Fiber options for support of 1 to 5 Peta bit subsea cables

September 20, 2022

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Agenda

01 Status quo loss @ 1550 nm

02 Options for increasing 0.5 to 5 Petabit/s

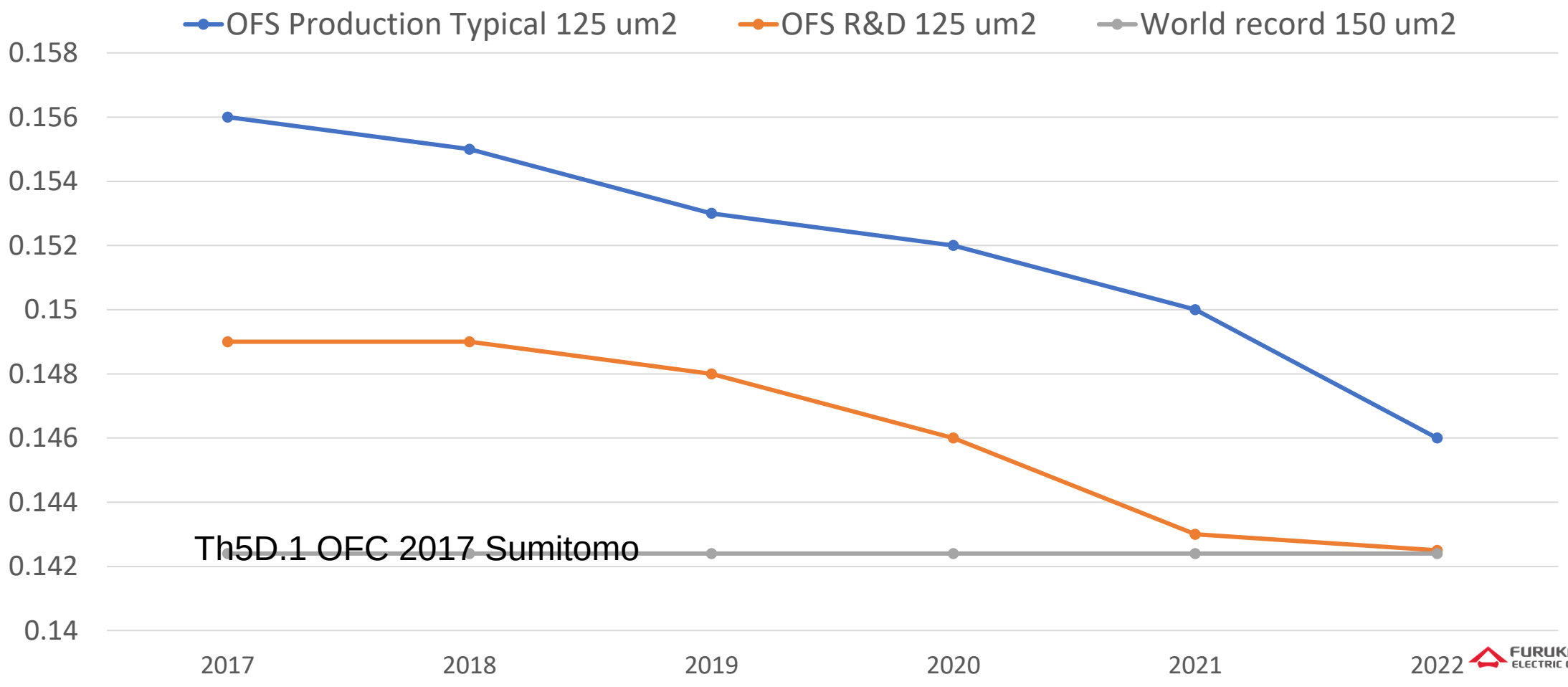
03 Fibers inside the repeater

04 Summary

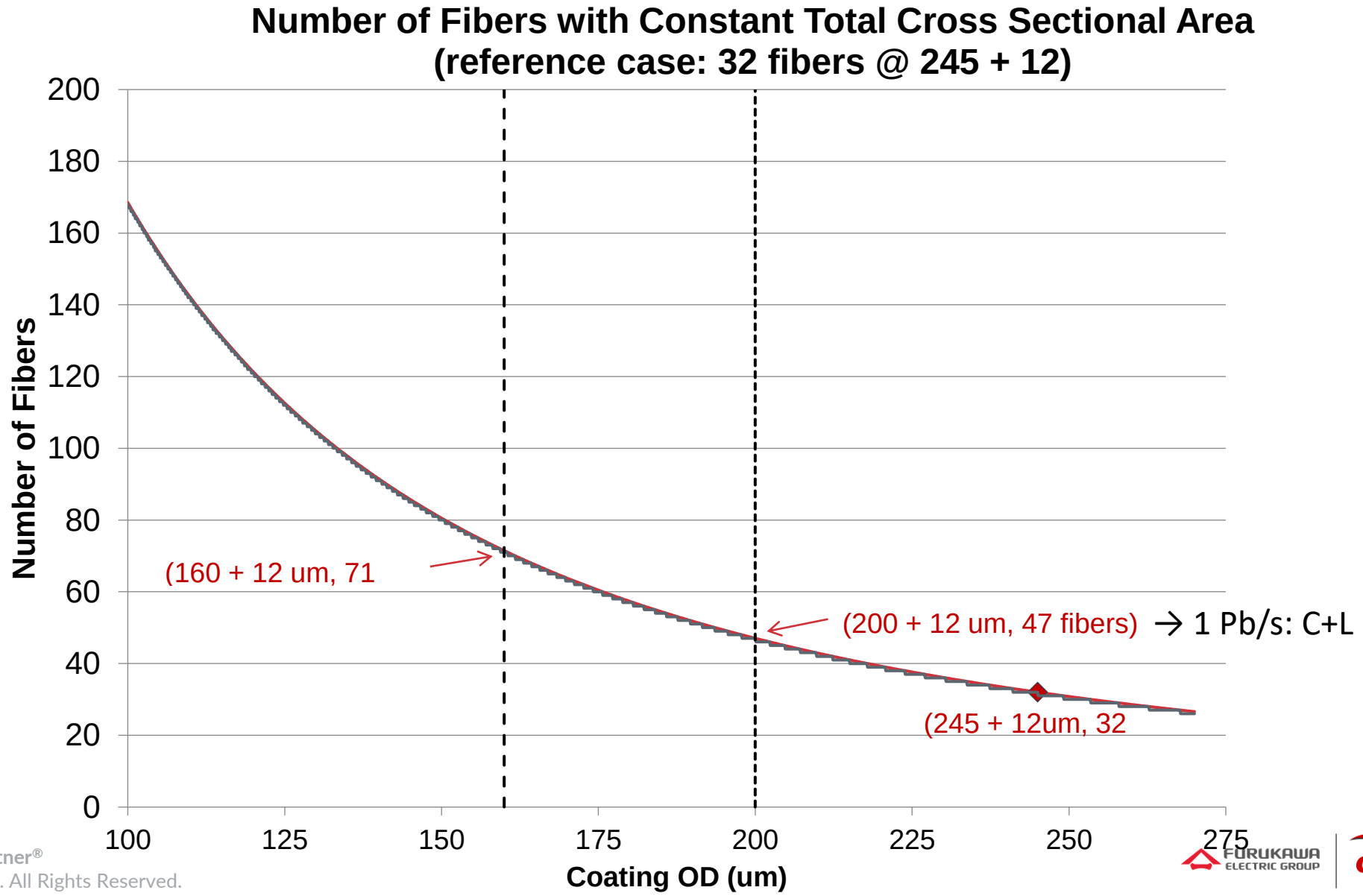
