# 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

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- **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

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- **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 )**

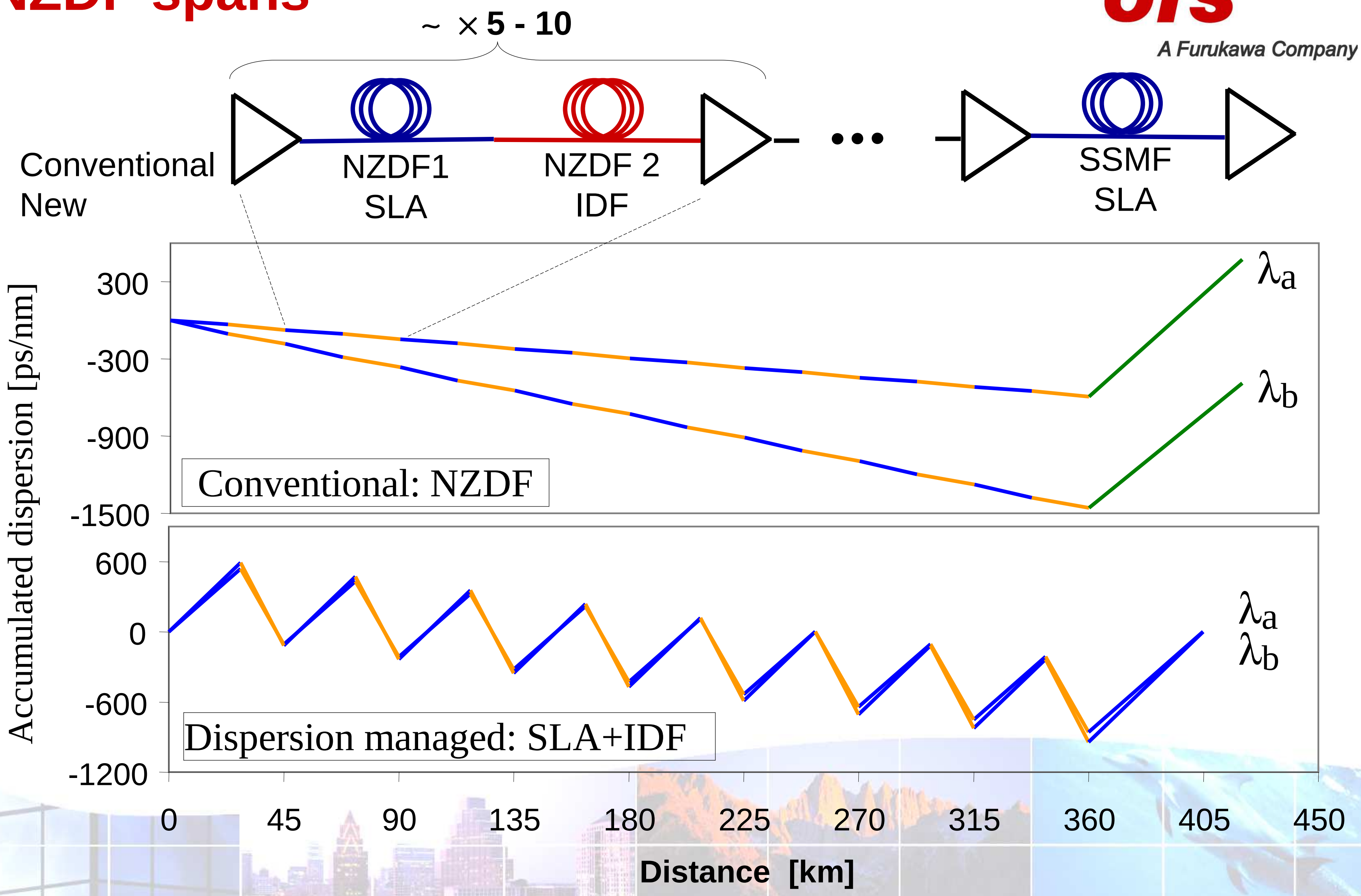
# Long Haul and Ultra Long Haul

- **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



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- **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

