Système de Supervision et d'Administration des Réseaux Optiques Passifs à Large Bande

Presentation: Habib Fathallah
King Saud University
Université Laval

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Presentation Outline

- Introduction:
  - FTTH PON evolution/ Optical performance monitoring
- PON monitoring challenges
  - Limits of OTDR / Existing alternative approaches
- Our Optical Coding (OC) System approach
  - 1 D , 2 D, and hybrid 1D/2D encoders
  - Our OC system *vs* Standard OCDMA
- Performance analysis and results
  - Power budget /Geographical distribution and Source effects
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- Summary and future work

Photonic Access Evolution

Point to Point

+ Follows Telco wiring Practices
+ Bit Rate & Protocol Independent

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- CO Fiber Management
- Fiber Availability

Active Remote

+ Simple deployment model
+ Flexibility of #Users vs Line Rate
+ Bandwidth Upgradeability

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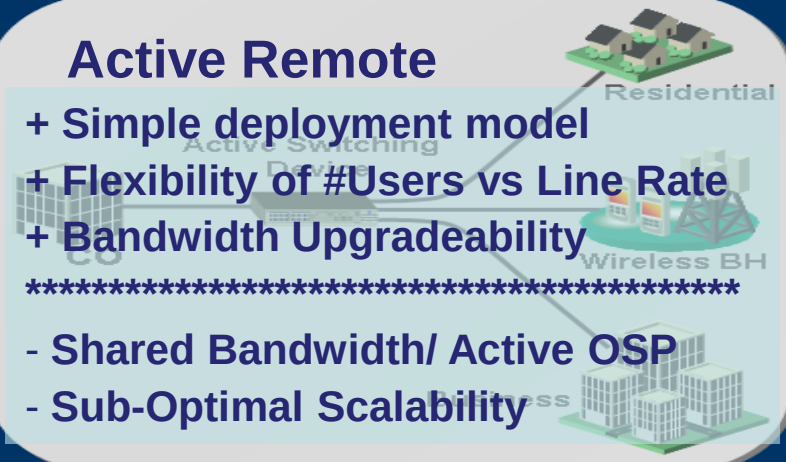
- Shared Bandwidth/ Active OSP
- Sub-Optimal Scalability



TDM PON

+ Simplified CO Fiber Management
+ Passive OSP Plant Solution
+ Maturing Technology

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- Shared Bandwidth (DS & US)
- Real time Software Intensive
- Complex upgrade/Link Budget

WDM Fiber Access

+ of P2P & TDM PON
+ Security,
+ Reach distance

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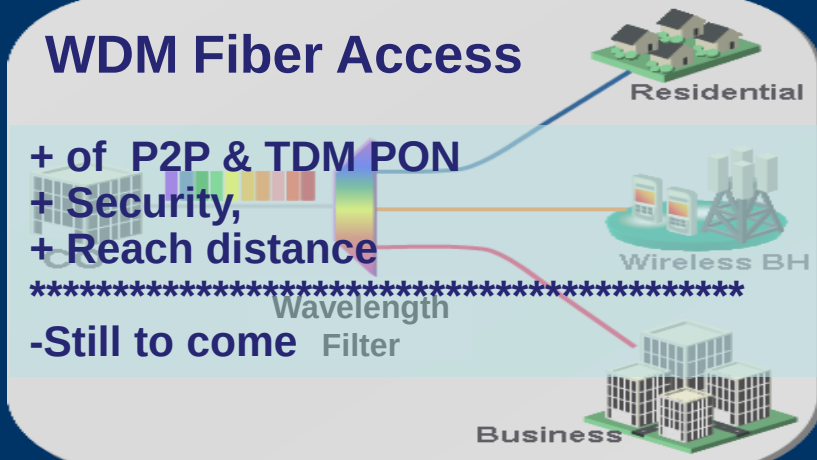
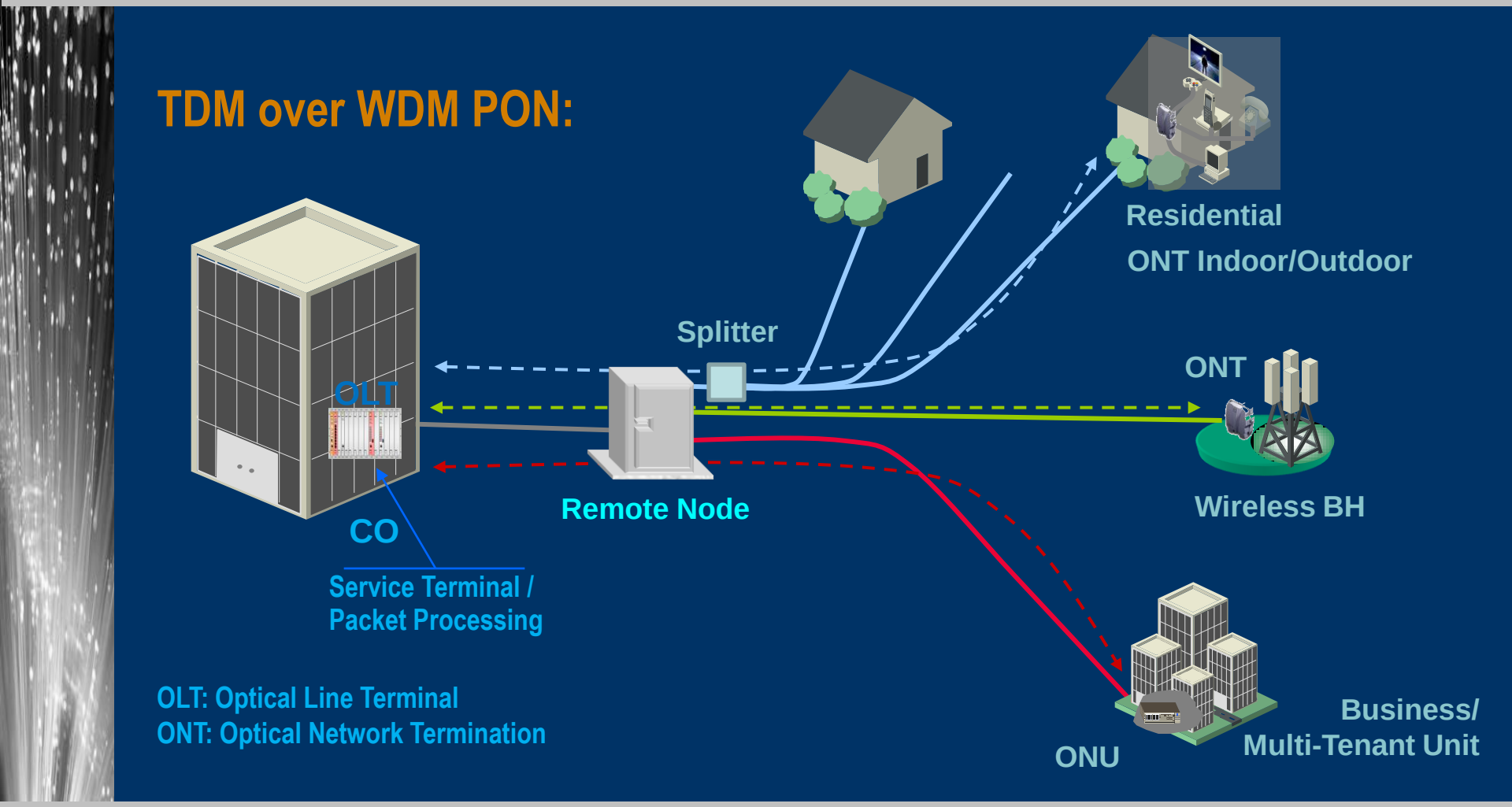
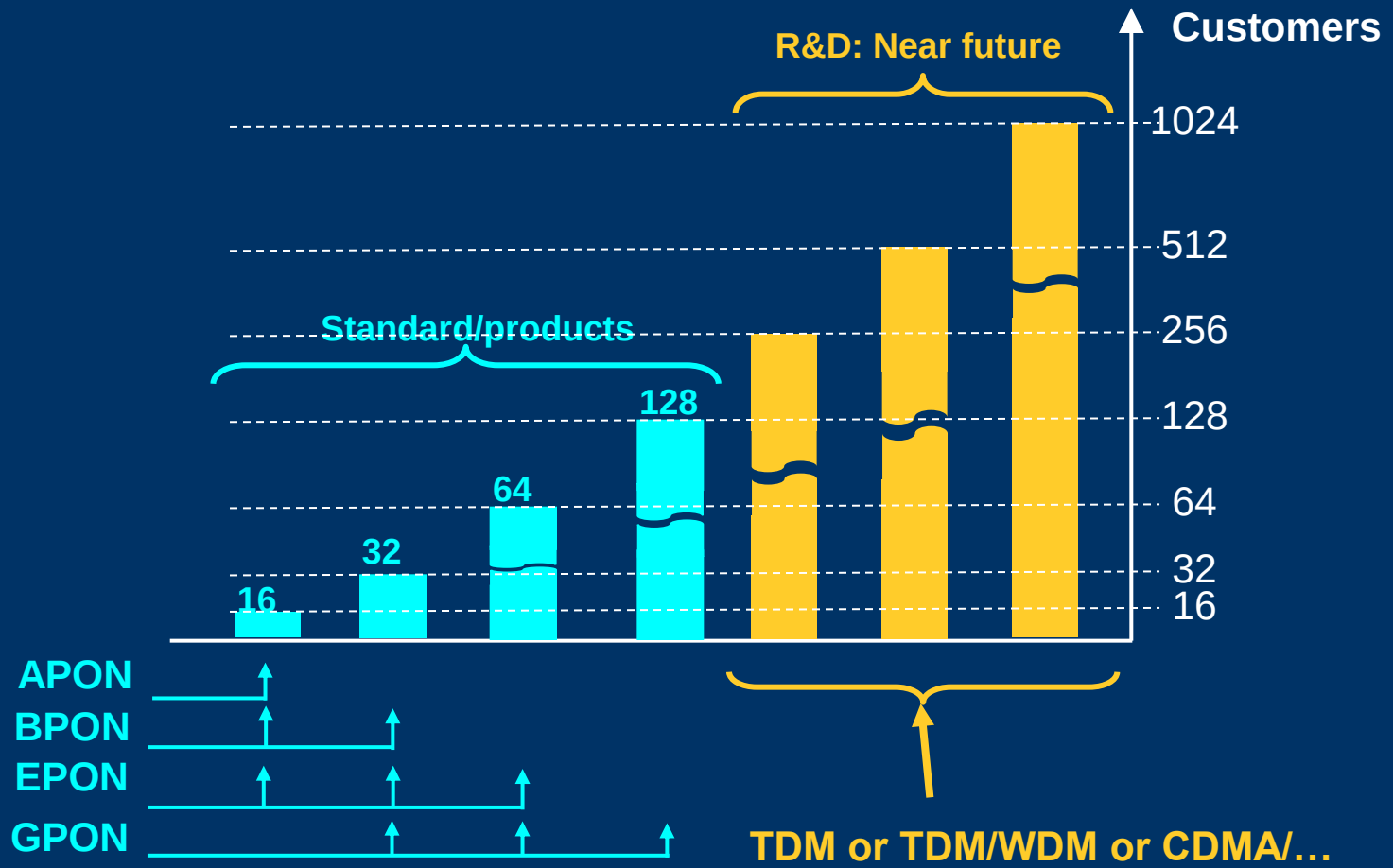
-Still to come



Photonic Access Evolution (2)



Photonic Access Evolution (3)



Photonic Access Evolution (4)

FTTX:

- FTTN: Fiber-To-The-Node (usually MDF)
- FTTC:
  - Fiber-To-The-Cabinet – usually Street Cabinet (“SC”)
  - Fiber-To-The-Curb
- FTTP: Fiber-To-The-Premise
- FTTB:
  - Fiber-To-The-Building
  - also: Fiber-To-The-Basement
- FTTM: Fiber-To-The-MDU (MDU = Multi-Dwelling-Unit)
- FTTH: Fiber-To-The-Home

Optical Performance Monitoring: Why

- We monitor to:
  - **Administer**
  - **Maintain provision**
  - **Guarantee a service quality**

- As Capacity and Complexity increases

  $\Rightarrow$ Importance of OPM increases.