05

06

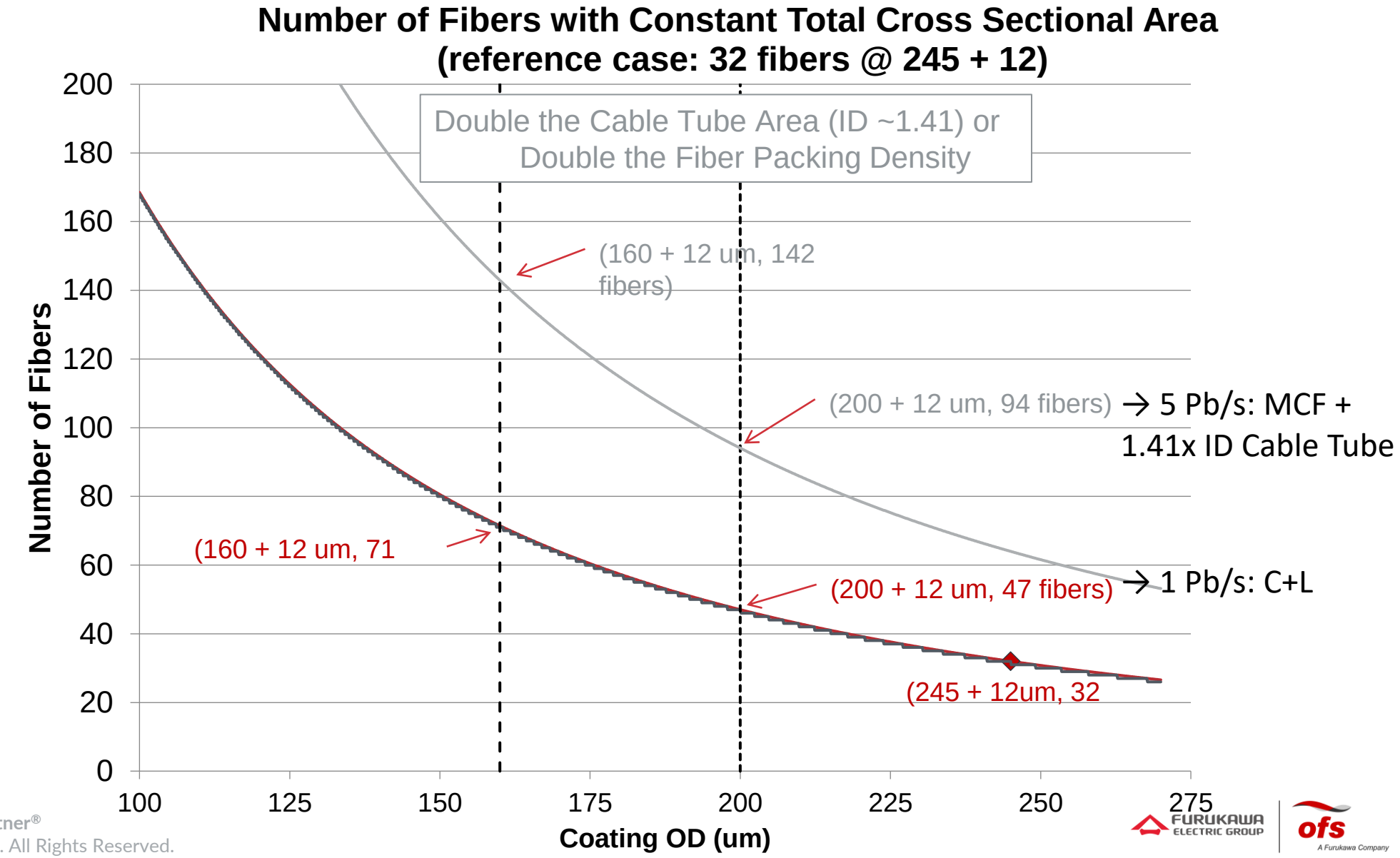
Fiber Attenuation at 1550 nm



Fibers inside the cable tube



Fibers inside the cable tube

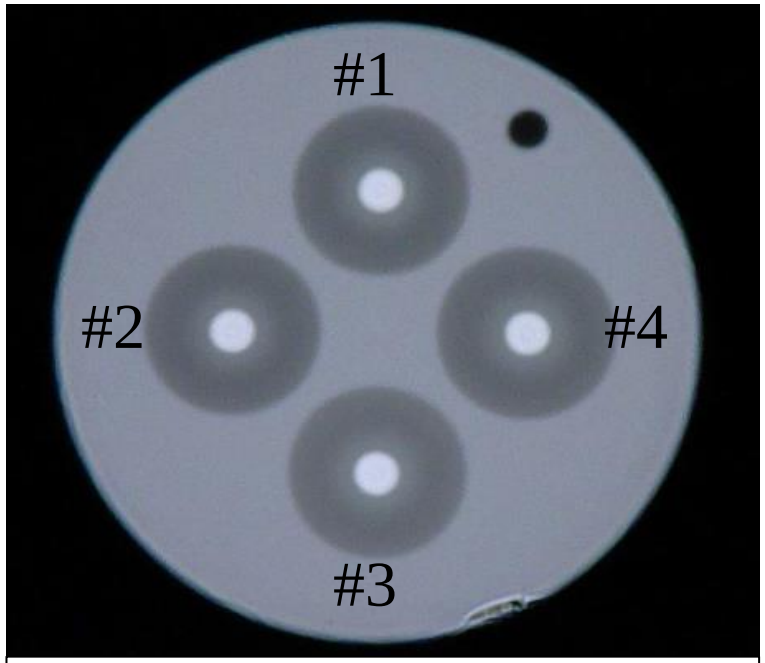


4-core Multicore Fiber (MCF)

Takahashi et.al. ECOC 2020

Tab. 1: Characteristics of fabricated MCF at 1550 nm