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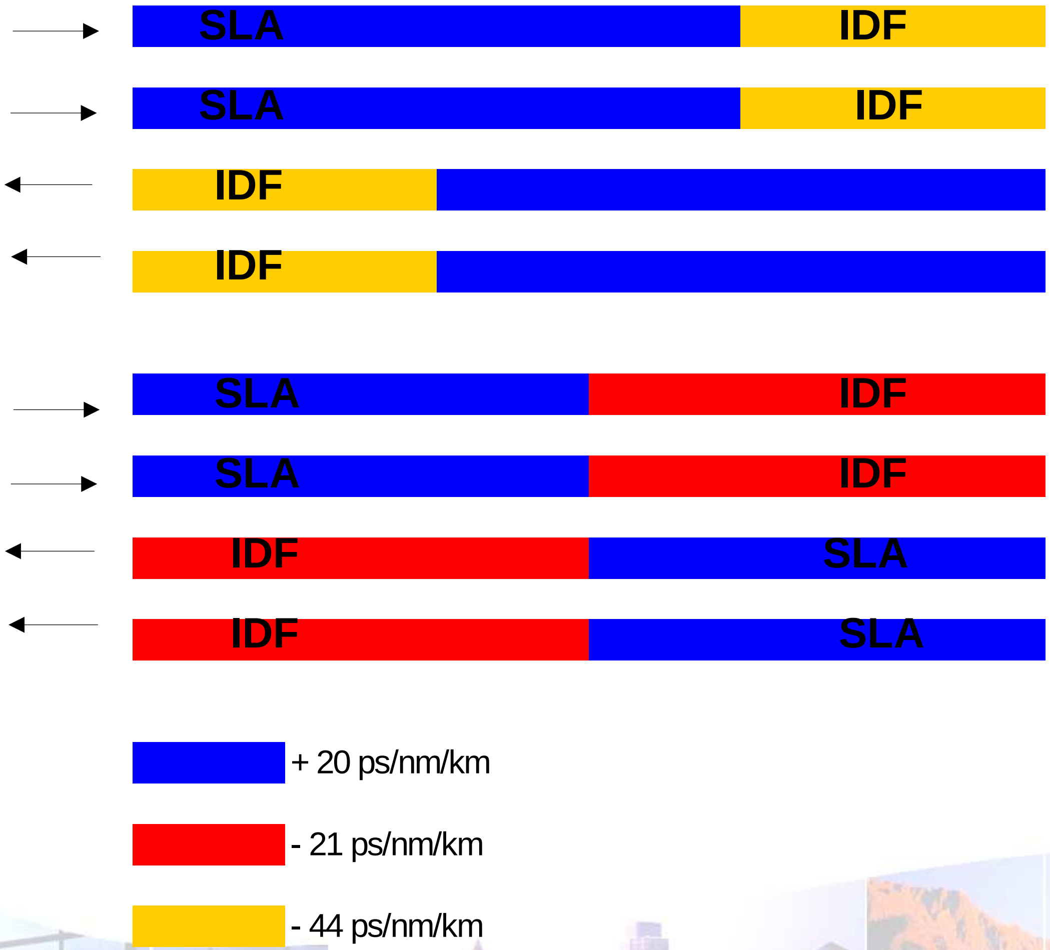


IDF: Inverse Dispersion Fiber

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<br>Span with SLA<br>0.208 dB/km | 0.225 dB/km<br>Span with SLA<br>0.206 dB/km |
| Effective Area at 1550 nm | 37 $\mu m^2$ | 32 $\mu m^2$ |
| PMD | 0.02 ps/√km<br>Span with SLA<br><0.02 ps/√km | <0.03 ps/√ km<br>Span with SLA<br><0.02 ps/√km |

# Fibers for 40 Gbit/s

- **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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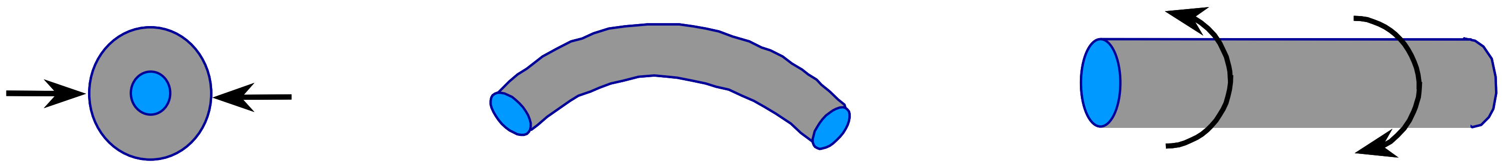
## "Internal causes" creating stress in the fiber:

