What can Fibers do for Future Submarine Systems?

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What can Fibers do for Future Submarine Systems?

- **Status**
  - Dispersion Maps
    - NZDSF
    - DMF
- **Future**
  - Simplified Dispersion Maps
    - IDF x 1
  - Fibers for 40 Gbit/s
    - PMD
    - Effective Area

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A Long History of Submarine Cable Innovations

1981 – First high strength single mode fiber for ocean applications
1984 – First Sea Trial using optical fiber
1987 – First application of fiber in trans-Atlantic TAT-8
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Status on Long Haul

- **1988:**
  - **TAT8 :**
    - 288 Mbit/s/fiber.
    - 6000 km cable.
    - O-E-O re-generation every 40 km

- **2008:**
  - **TPE :**
    - 64 x 10 Gbit/s/fiber
    - > 11000 km cable
    - optical amplification every 80 km

Primary Fiber Parameters for Current Systems

- **Attenuation (long distance between amplifiers)**

- **Chromatic Dispersion (WDM)**
  - **Negative dispersion in transmission band due to Modulation Instability**
  - **Dispersion Slope**

- **Effective Area (Large Signal Power , lower non linear impairments)**

- **Strength (deployment from ship)**

- **Reliability (25 years life expectancy)**

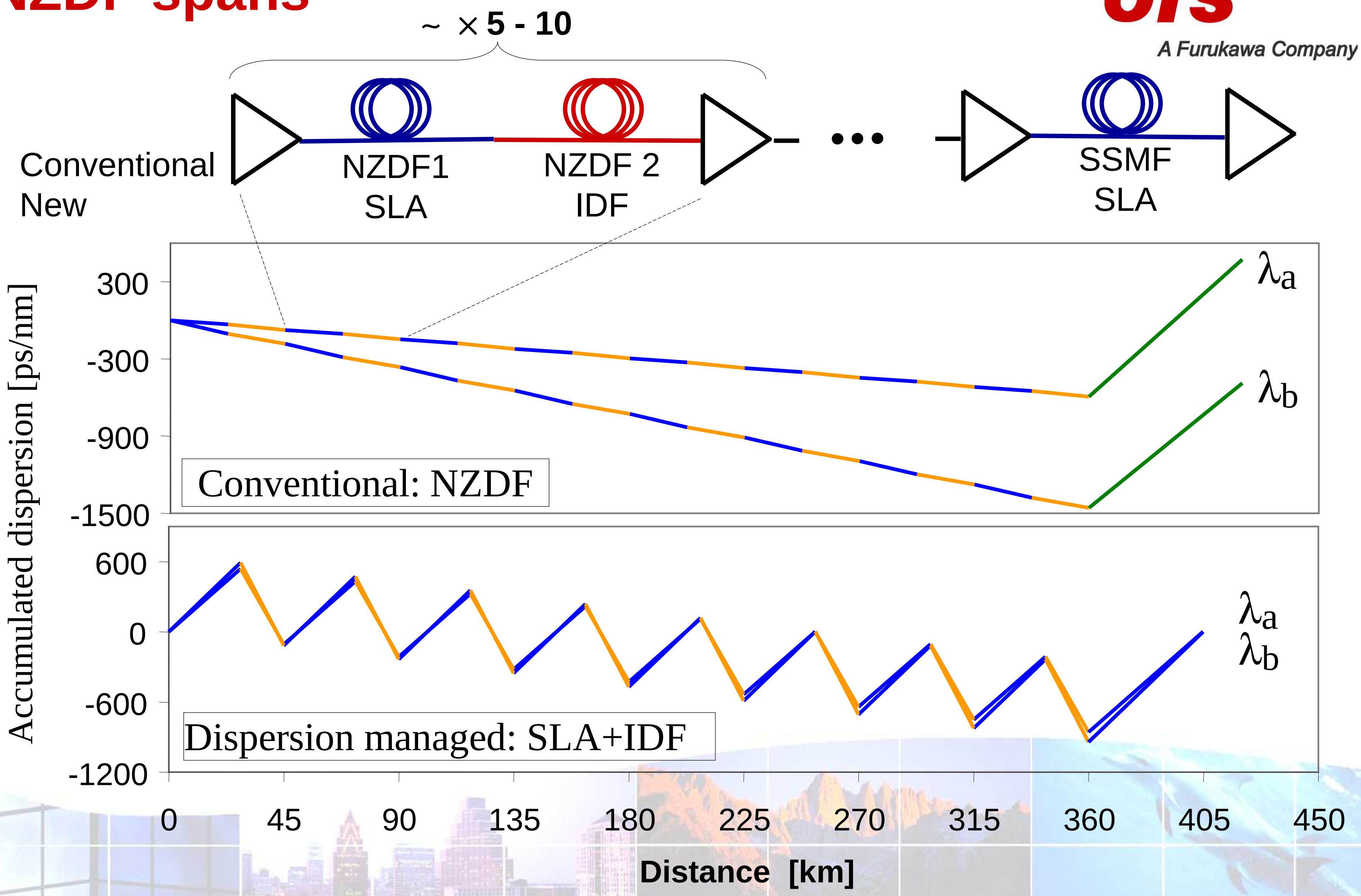
Long Haul and Ultra Long Haul

- **NZDF spans**
  - **Hybrid spans**
    - Large effective area fiber near amplifier
    - Low effective area fiber (with low slope) at other end

- **Dispersion and slope matched fibers**
  - **Hybrid spans**
    - Large effective area fiber near amplifier
    - Compensating fiber, that compensates dispersion and slope at other end

- **Accumulated dispersion**
    - Dispersion compensated every 5 – 10 spans with SSMF or SLA

Dispersion managed spans versus conventional NZDF spans



What can Fibers do for Future Submarine Systems?

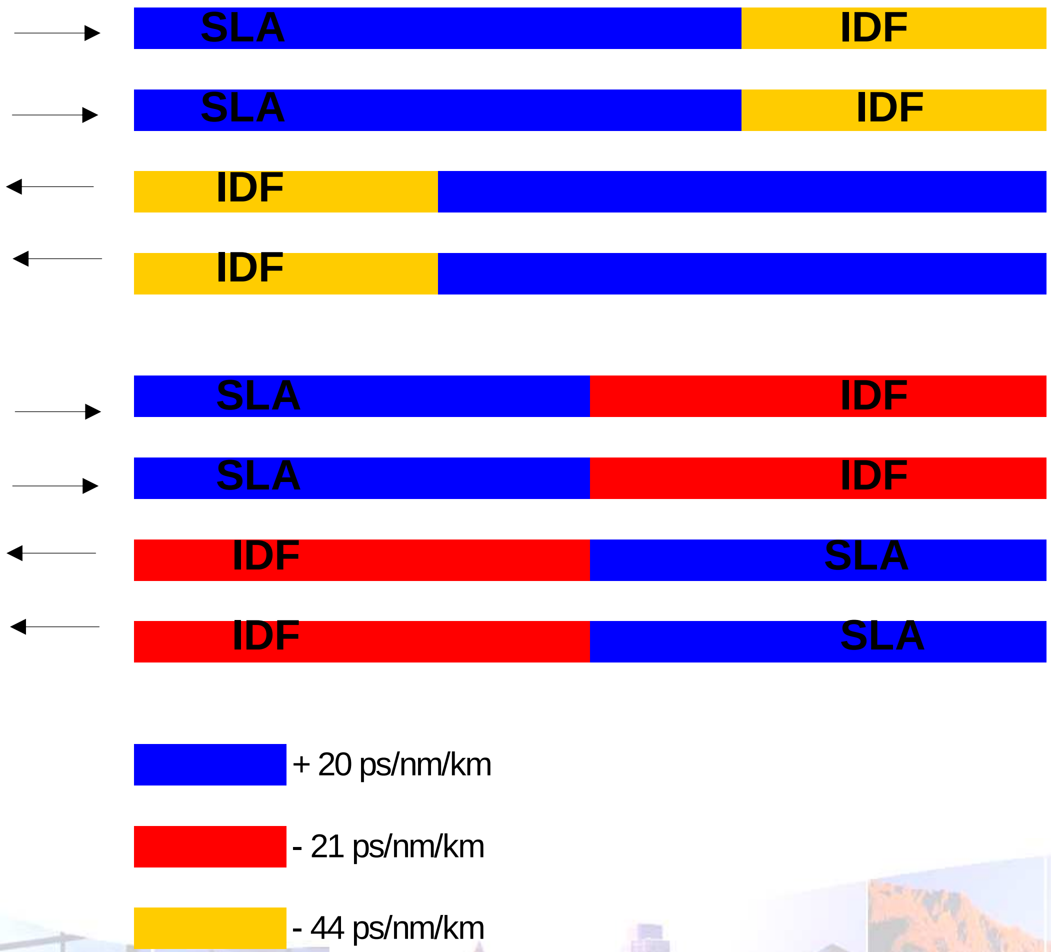
- **Simplified Dispersion Maps**
  – IDF x 1