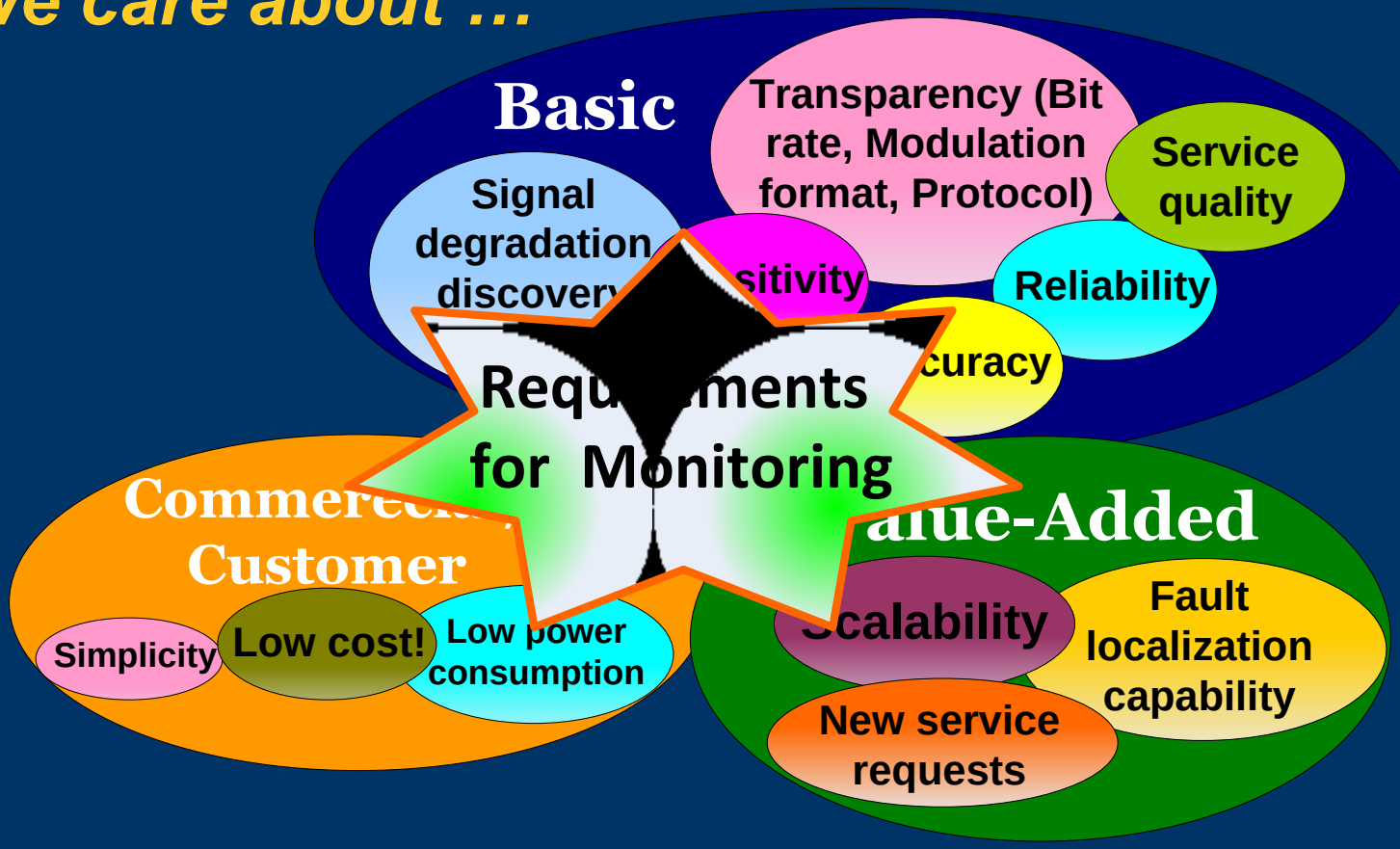
- OPM is the physical layer monitoring in order to:
  - determine the quality of the signal: power, dispersion, λ shift, …
  - root the cause(s)

Principle of OPM

Good quality signal $\Rightarrow$ ***all network components working well***

Optical Performance Monitoring: *Why*

We care about …



Optical Performance Monitoring: *Why*

We exploit the monitoring information …

- For **fault management:**
  - Identification,
  - Localization, …
- As a **feedback** for active modules:
  - Amplifiers and attenuators for gain balancing
  - Nodes, switches, routers, attenuators
  - Dynamic dispersion compensators
- As an **alarm** to predict network failures:
  - For traffic routing before or after failure occurring.

D. C. Kilper, *etal* , "Optical performance monitoring," *J. Lightwave Technology.*, vol. 22, no. 1, 2004.

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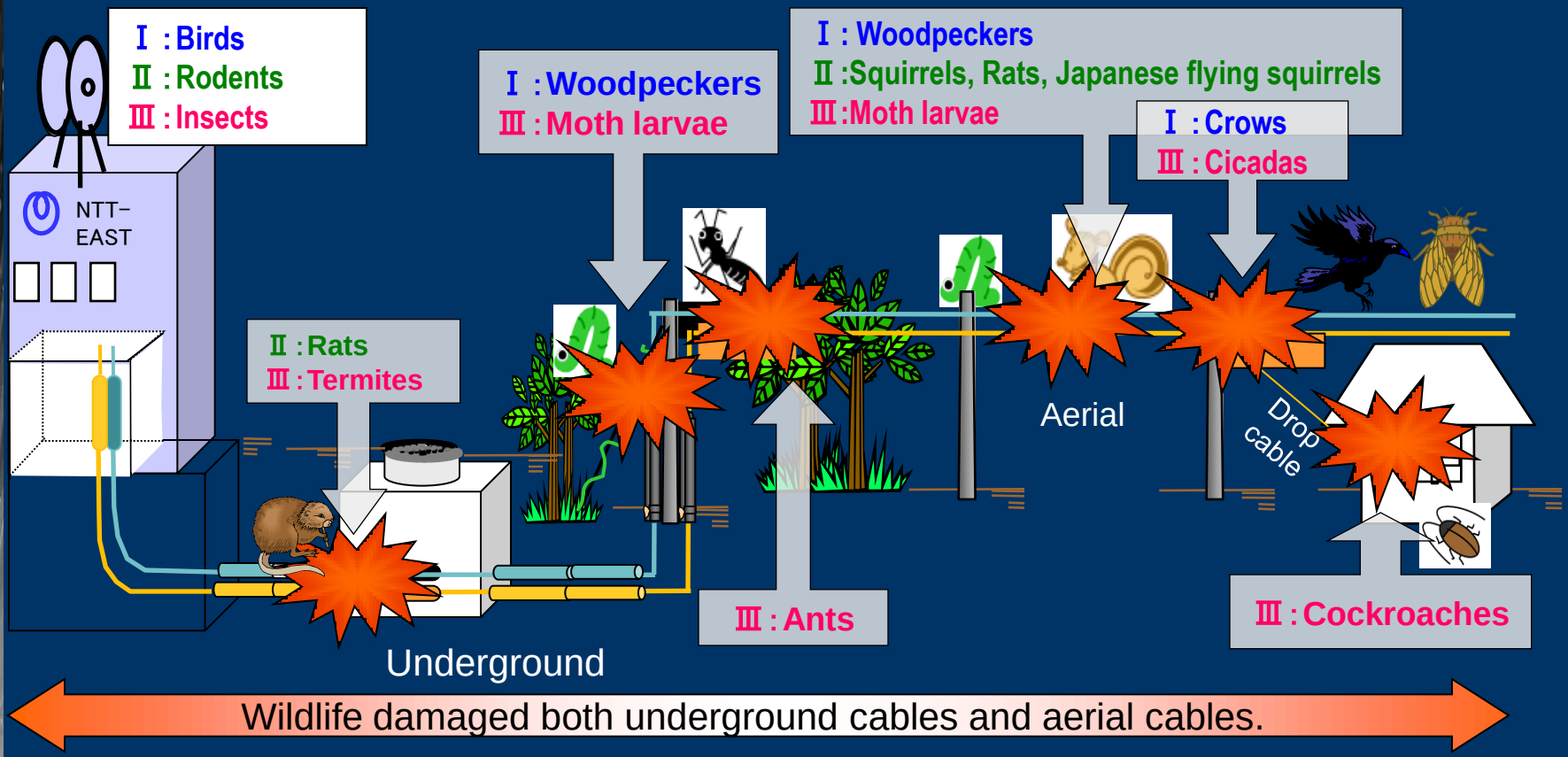
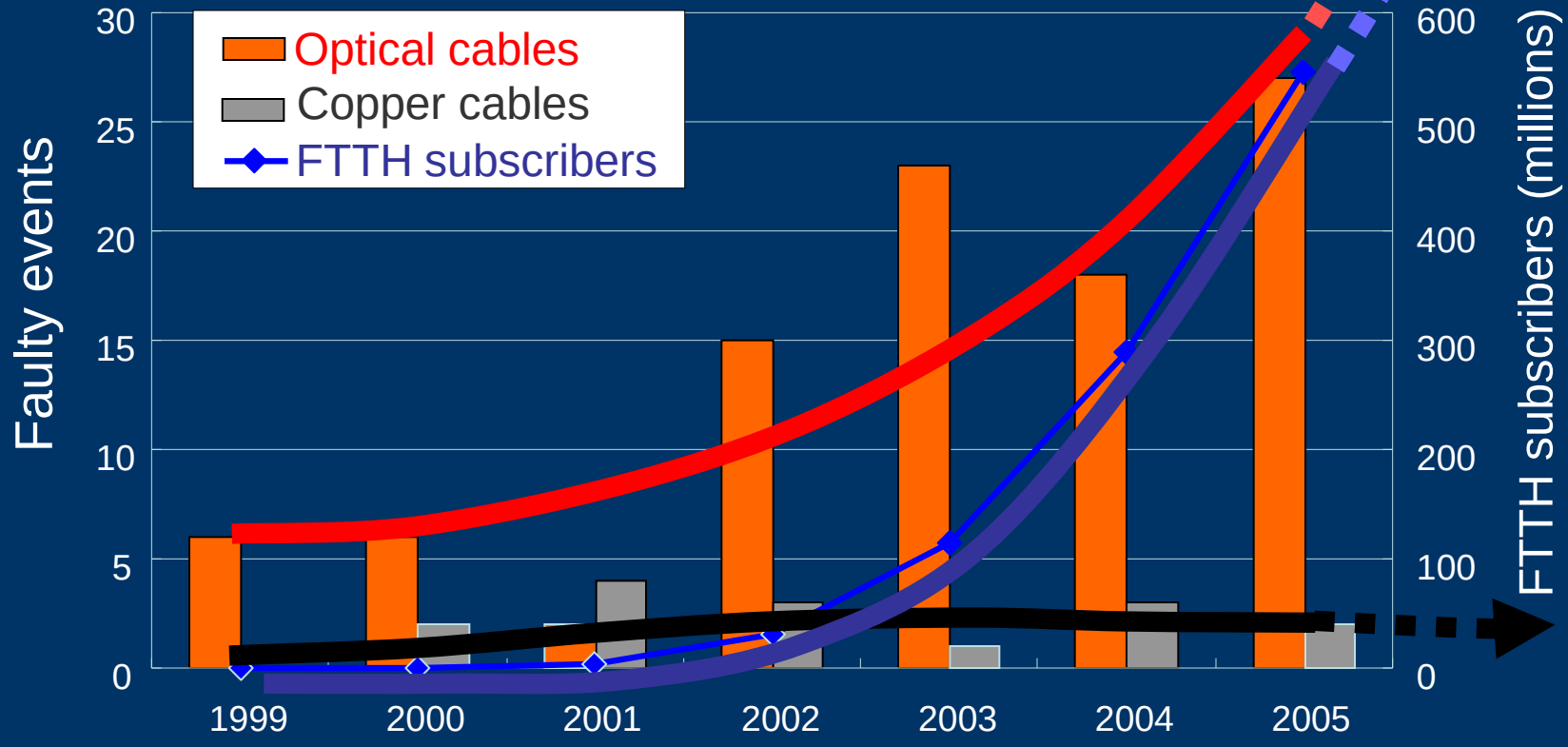
OPM for FTTX: *NTT-Japan case*

Places damaged by wildlife in FTTH infrastructure…



OPM for FTTX: *NTT-Japan case*

Fault events caused by wildlife in FTTH …



OPM in FTTX PON Context: *Motivation*

- **In-Service and in-time full knowledge of the state of the network is required because this allows :**
  - Speed up the installation of new networks and reduce its cost
  - Speed up the provisioning of new customers and new services
  - ameliorate fault prevention reducing the maintenance cost
  - Increase the network reliability and reduce the network down-time
  - Increase the customers satisfaction and reduce their complaints
  - Contract, guarantee and respect service level agreements with customers