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

## "External causes":



Stress    Bend    Twist

# PMD Reduction:

- 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

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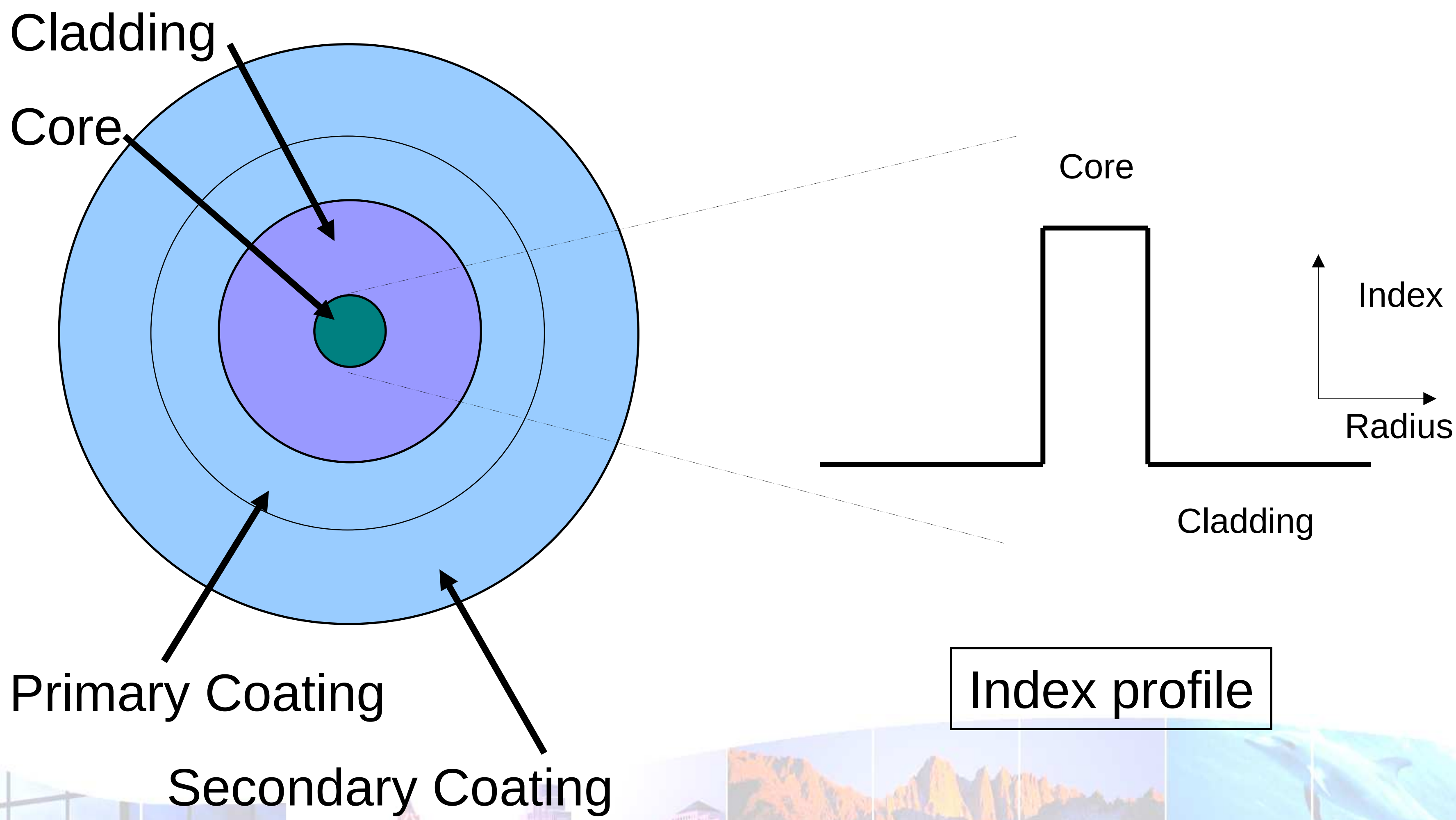
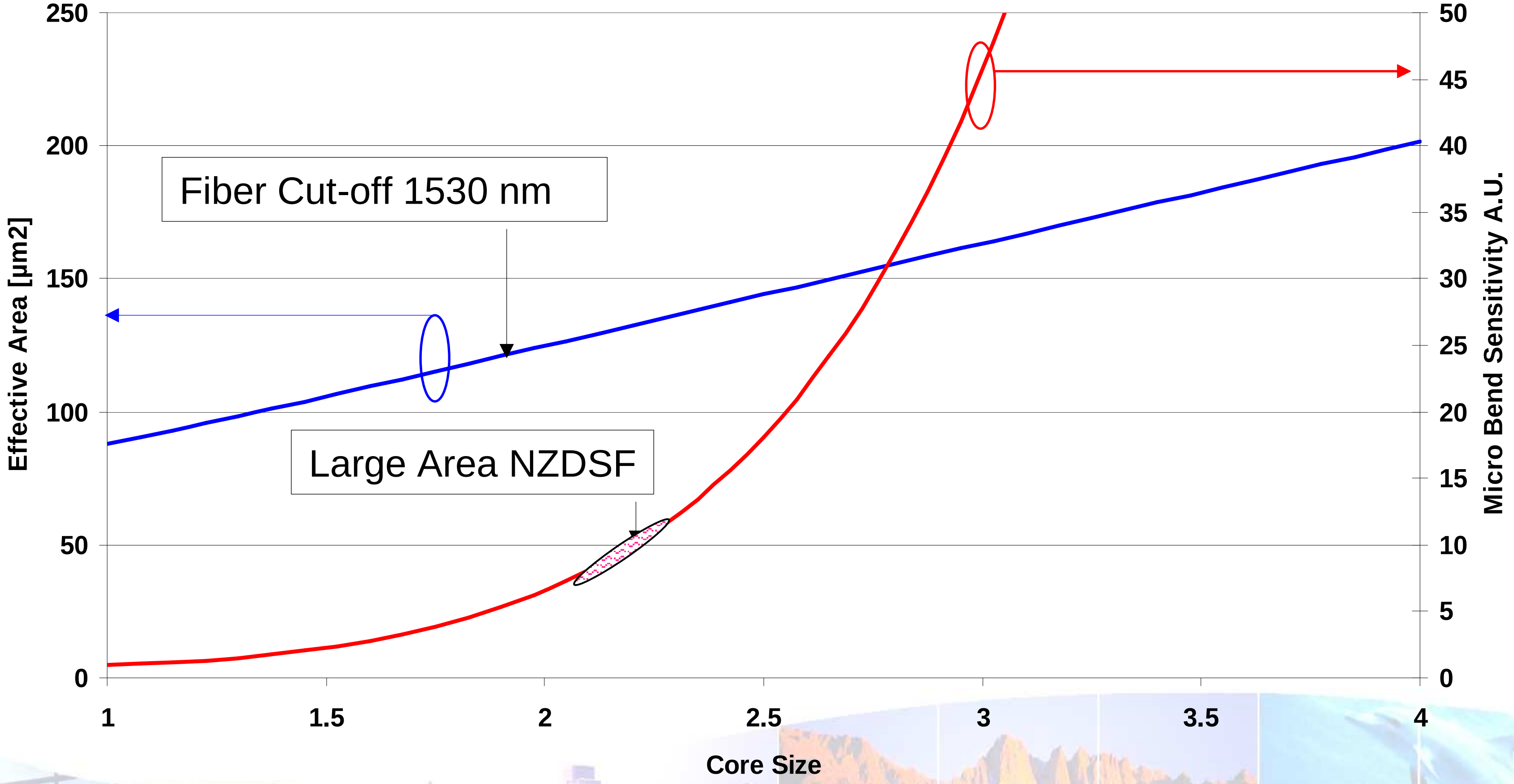