- **Fibers for 40 Gbit/s**
  – PMD
  – Effective Area

Simplified Dispersion Map

- Symmetric dispersion and slope matched spans

IDF x 1 vs. IDF x 2 Cable Layout



IDF: Inverse Dispersion Fiber

Compensates dispersion and dispersion slope of the positive dispersion fiber in a span

IDF x 1

- **Advantages**
  - **Simple cable lay-out**
    - Symmetry
  - **Simple repair**
    - All cable segments have equal length of SLA and IDF
  - **Lower PMD**
    - IDF x 1 intrinsically has lower PMD, which more than compensate the longer length of IDF in the span.
- **Disadvantage**
  - **Slightly higher span loss**
  - **Slightly higher non-linear impairment**

IDF Data Summary

	IDF x 1	IDF x 2
Dispersion at 1550 nm	-21 ps/nm/km	-44 ps/nm/km
Loss at 1550 nm	0.222 dB/km Span with SLA 0.208 dB/km	0.225 dB/km Span with SLA 0.206 dB/km
Effective Area at 1550 nm	37 μm^2	32 μm^2
PMD	0.02 ps/√km Span with SLA <0.02 ps/√km	<0.03 ps/√ km Span with SLA <0.02 ps/√km

Fibers for 40 Gbit/s

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- **PMD limit lowered by a factor of 4 with direct detection**

- **6 dB improvement in OSNR is needed compared to 10 Gbit/s system**
  - **Span loss**
    - Decrease loss of fibers
  - **Increase signal power**
    - Non linear impairments
    - Increased effective Area

What causes PMD ?

(what makes a fiber –"non-perfect" ?)

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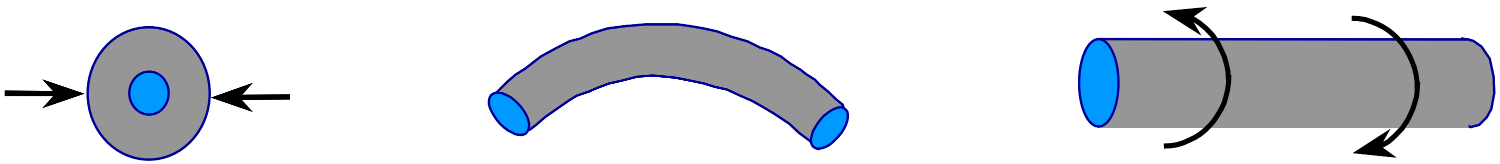
"Internal causes" creating stress in the fiber:

Non-perfect geometry — Air void ("bubble") — Stress

"External causes":



Stress — Bend — Twist

PMD Reduction:

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- The first step of PMD reduction is to identify and eliminate sources of PMD during manufacture, sources are plenty !
- This requires good control of all manufacturing processes and the ability to evaluate intrinsic PMD of a fiber
- This, however, is not sufficient – bending resulting from stranding of the fiber in a cable will for instance always cause stress.
- So at OFS we use a patented spinning process in order to build-in a lot of mode-mixing (internal) during the manufacturing process.
- This further reduces PMD – and makes the fiber less sensitive to EXTERNAL mode-coupling changes.