Characteristics	Unit	Value
Cladding diameter	µm	125
Coating diameter	µm	245
Core pitch	µm	43.0
Effective area	μm^2	87.1
Cut-off wavelength (22m)	nm	1539
Dispersion	ps/nm/km	22.6
Dispersion slope	$ps/nm^2/km$	0.06
Attenuation loss	-	-
Core 1	dB/km	0.155
Core 2	dB/km	0.156
Core 3	dB/km	0.157
Core 4	dB/km	0.155
Inter core crosstalk	-	-
Core 1 – Core 2	dB/100km	-63.8
Core 2 – Core 3	dB/100km	-60.7
Core 3 – Core 4	dB/100km	-62.7
Core 4 – Core 1	dB/100km	-61.8



Work last 2 year
* Scalable solution
* Splice loss 0.03 dB

Tu3A.3 Kremp et al

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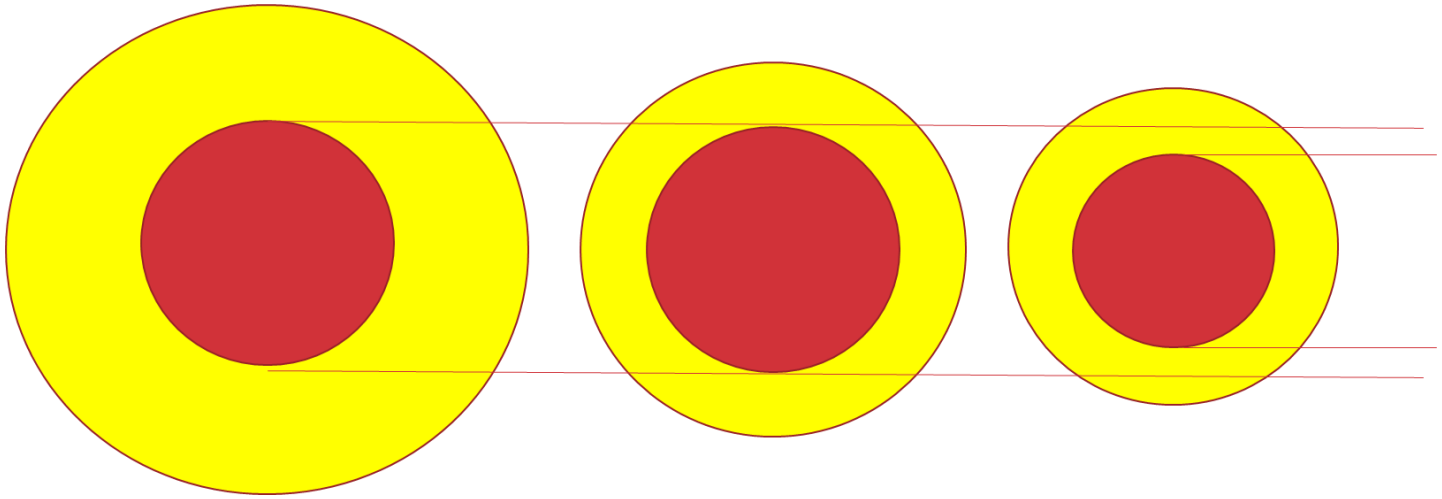
Smaller fibers