OPM in FTTX PON Context: *Cost*

Key issues:

- Cost (CAPEX & OPEX)

- Capacity

- Scalability

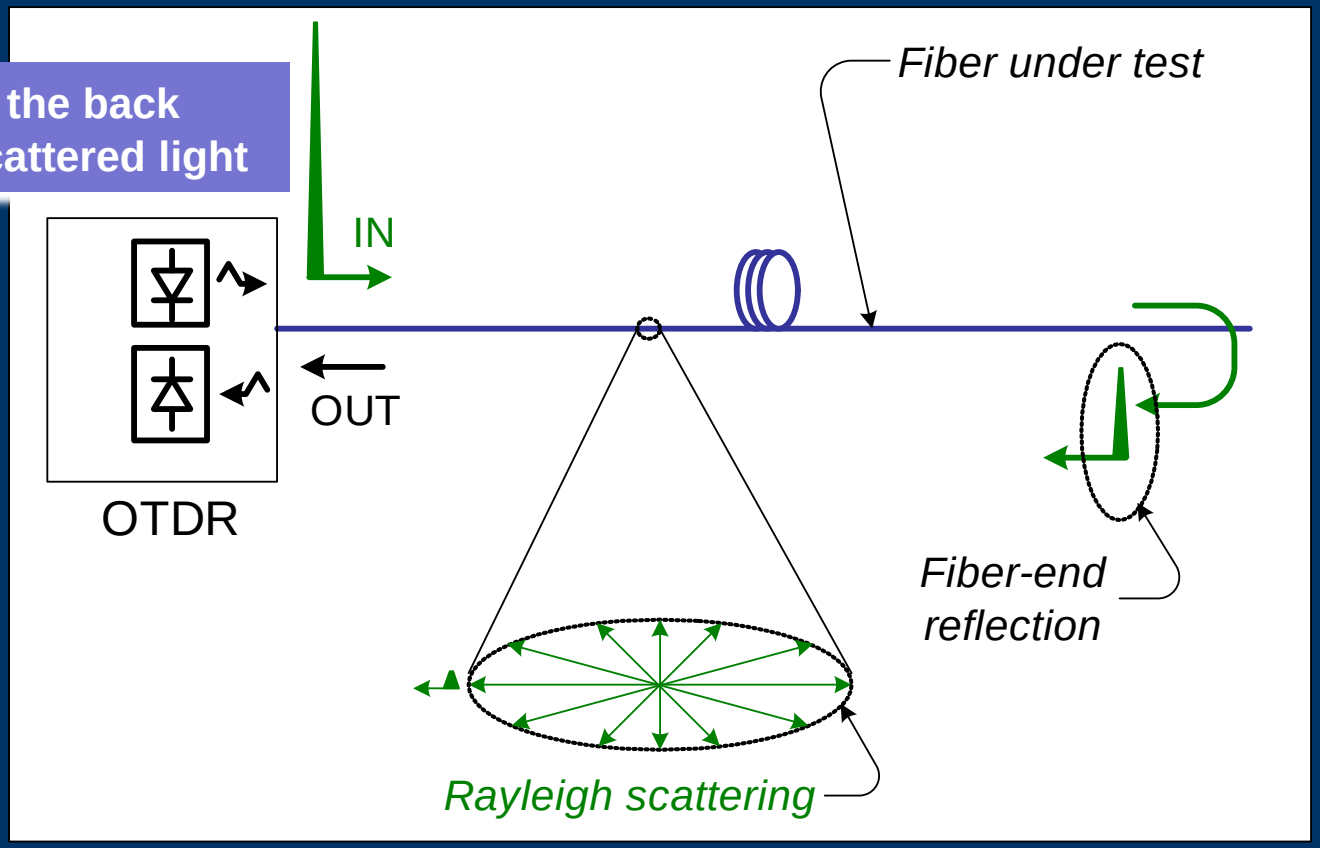
- Complexity

CAPEX: Capital Expenditure

OPEX: Operational Expenditure

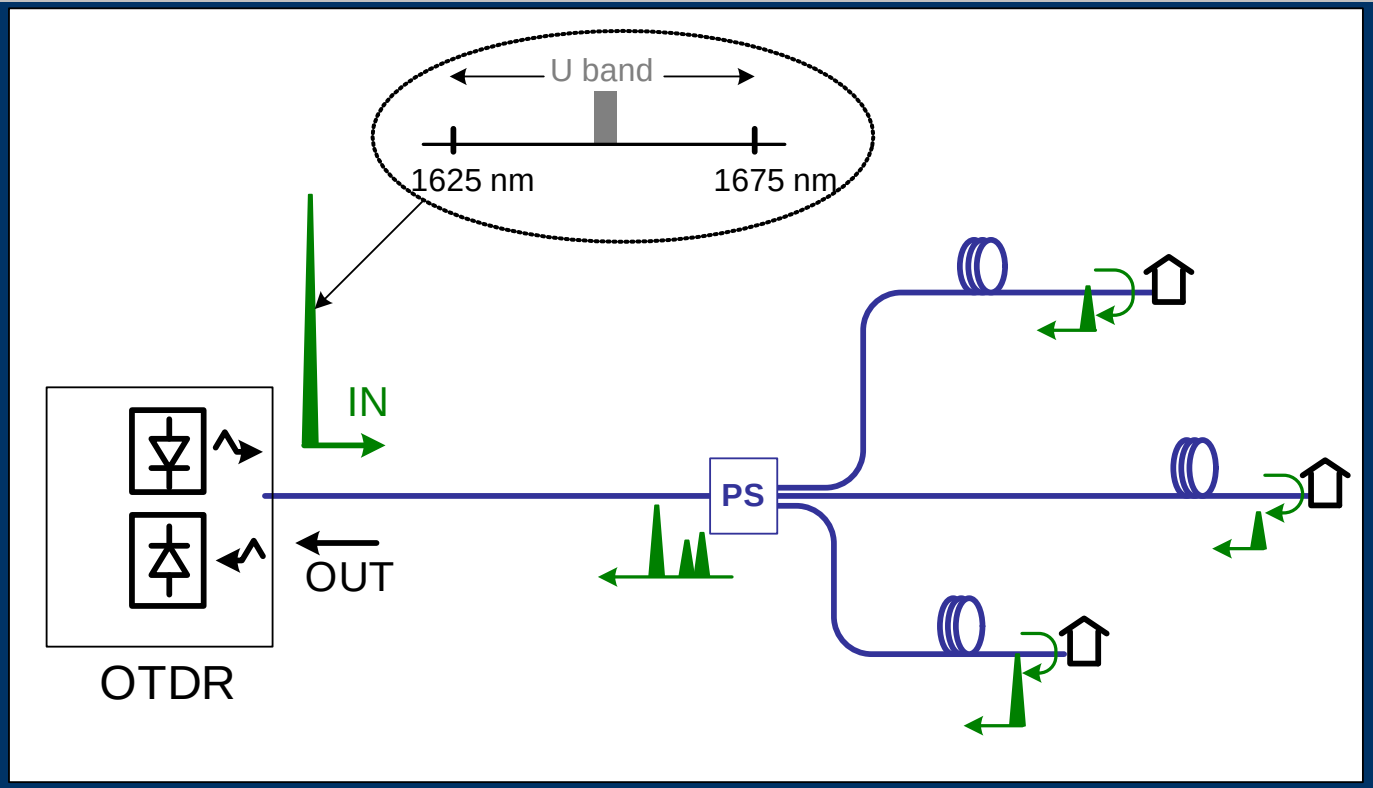
Challenges of FTTX Monitoring: *Limits of OTDR*

OTDR: Measures the back reflected + backscattered light



The OTDR is adequate for POINT-TO-POINT networks

Challenges of FTTX Monitoring: *Limits of OTDR*

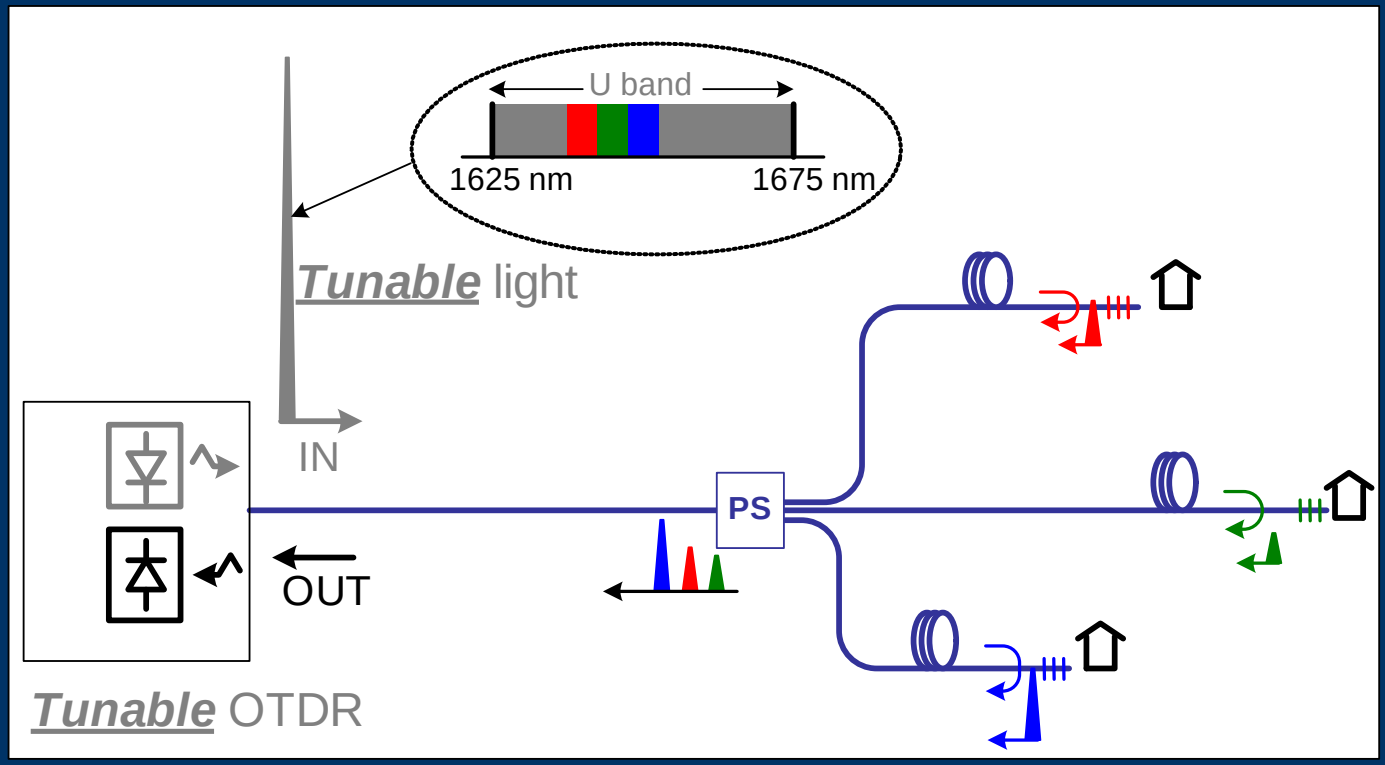


OTDR: Measures the *cumulative* back reflected + backscattered light

➔ ***Information about individual branches is lost***

➔ **OTDR inappropriate for POINT-TO-MULTIPOINT Networks**

Challenges of FTTX Monitoring: *Existing approaches*



Bragg grating based identifiers with:

- tunable OTDR laser, or
- broadband source and tunable filter, or
- multi-wavelength laser and tunable filter