PMD on Submarine Fibers

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Ready for 40 Gbit/s long haul

- **NZDSF**
  - TrueWave
    - SRS   Average LMC PMD : < 0.02 ps/ √ km
    - XL   Average LMC PMD : < 0.02 ps/ √ km

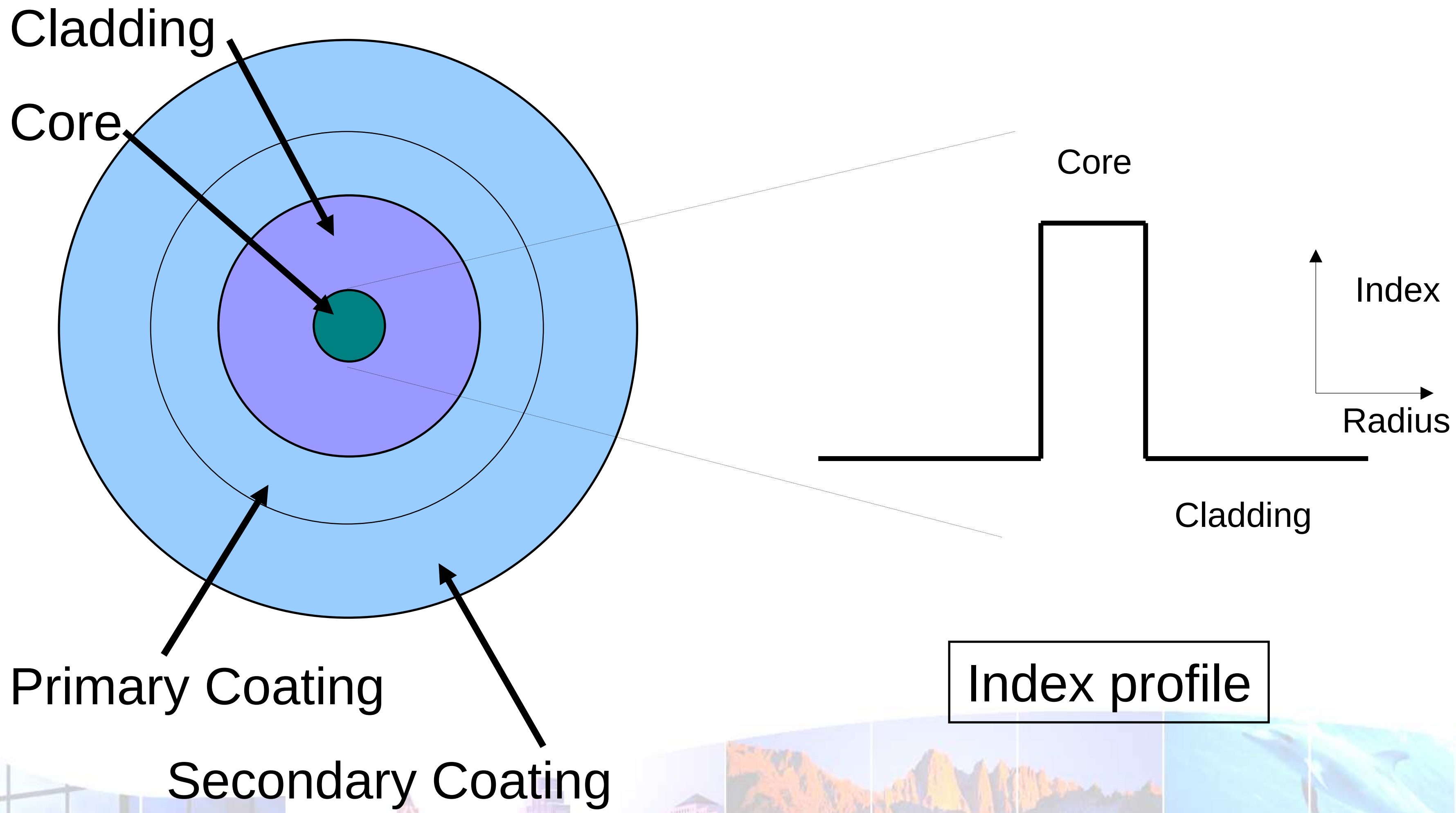
- **Dispersion and Slope matched fibers**
  - UltraWave Link (SLA+IDF)
    - SLA   Average LMC PMD : < 0.02 ps/ √ km
    - IDF   Average LMC PMD: < 0.03 ps/ √ km
    - SLA+IDF   Average LMC PMD : < 0.02 ps/ √ km