250 μm coating
125 μm fiber
Coating 62.5 μm

200 μm coating
125 μm fiber
Coating thickness 37.5

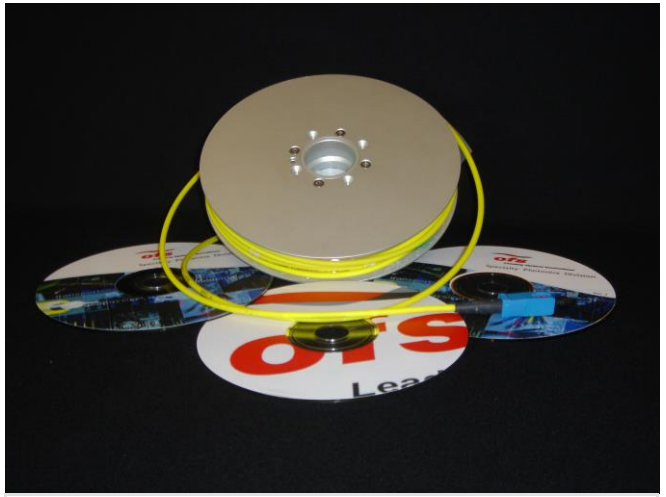
165 μm coating
100 μm fiber
Coating thickness 32.5



1X packing density

1.5 X packing density

2 X packing density



Dispersion comp fiber	
Cladding	90 um
Coating	145 um
Introduced	2006
Splices #	700000
Volume (mio km)	1.5

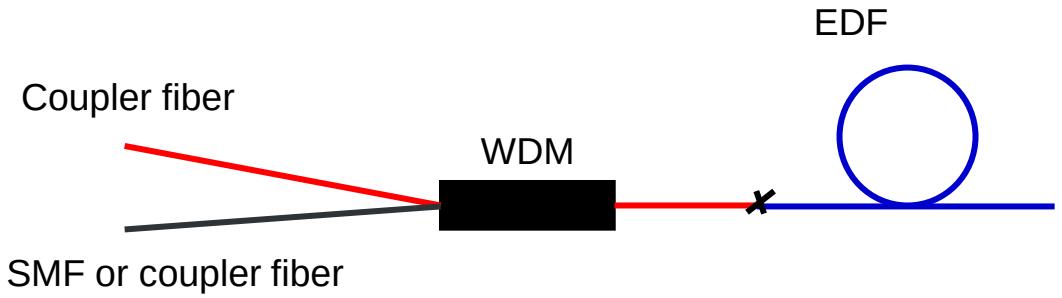
- 165 μm coated fibers may require (~100 μm) fibers and thinner coatings.
- Can we hit attenuations equivalent to the standard SCUBA fibers?
- Microbending will be higher for the smaller dimension fiber.
- Can we move to a lower effective area? This will improve bending properties