➡ ***Capacity of existing approaches is very limited***

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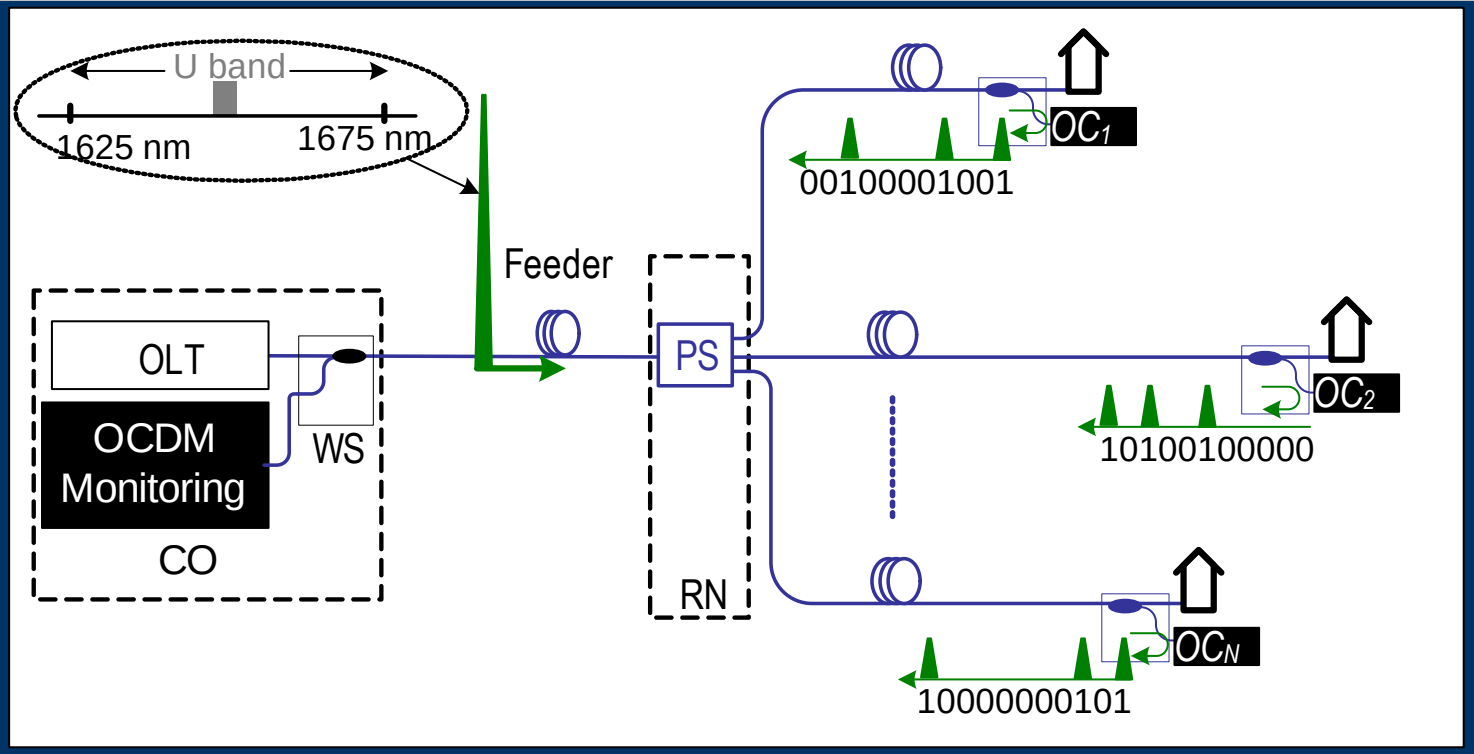
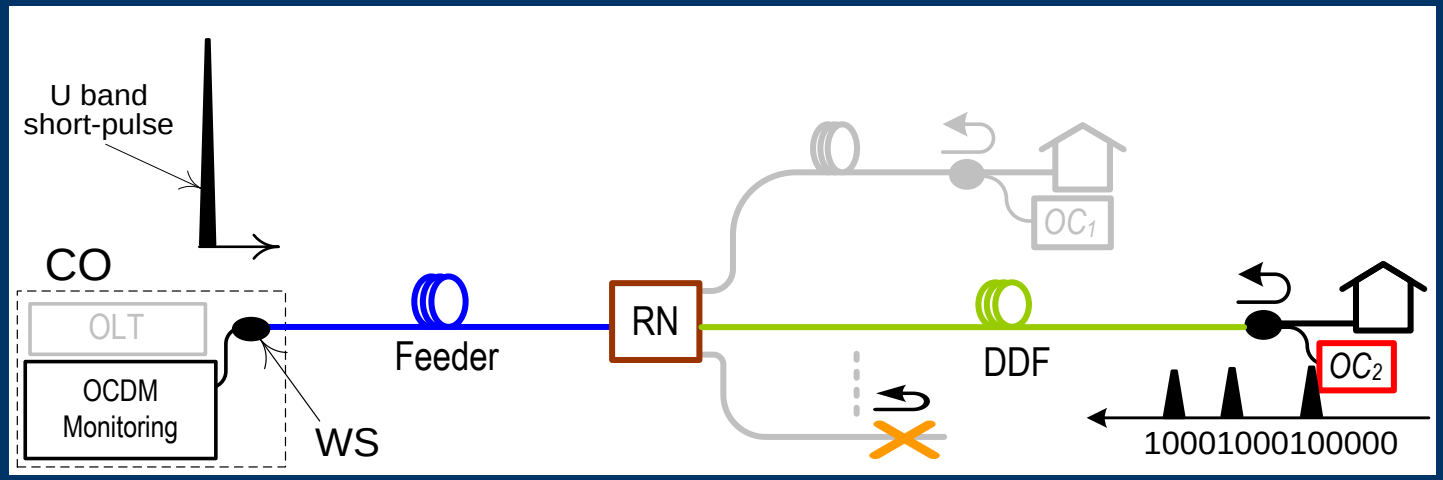
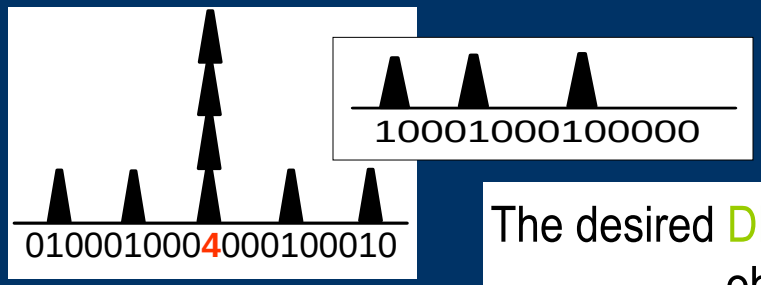
FTTX Monitoring: Our Optical Coding Approach



- *Encoding the reflected pulses using passive devices*
- *Out-of band coding allows In-Service operation (U band)*
- **Time coding allows sharing of the same monitoring source**

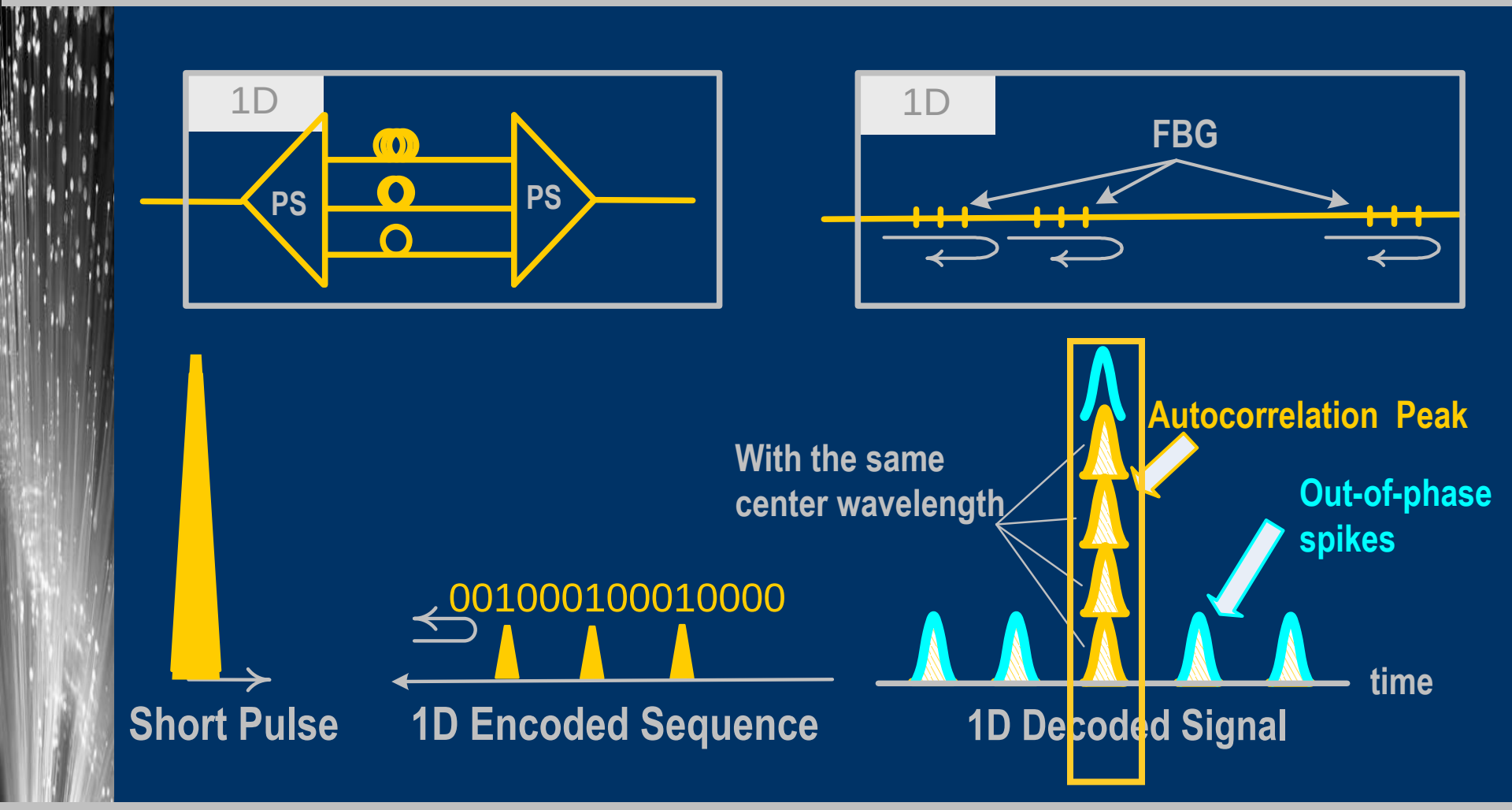
FTTX Monitoring: Our Optical Coding Approach (2)



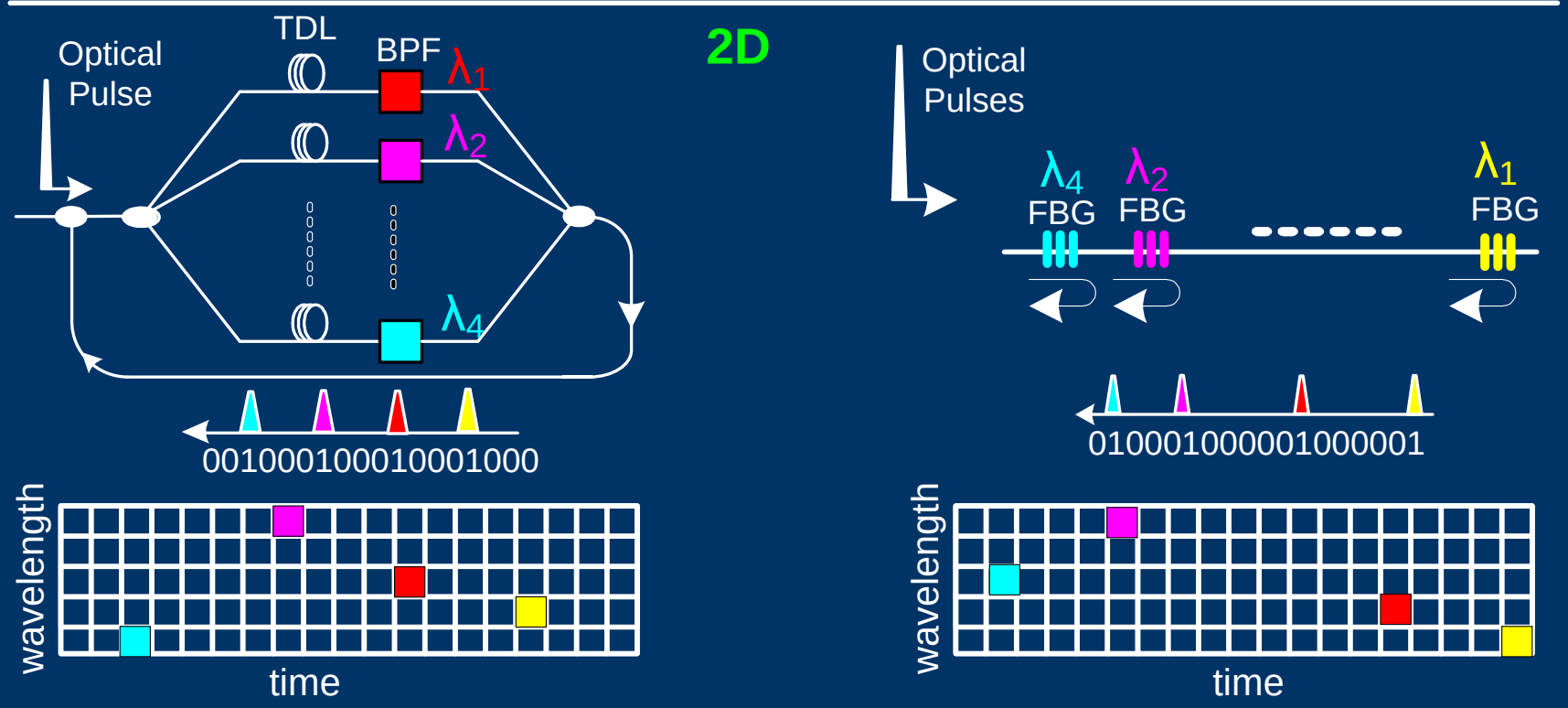


The desired DDF status (healthy/faulty) can be monitored by observing the auto-correlation peak