Increase Effective Area

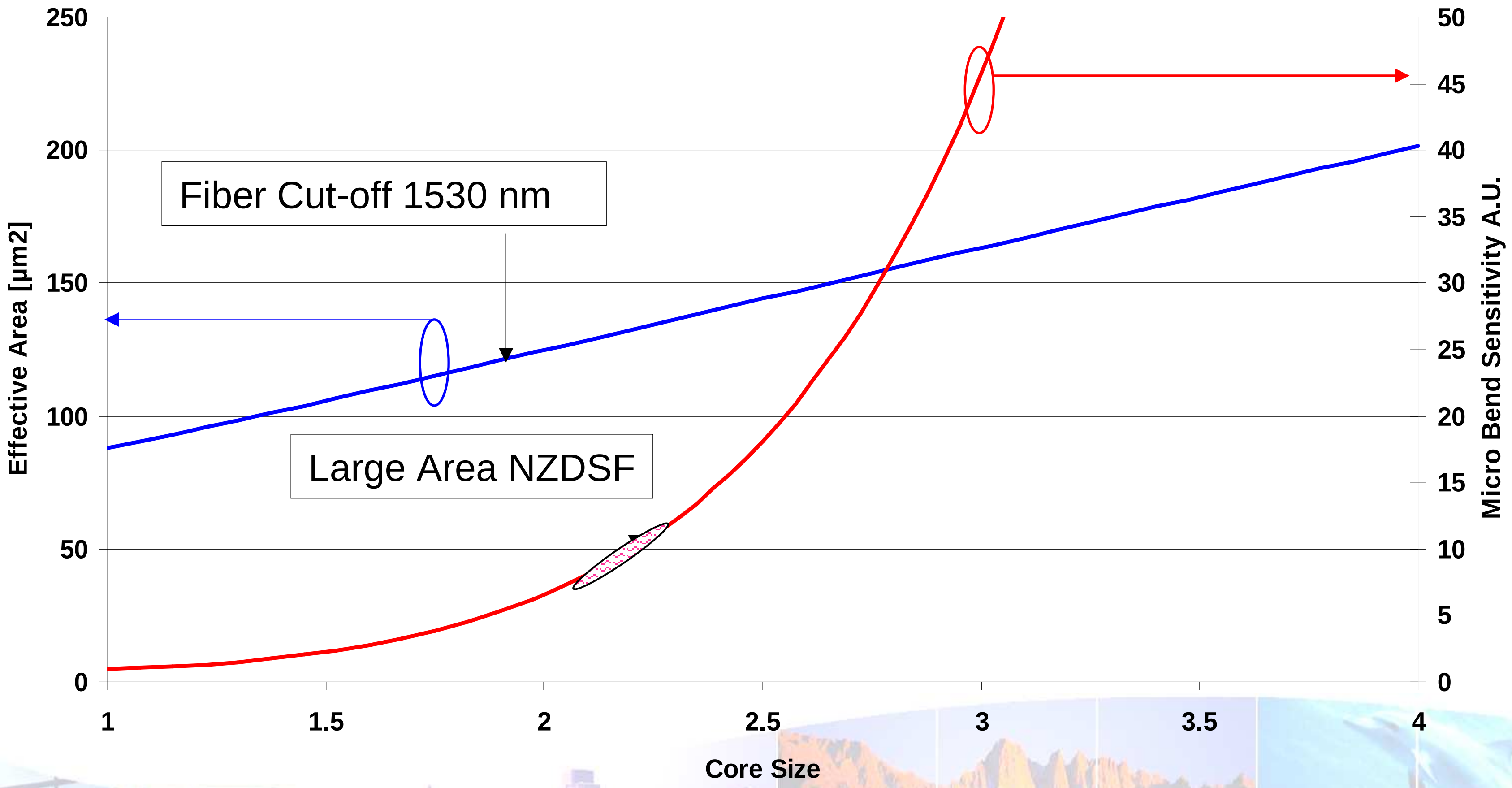
- A new positive dispersion fiber with increased effective area and low loss is required independent of the transmission format of the future.

