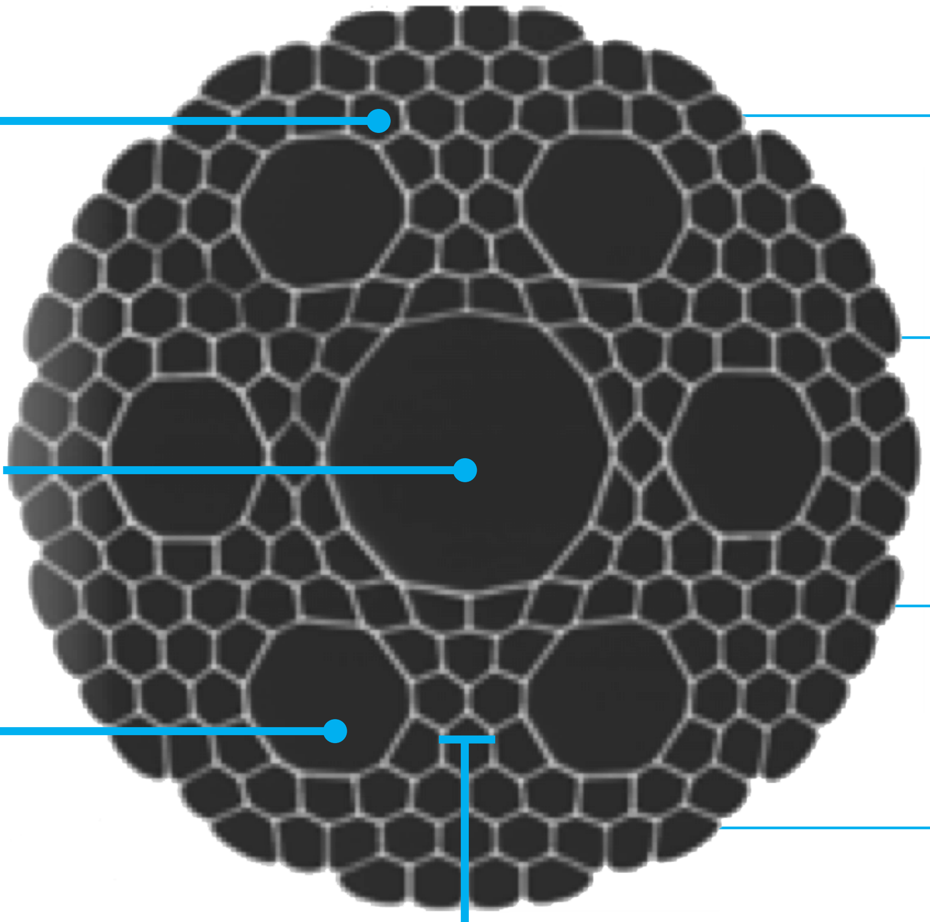
AccuCore HCF (Hollow-Core Fiber) Cables Operational Today in Real Networks
*STAC Benchmark: 1.6 ns per meter latency improvement

Period Air/Silica Cladding
Photonic Bandgap Fiber: For Low-Loss Confinement at Desired Wavelength