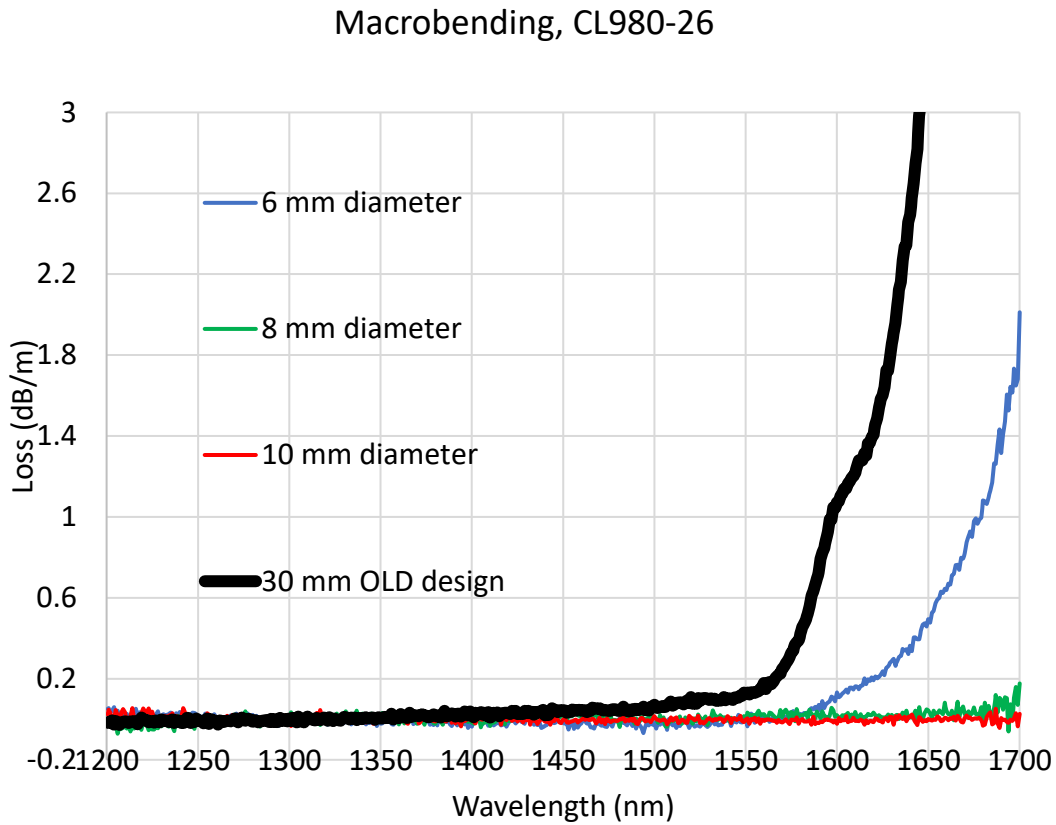
Fibers inside the repeater

- With # cores increasing to 100's the repeater box is becoming "busy"
- Bend insensitive fiber designs desirable – eg coupler fiber

Next generation fiber for making fused coupler/WDM's

- Lower or similar splice loss @ 1550 nm (0.1 dB)
- Half splice loss at 980 nm (0.04 dB)
- Better bending performance – practical bending diameter from 40 mm to 6 mm





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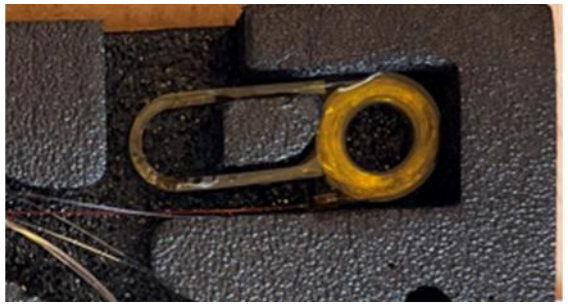
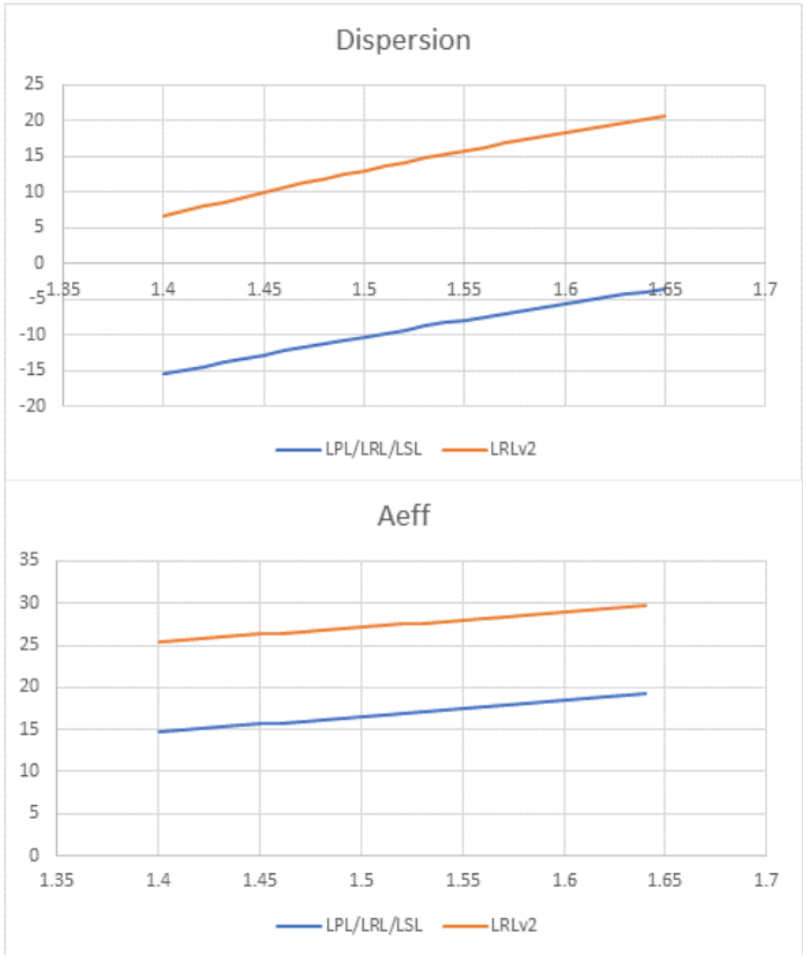
EDFA both C band and L band working well