- With coherent detection the dispersion compensation may not be needed.
  - This could lower the span loss with approximately 1 dB

Increased Effective Area



Model Calculation on SSMF



Large Effective Area Fibers

- **Effective area is limited by microbend sensitivity**

- **Optimized designs**
  - **Waveguide parameters**
    - Currently experimental fibers are around 125µm^2 with 0.185 dB/km loss

- **Increased fiber diameter**
  - **125 µm -> 140 µm**

-> Decrease Factor of 2 in µBend

- **Increased coating diameters (with 125µm fiberdiameter)**
  - **POD / SOD from 190/250µm -> 225/285 µm**

-> Decrease Factor of 2 in µBend

- **New coating materials: “Super Coatings”**

-> Decrease Factor of x in µBend

  - **Lower T_g of primary (better temperature performance)**

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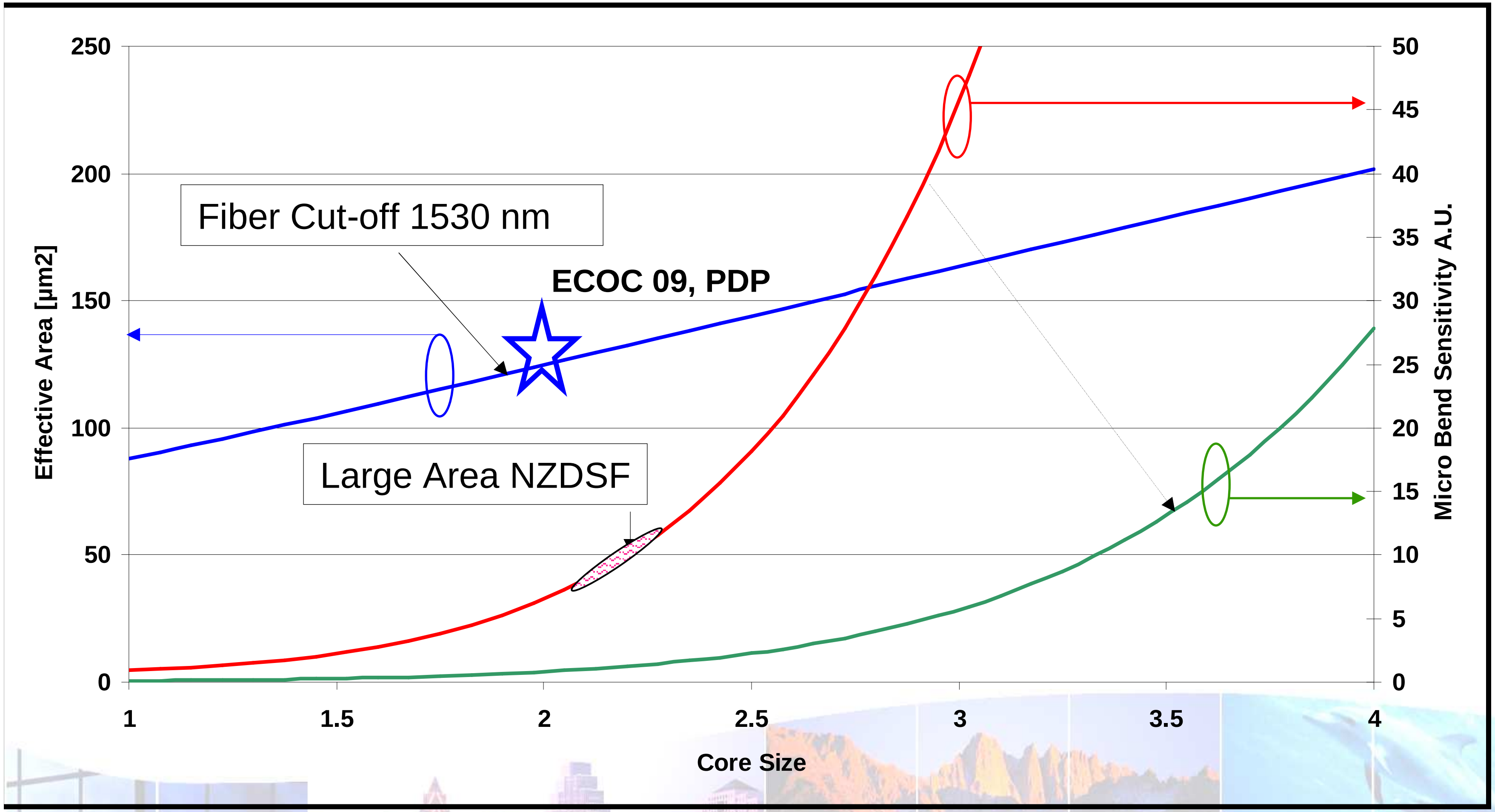
Model Calculation on SSMF



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