Optical Coding Monitoring: 1-D Encoders



Optical Coding Monitoring: 2-D Encoders



Optical coding: Monitoring vs standard OCDMA

Monitoring *vs.* standard OCDMA applications

- ✓ Codes transmit monitoring (*or state*) information instead of data
- ✓ No data modulation at the encoders
- ✓ No transmission of streams of data
- ✓ No need for high speed transmission

OCDM monitoring

- ✓ Exploits mature and inexpensive components
- ✓ Avoids high speed electronics
- ✓ Suffers less from interference
- ✓ Suffers less from near-far problem

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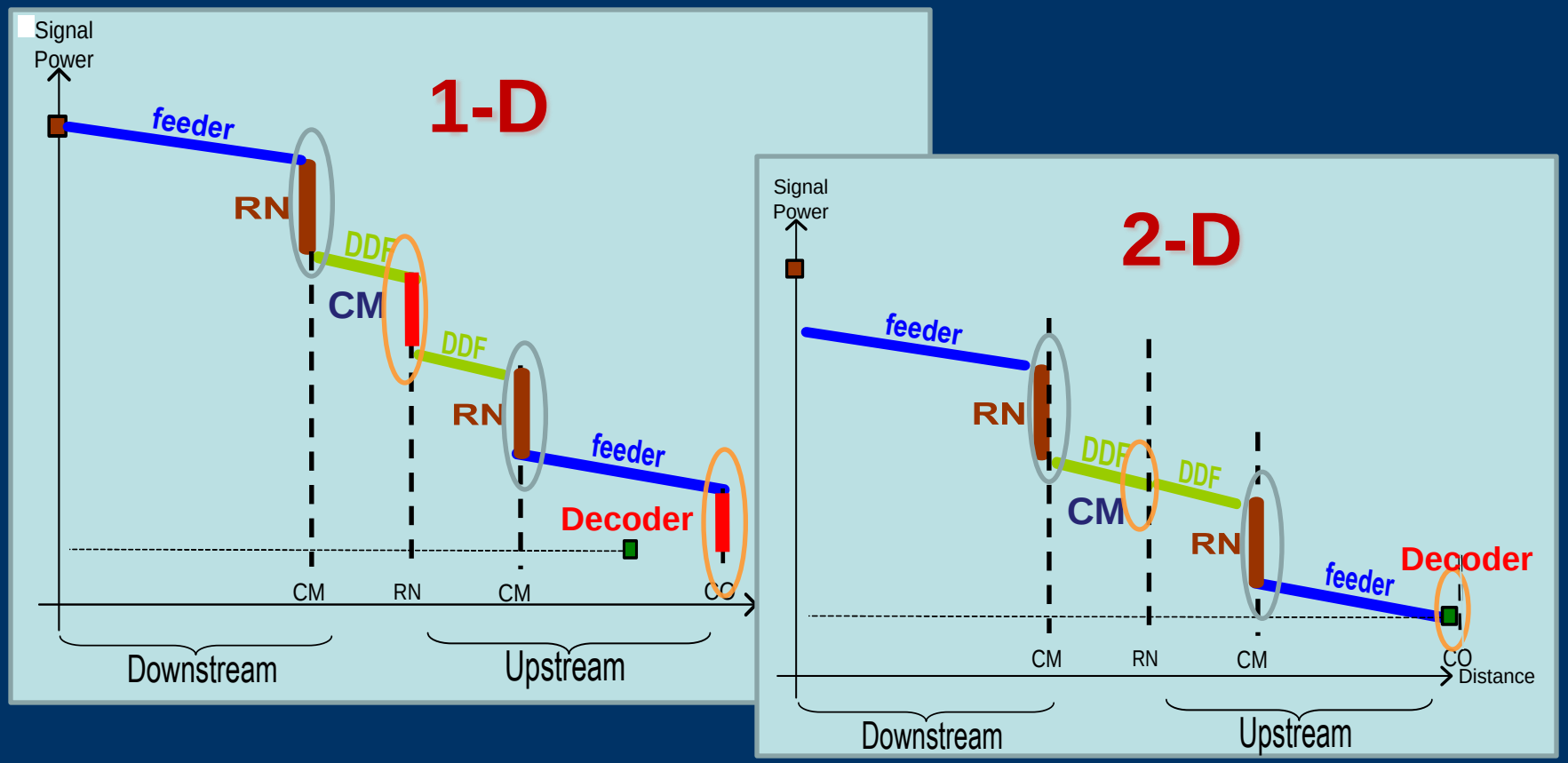
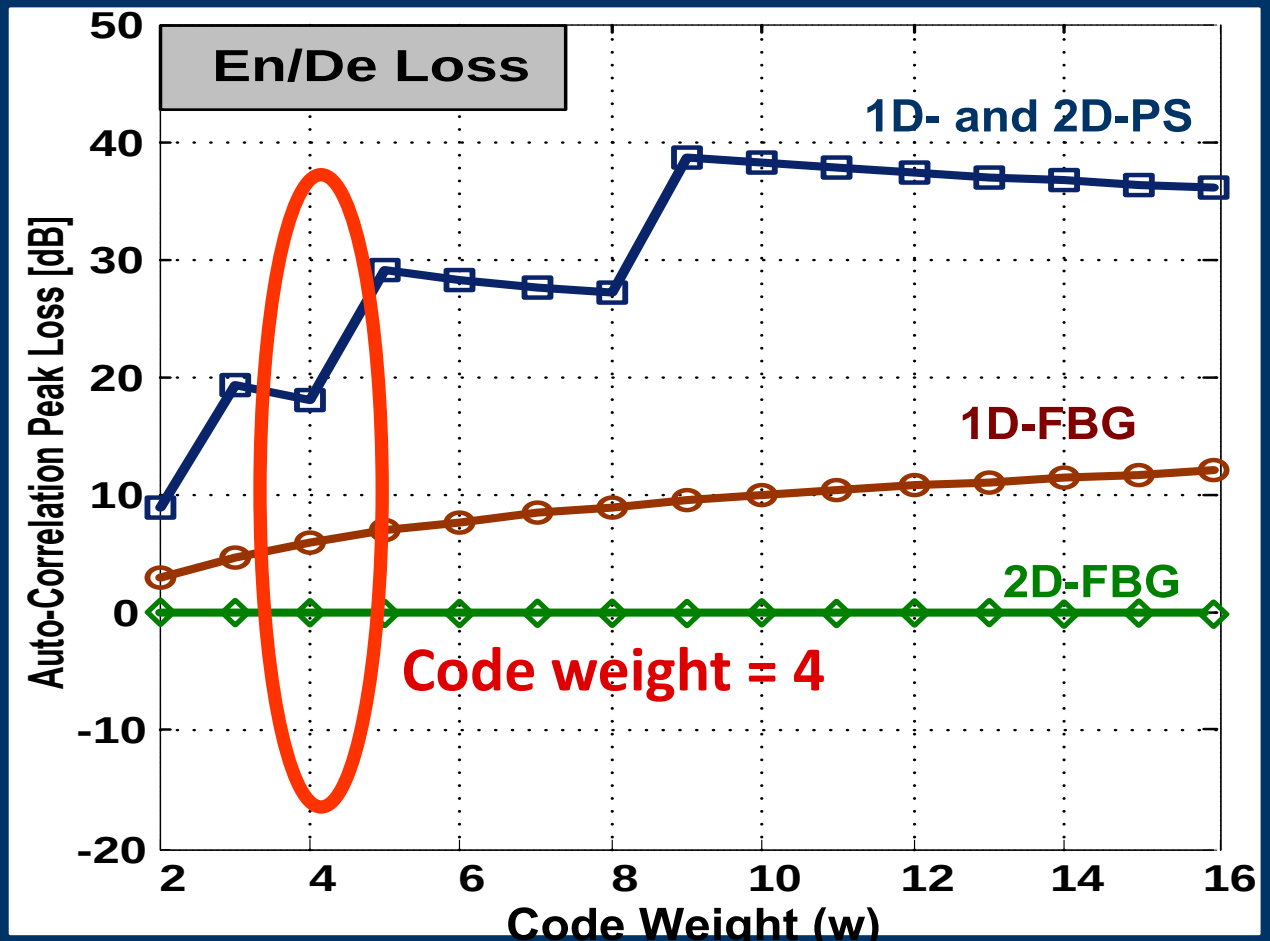
Performance of OC Monitoring: Power Budget

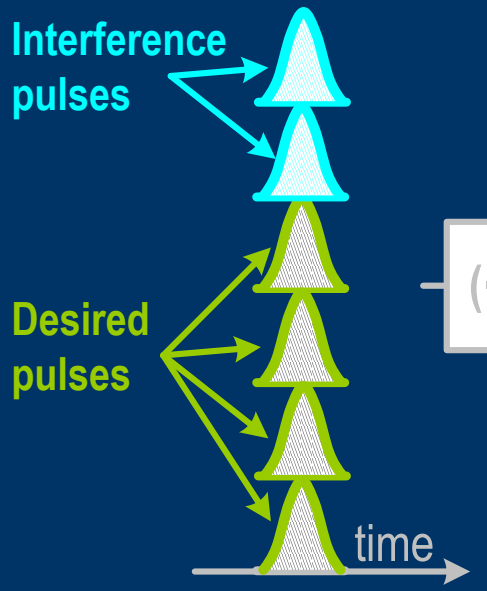


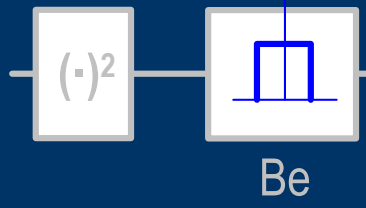
→ *2-D reduces the coding-decoding loss to Zero*

Performance of OC Monitoring: Coding Loss



Performance of OC Monitoring: *Beat Noise*





Square Terms
(1)- (·)² Desired Signal (DC)
(2)- (·)² Interference noise (DC)