- L band EDF
  - Noise optimized by mitigating FWM:
    - Effective area 30 um2 – 2 X ”normal”
    - Dispersion 2 digit in L band
  - Efficiency vs length optimized
    - App 30 m / amp
  - Low bending loss
    - Can be fully utilized in 80 um version





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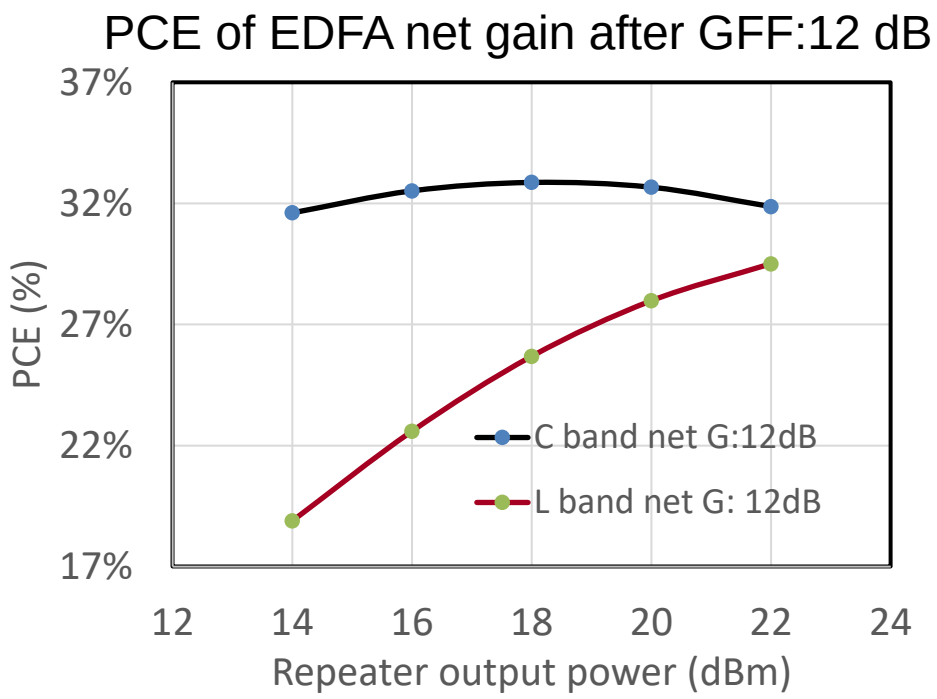
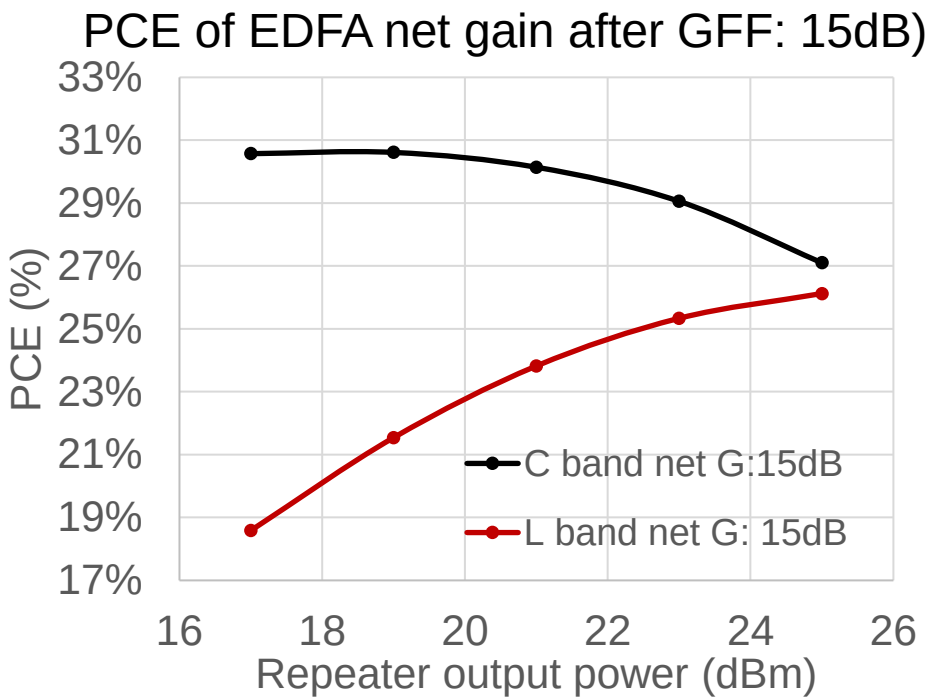
EDFA PCE C-band vs L-band