Hollow (air) Core

Shunt
OFS technology to improve signal purity



Cable
Indoor/Outdoor

Termination
Factory and Field

Installation
OFS Service

Component Selection
Passive and Active

*https://stacresearch.com/OFS210430

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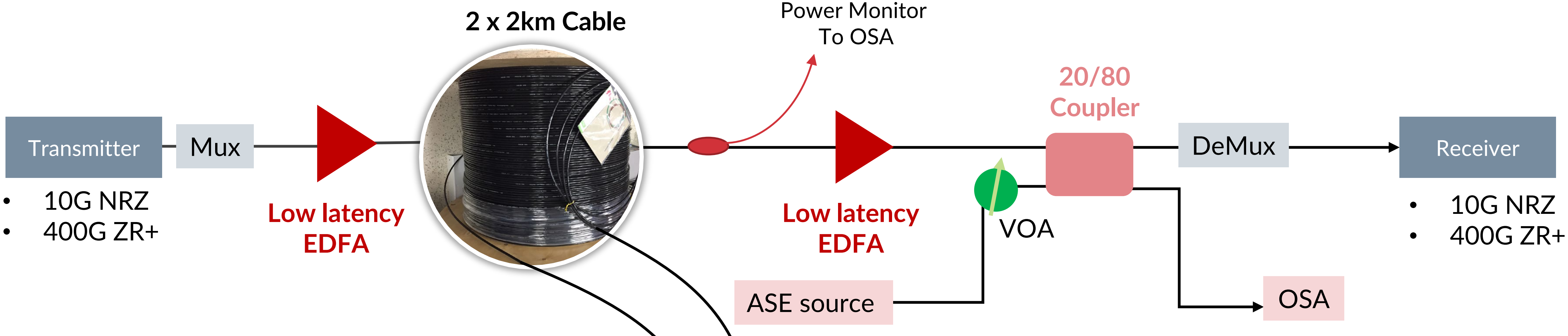
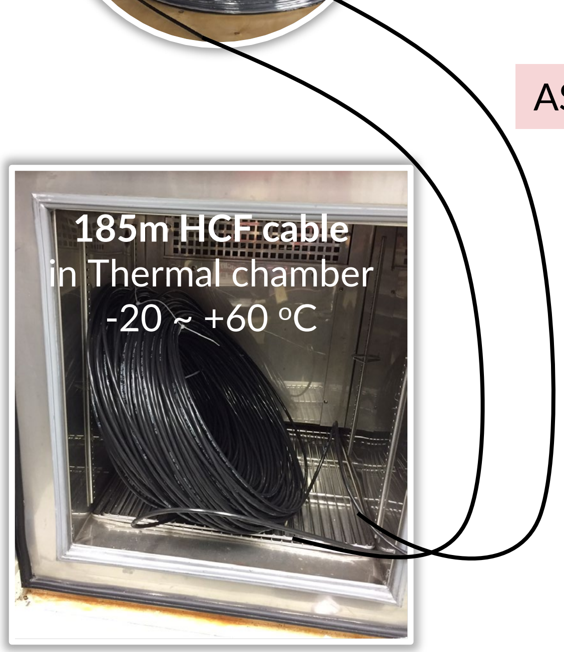
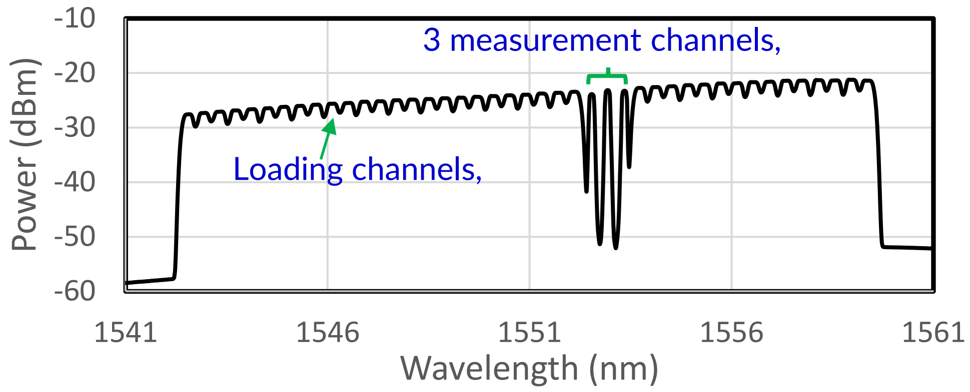
Experimental Setup for 4km System Evaluation







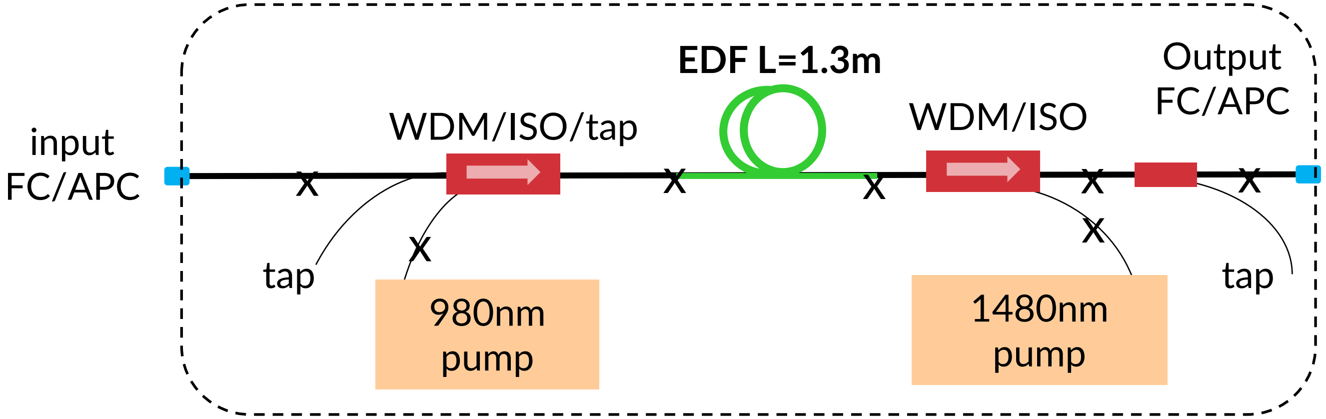
Acronyms:
NRZ—non-return to zero;
G—gigabits per second;
Mux--multiplexer
EDFA—erbium doped fiber amplifier;
ASE—amplified spontaneous emission;
VOA—variable optical attenuator;
OSA—optical spectrum analyzer;
DeMux--demultiplexer