Cross-Terms: Beat Noise
(3)- (·)(·) desired-to-desired
(4)- (·)(·) desired-to-Interference
(5)- (·)(·) Interference-to-Interference

$$i = i_{dsig} + i_{Int} + i_{BN} + i_{SN} + i_{TH} + i_{D}$$

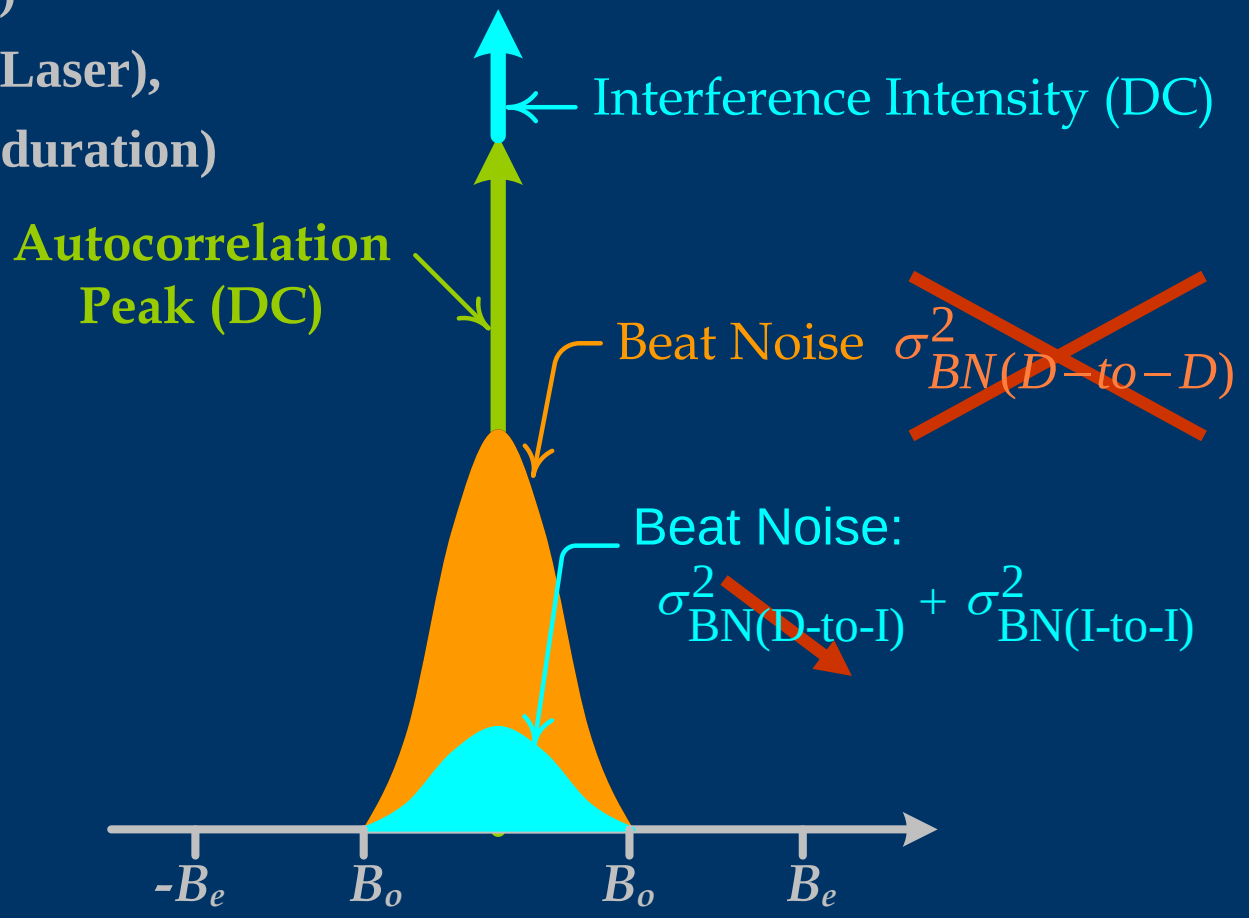
$$i_{BN(d-d)} + i_{BN(d-Int)} + i_{BN(Int-Int)}$$

Performance of OC Monitoring: *Beat Noise*

Example: (Bo « Be)

Bo=10 MHz (DFB Laser),

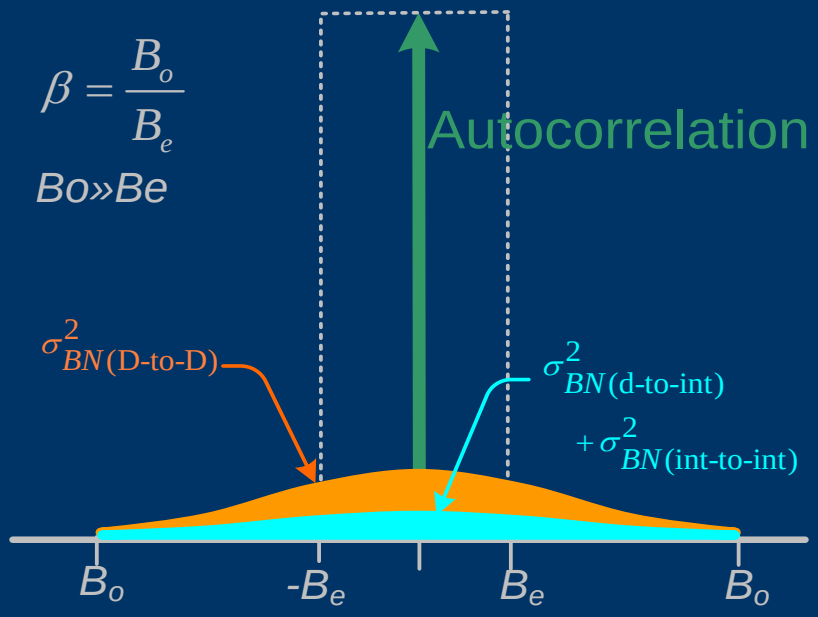
Be=1GHz (1/pulse duration)



Performance of OC Monitoring: *Beat Noise*

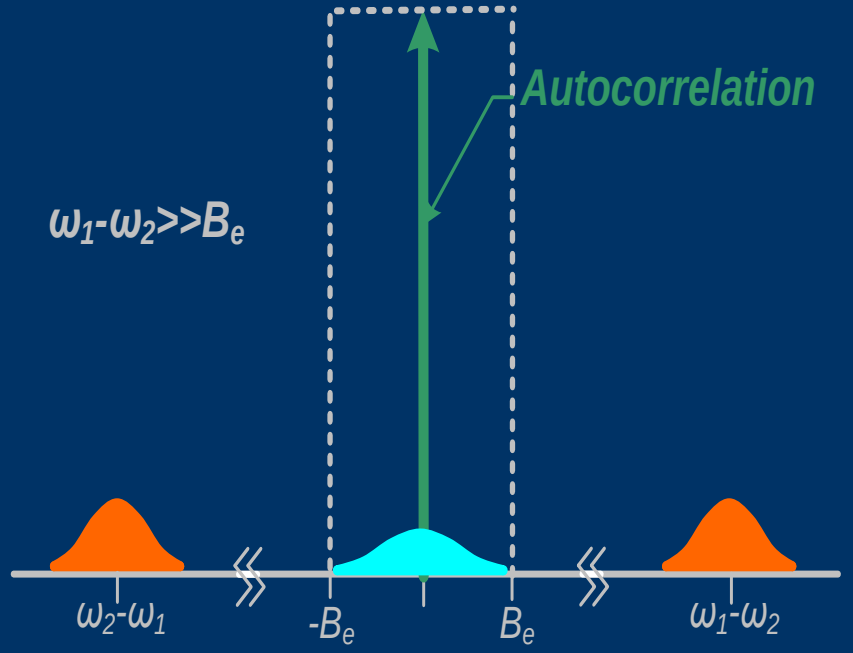
1 **Broadband Sources (BBS)**

Bo=1 THz, Be=1GHz



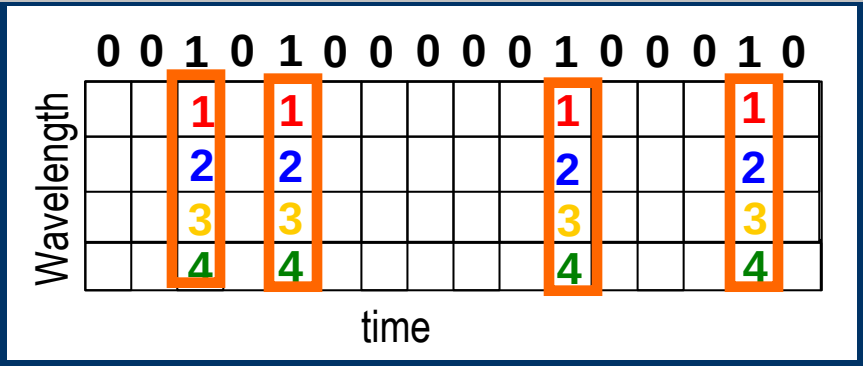
Bandwidth consuming!!

2 **2D Coding (wavelength & time)**

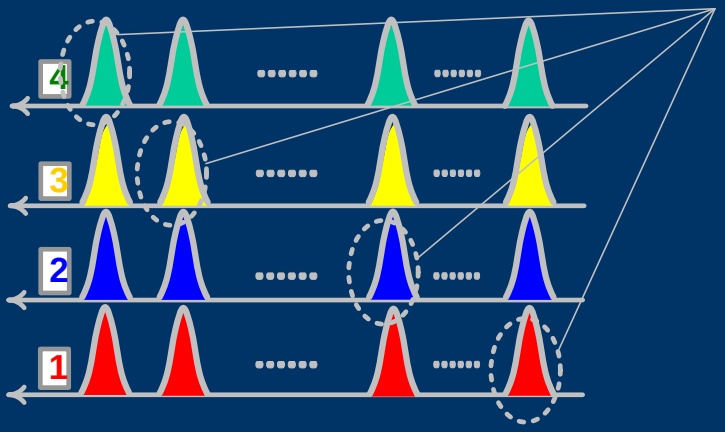


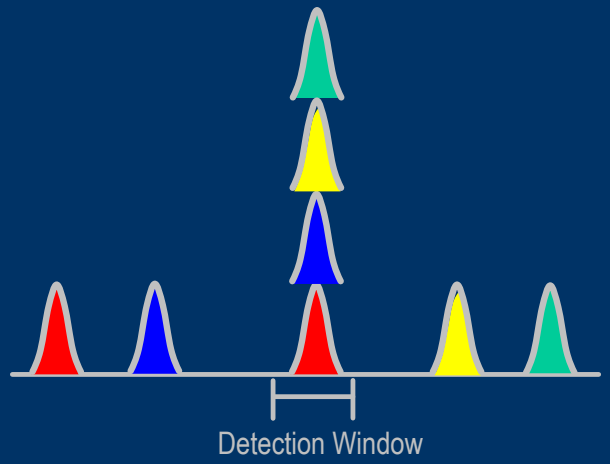
Expensive!!