# Model Calculation on SSMF



# 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**

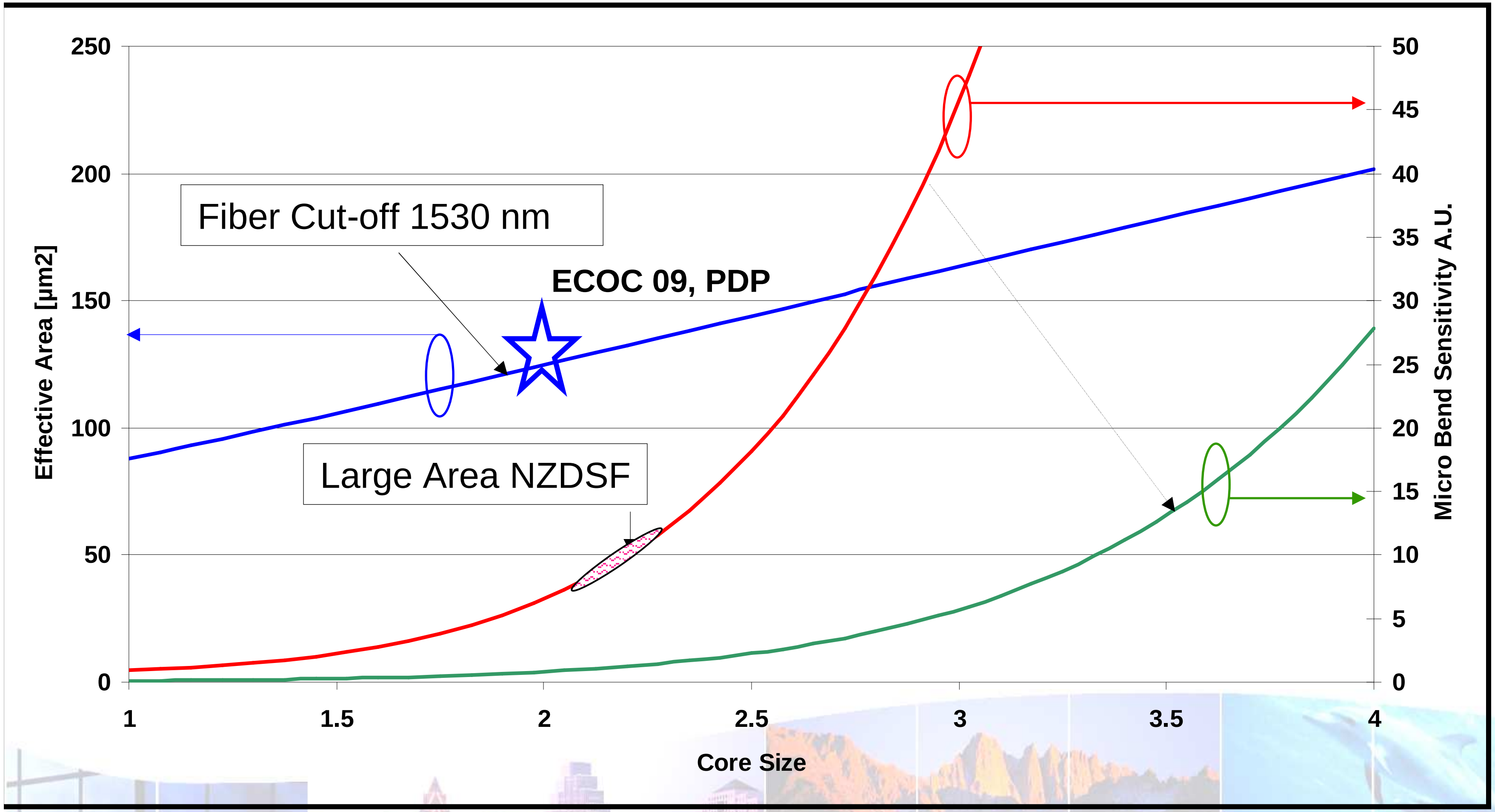
- **New coating materials: “Super Coatings”**

  **-> Decrease Factor of x in µBend**

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

## What can Fibers do for Future Submarine Systems?

# Model Calculation on SSMF



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201x – Large effective Area fibers for coherent detection