Low-Latency Erbium Doped Fiber Amplifier (EDFA)

- **High gain**
  - 30 dB; P_{out} >25 dBm; NF < 5 dB
- **Low Latency**
  - 1.9 m amplifier length
- **10 times amplifier length reduction**
  - ~88 ns time savings per amplifier

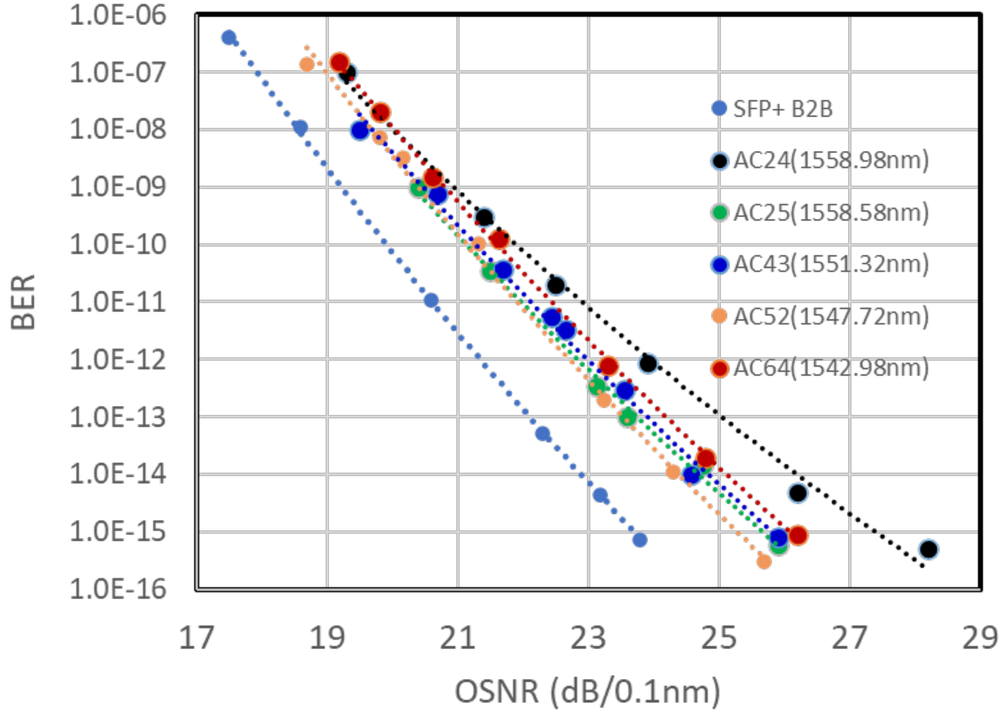
Beneficial for long-length HCF systems

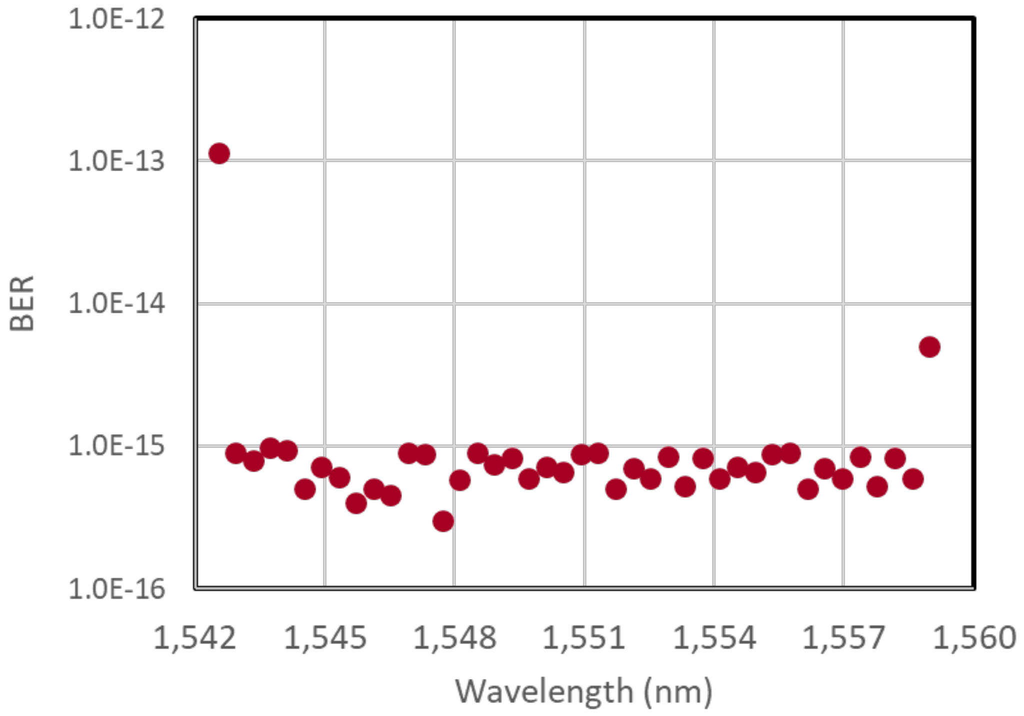
Configuration of Low Latency Booster EDF



Acronyms: NF is noise figure; m is meter; nm is nanometer; L is length; WDM is wavelength division multiplexing; EDF is erbium doped fiber; ISO is isolator