Performance of OC Monitoring: *Beat Noise*



Are chosen to make the autocorrelation peak

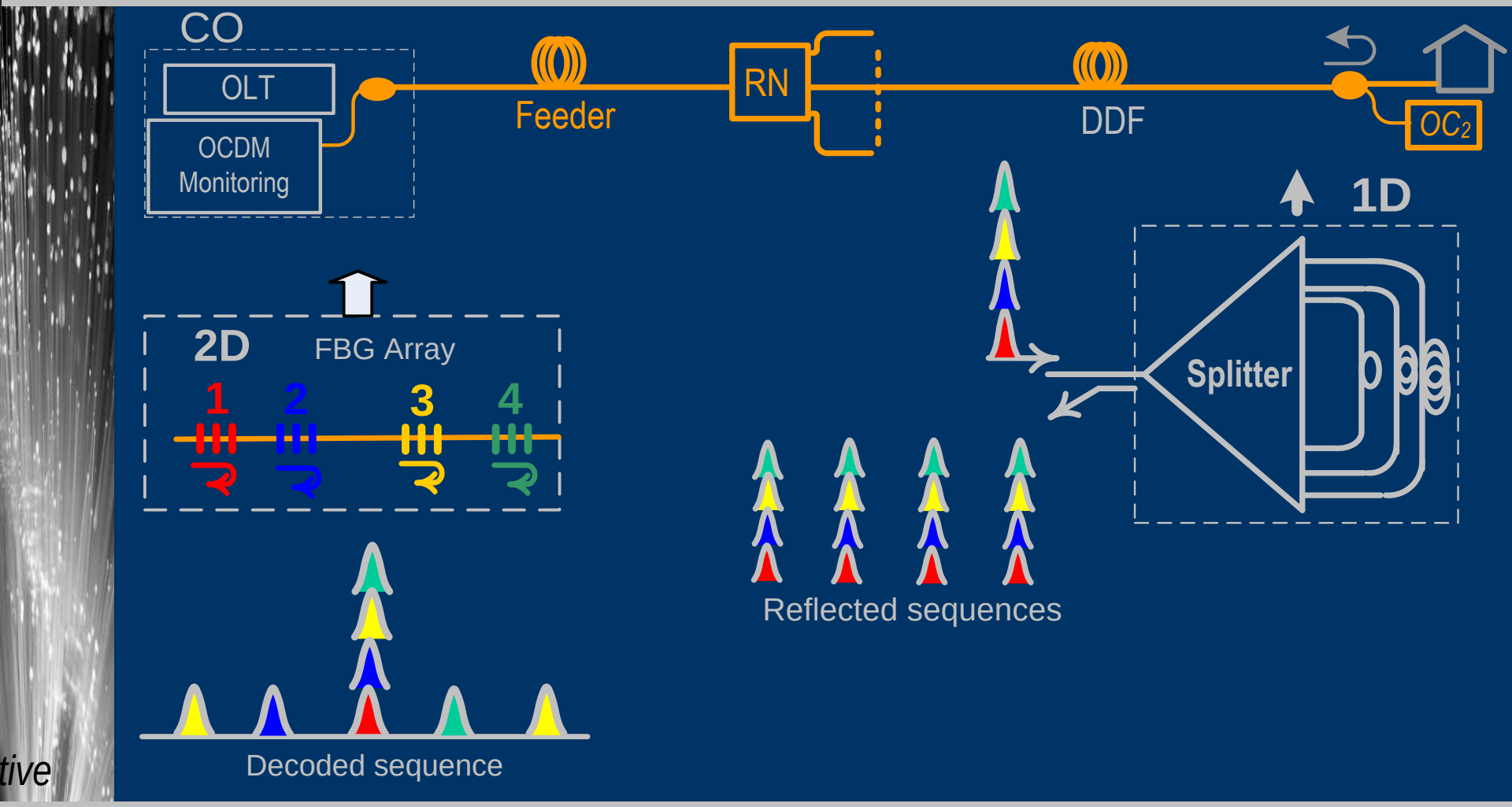




- No beating between desired pulses
- Interference related beating reduces

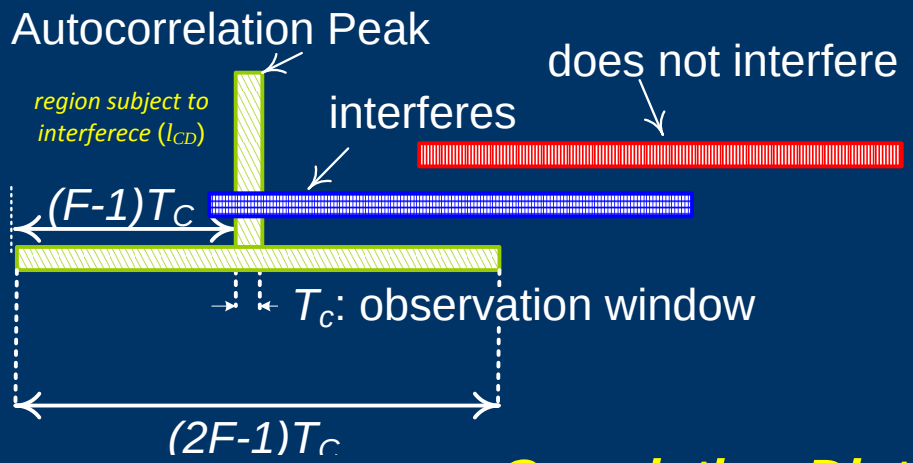
L. Tansevski, L. A. Rusch, "Impact of the beat noise on the performance optical CDMA systems," IEEE Comm. Letters, vol. 4, no. 8, 2000

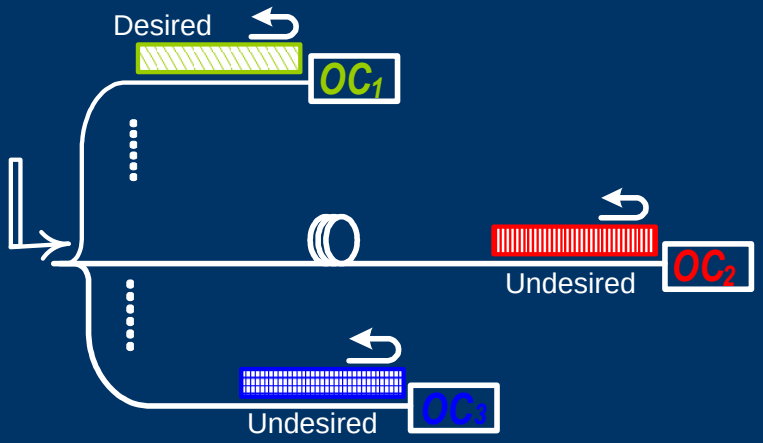
Performance of OC Monitoring: *Hybrid Coding*



Performance of OC Monitoring: *Network Geography*

Interference Statistics





***Correlation Distance* (CD)**

Only CMs closer than CD can interfere with the desired CM sequence

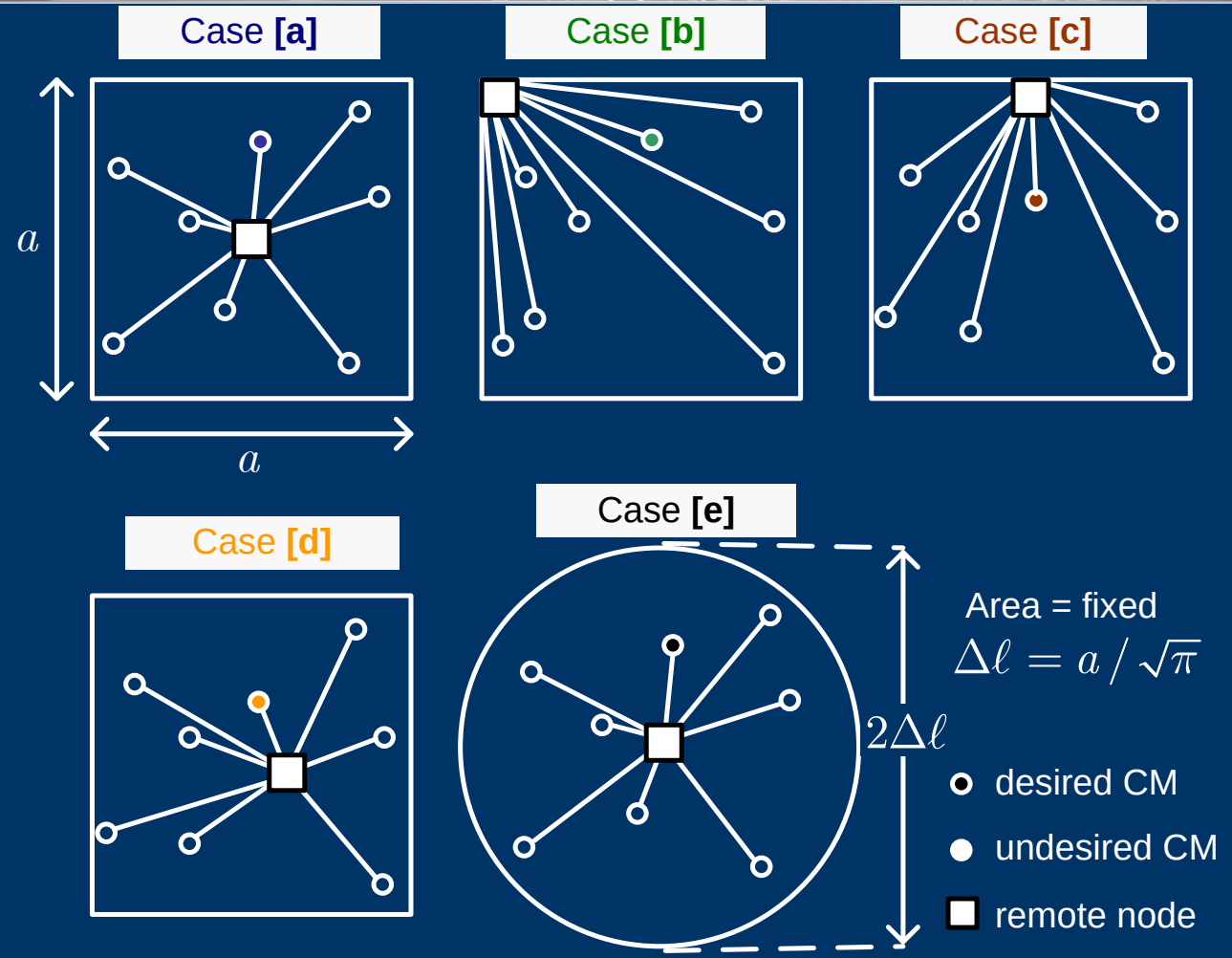
$$l_{CD} = c\,FT_c/2$$

CD= Half of the physical length of a code

F: Code Length, T_c: Pulse Width, c: Light Speed in Fiber

Physical distance respect to the CO affects interference statistics

Performance of OC Monitoring: *Geographical distribution*



Performance OC Monitoring: *Geographical distributions*

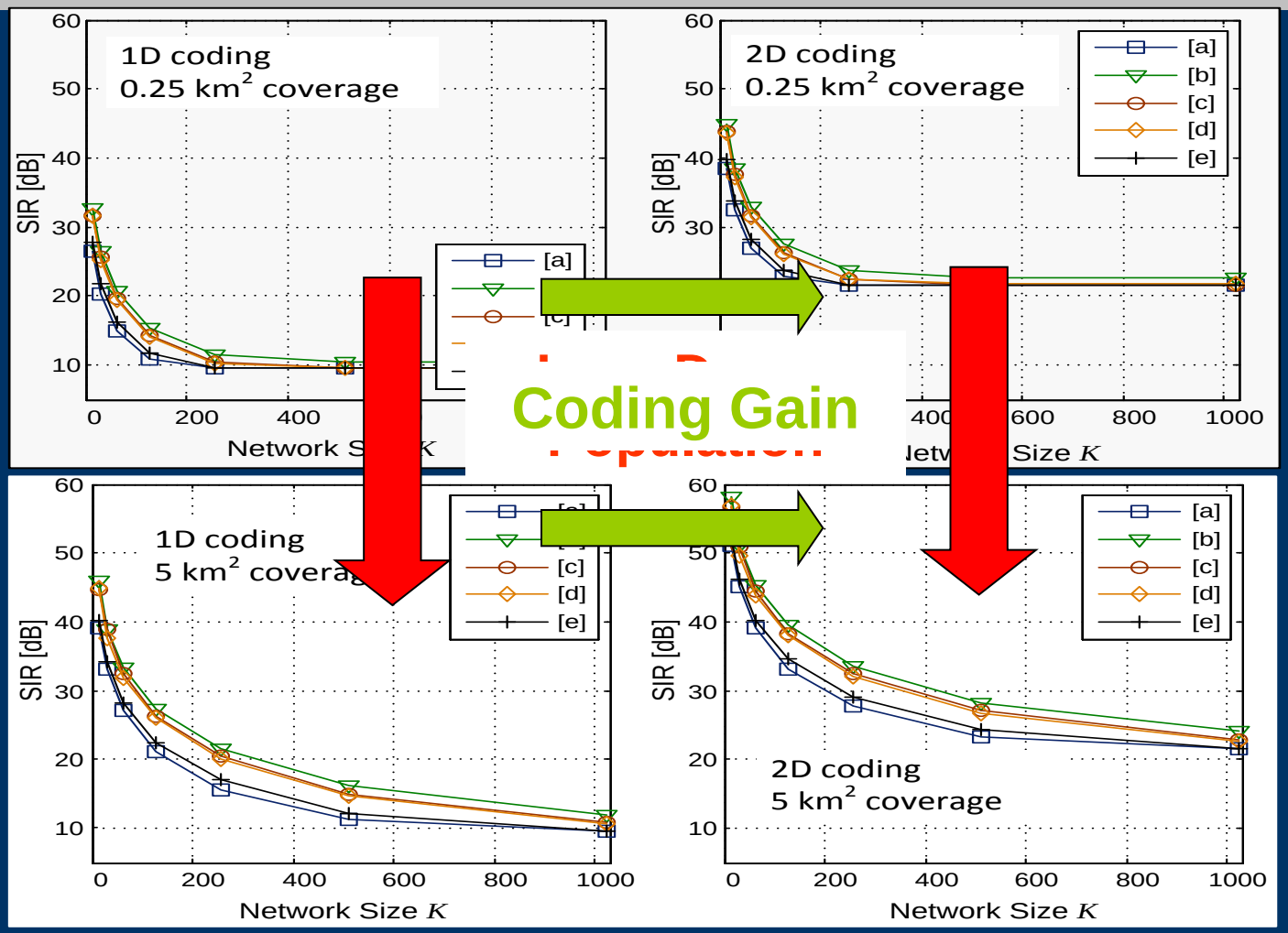
Signal-to-interference-ratio (SIR)

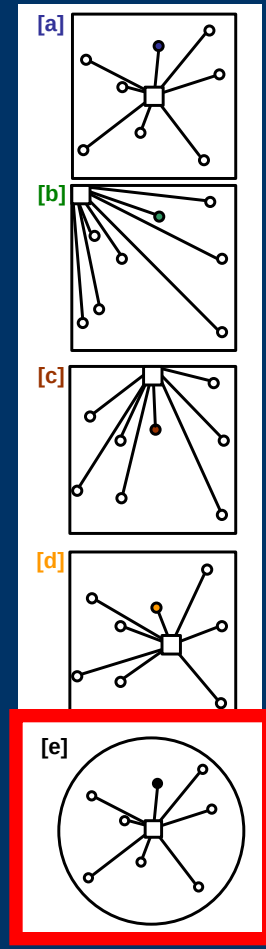
$$SIR \triangleq \left[\frac{\text{Average of Autocorrelation Peak}}{\text{Average of Interference}}\right]^2$$

Geographical distribution & code choice

We assume a *linear detection* process, i.e., powers add together.