40nm bandwidth for each band

Repeater design for transpacific link



Repeater design for transatlantic link



- C-band wavelength 1526.8nm-1566.8, L-band 1568.8nm-1608.8nm
- At high power operation, the PCE of L-band is close to C-band, the PCE of L-band at low power operation can be improved by optimize the waveguide design of EDF (e.g. reduce the MFD)
- 0.5dB loss at in/output is included in the OASix simulation

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MCF EDFA – preview of Th2A.4

Power consumption is decreasing

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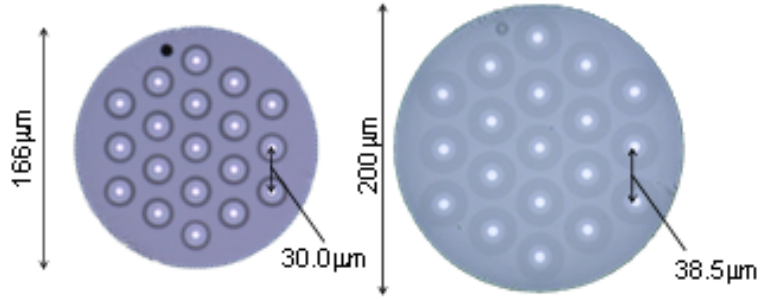
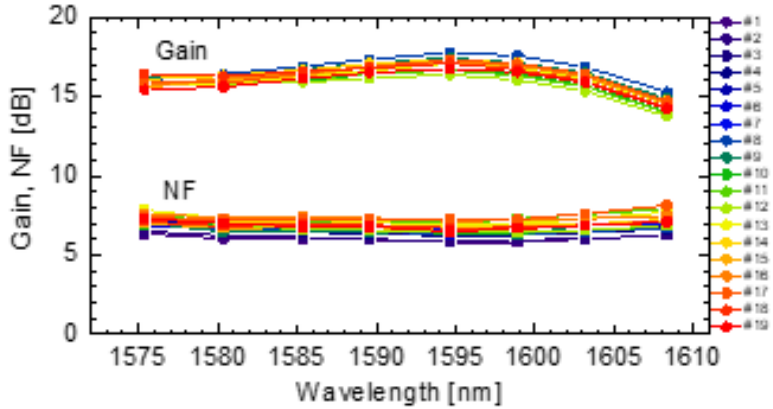
- Power consumption close to that of conventional EDFAs was achieved by reduction of cladding diameter Check Th2A.4
  - 1.2 W/core for L-band 20 dBm/core output where output power of MM-LD was 11.2 W with power consumption of 22.1 W



Recent 19-core EDF Previous 19 core EDF

Cross-sections of 19-core EDFs



Gain and NF of the recent 19-core EDFA

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Can EDFA be replaced by semiconductor amplifier (SA) to reduce footprint and cost?

- Noise
- Power efficiency
- PDL
- Cross talk
- Reliability
- Footprint
- Cost

Summary :
Options for increasing # cores/bands to >100 in a submarine cable
Subject to power availability

	Cable diameter Up	MCF	Reduced dia fiber	C + L
BW multiplier	2 X	2-4 X	1.5-2 X	2 X
Cost (/bit/s)	?	?	?	?
Reliability	GOOD	GOOD (TBC)	GOOD (TBC)	GOOD
Loss (# repeaters)	GOOD	NEG	GOOD (TBC)	GOOD
MPI	NA	TBD	GOOD	WORKS
FIFO	NA	NEG	GOOD	SPLIT BANDS