10Gbps NRZ transmission over 4km HCF cable

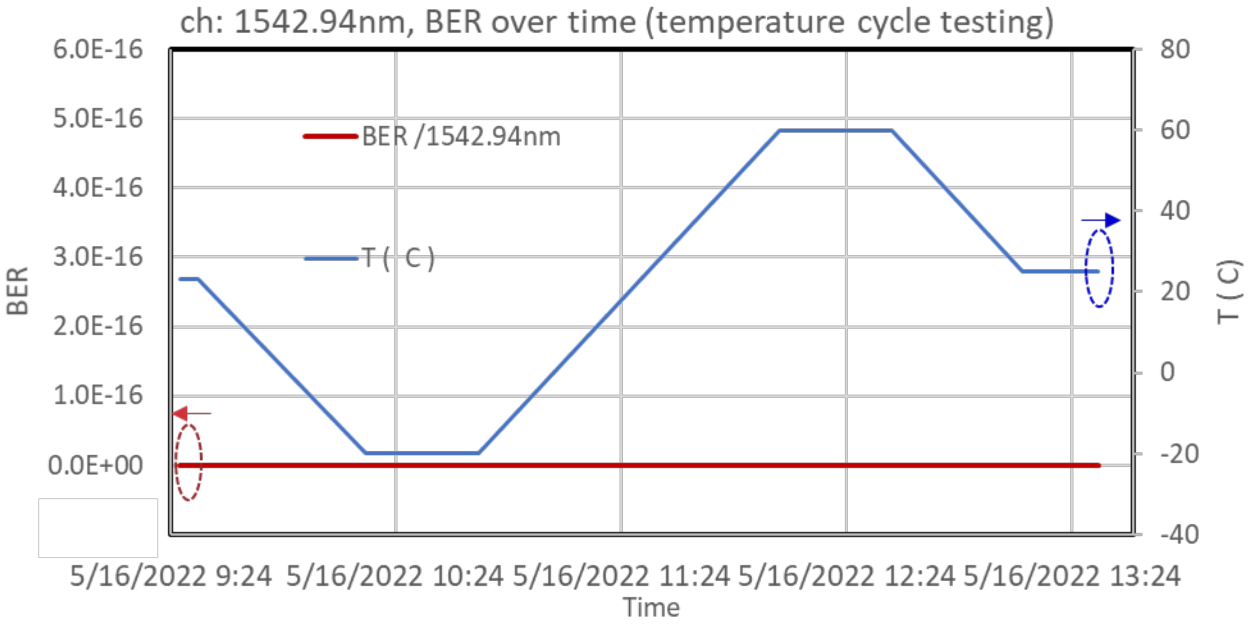


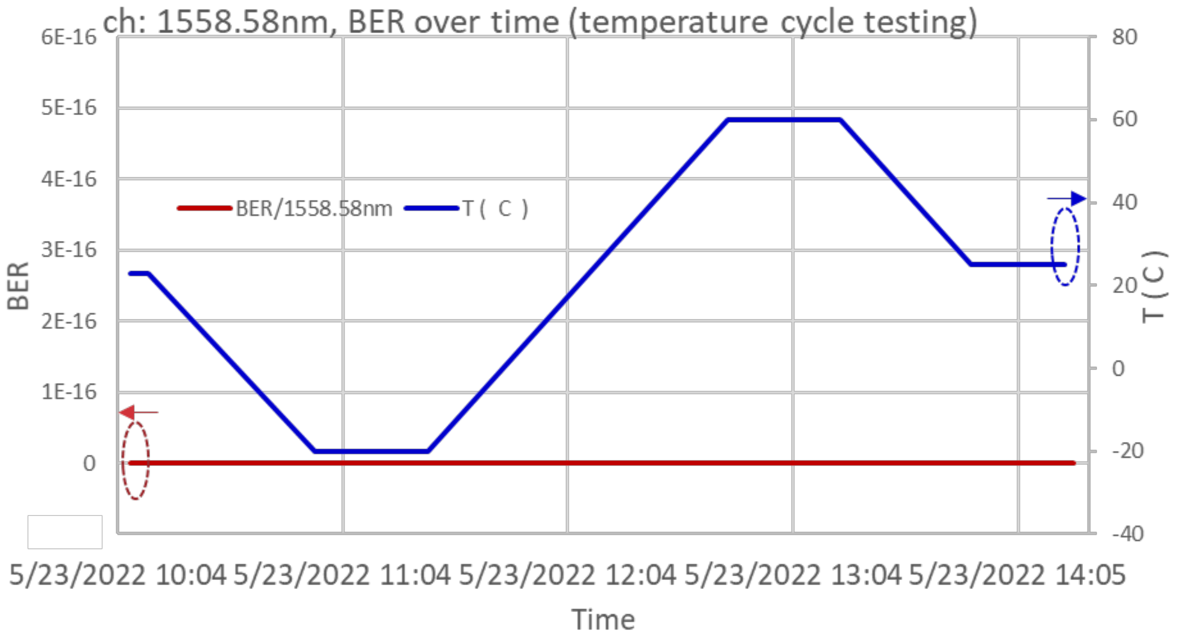


Forty 10 Gbps channels at 50 GHz spacing

- BER<1x10^{-15} at OSNR of around 26 dB/0.1 nm
- Typical OSNR penalty <2.2 dB/0.1 nm (compared to B2B)

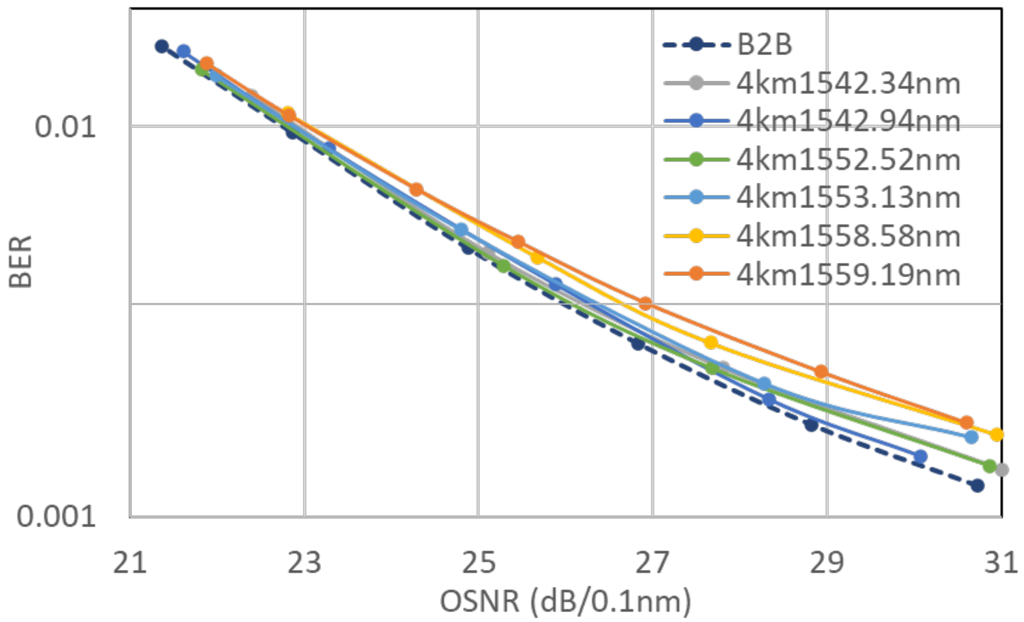
10Gbps NRZ temperature cycle (-20 to 60 ˚C) testing

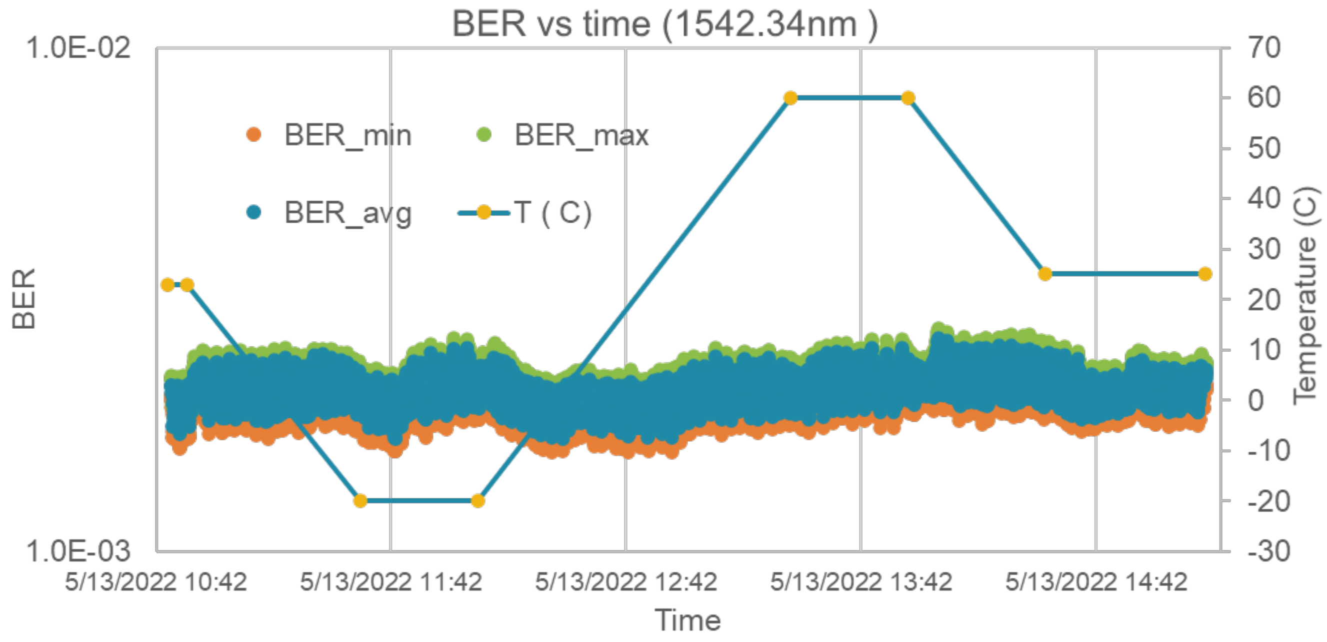




- BER of 3 channels recorded every 5 seconds during temperature cycle
- Received OSNR set to 27.5 dB/0.1 nm
- No error recorded during the temperature cycling
    - Implications: the impact of CD, DGD, MPI, and loss is small due to temperature change

400Gbps DWDM test results using ZR+ transceivers





- 29 channels at 400 Gbps with 75 GHz channel spacing at room temperature
  - BER<3.5×10^{-3} at OSNR of ~27 dB/0.1nm; OSNR penalty <1.5 dB/0.1 nm at BER of 3.5×10^{-3} (compared to B2B)
- BER are stable over the time during temperature cycling
  - 28 channels at 400 Gbps can be transmitted during temperature cycling
  - Impact on MPI and attenuation are small

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AccuCore Low-Latency Amplified Signals to Trim Transmission Time

Generation 1: Use AccuCore where glass core single mode fiber is typically used.

Key Transmission Accomplishments for 4 km

- Low-latency erbium amplifier developed
- 40 channels of 10 Gbps transmitted
- 28 channels of 400 Gbps transmitted
- Preliminary temperature cycling show good performance

Generation 2 Under Development
1310 nm transmission window

OFS is happy to discuss user needs

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Thank You

Any Questions?

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