Performance of OC Monitoring: *Geographical distributions*





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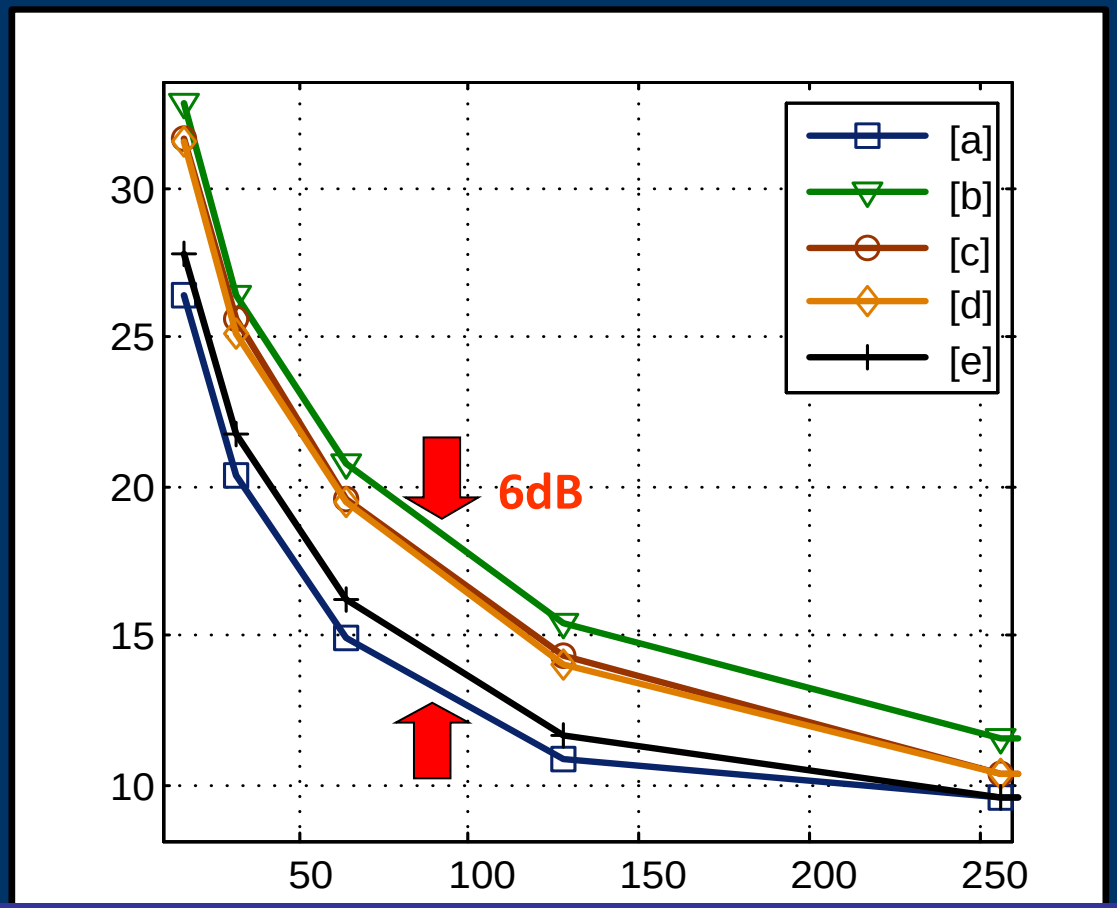
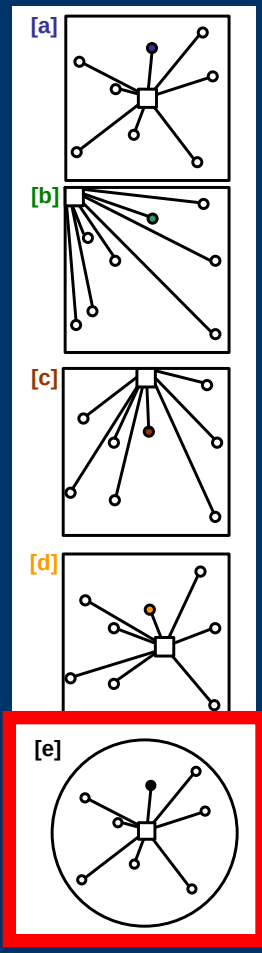
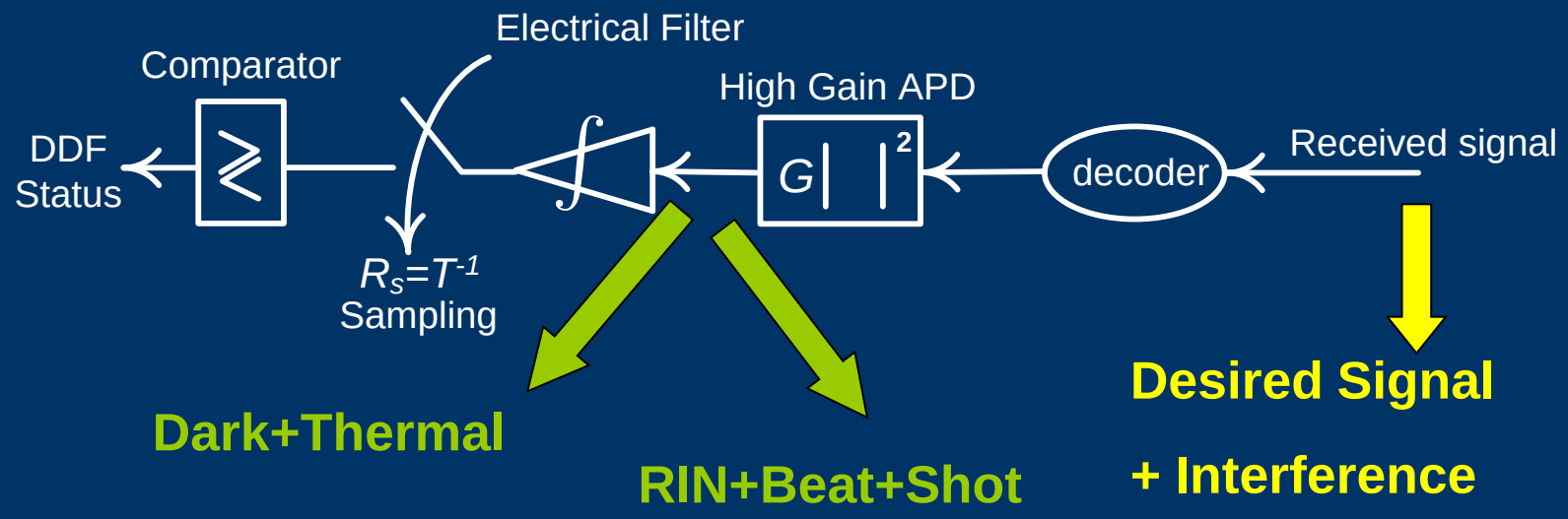




Uniform Radial gives the middle SIR…

Optical Coding Monitoring; A more realistic consideration



$$i_{PD}(t) \triangleq G\left|r(t)\right|^2 + i_{RIN}(t) + i_{SN}(t) + i_{DN}(t) + i_{TN}(t)$$

Signal dependent ⇒ **interference dependent**

PON Monitoring: Signal-to-Noise-Plus-Interference Ratio

$$SNIR \triangleq \frac{\bar{\mu}_{sig}^{2}}{\bar{\mu}_{int}^{2} + \overline{\sigma_n^2}}$$

Desired signal: Auto-correlation Peak

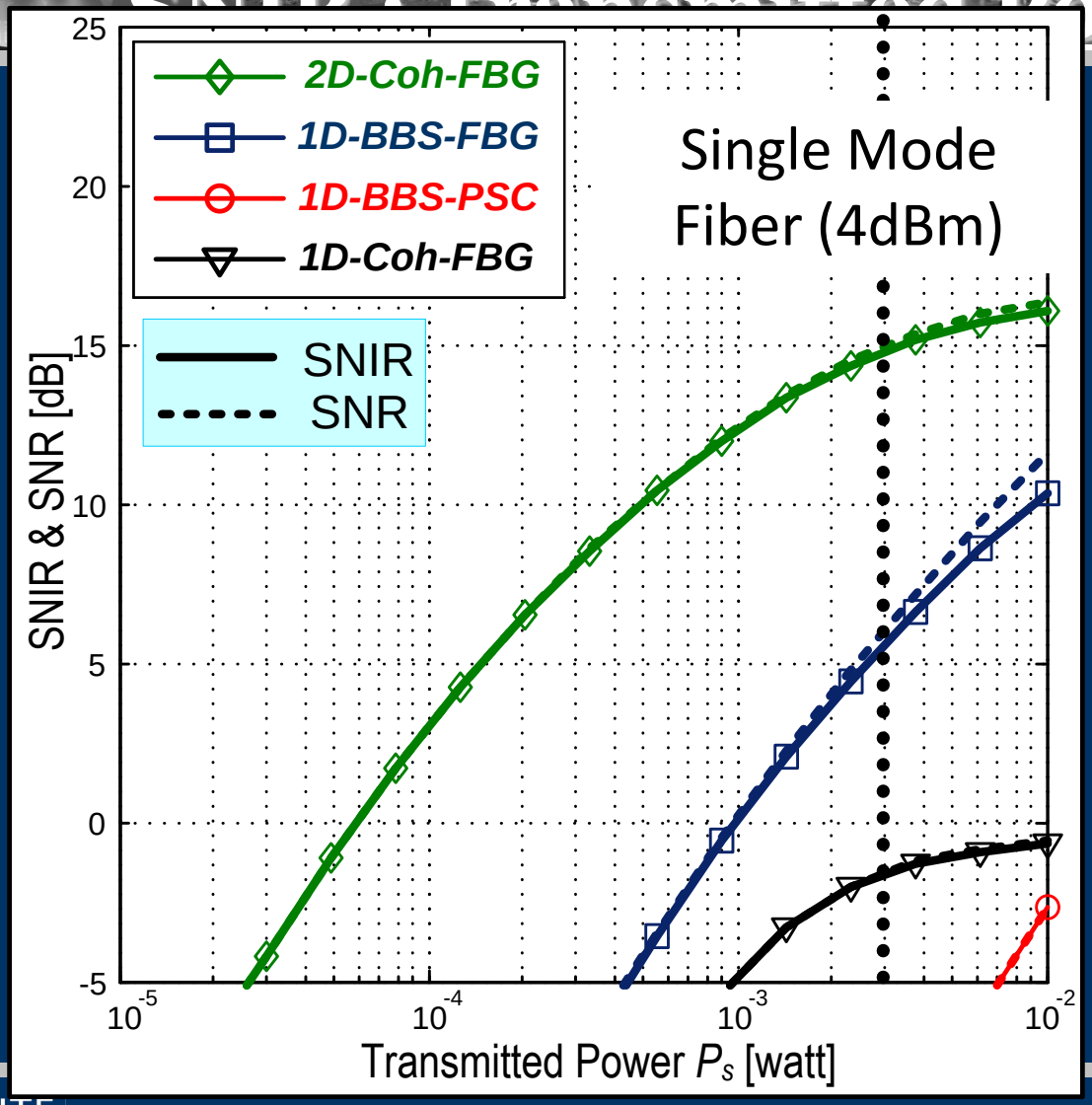
RIN+Beat Noise

Shot+Dark+Thermal

Interference

$$SNR \triangleq \bar{\mu}_{sig}^{2} \Big/ \overline{\sigma_n^2} \quad \Rightarrow \quad SNIR^{-1} = SIR^{-1} + SNR^{-1}$$

PON Monitoring
SNIR : Transmitted Power



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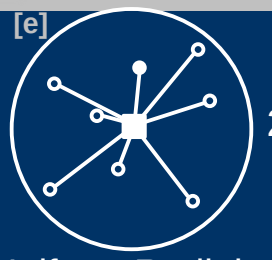


Uniform Radial

Δl = 564 m
l_f = 20 km

B_o = 1 THz (BBS)
B_o = 10 MHz (laser)
T_c = 1 ns
K = 128

False-Alarm Probability

- **False-Alarm Probability**

P_{FA} = The probability we falsely declare a broken fiber

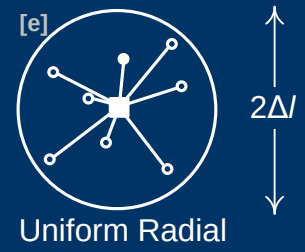
- **Detection Probability**

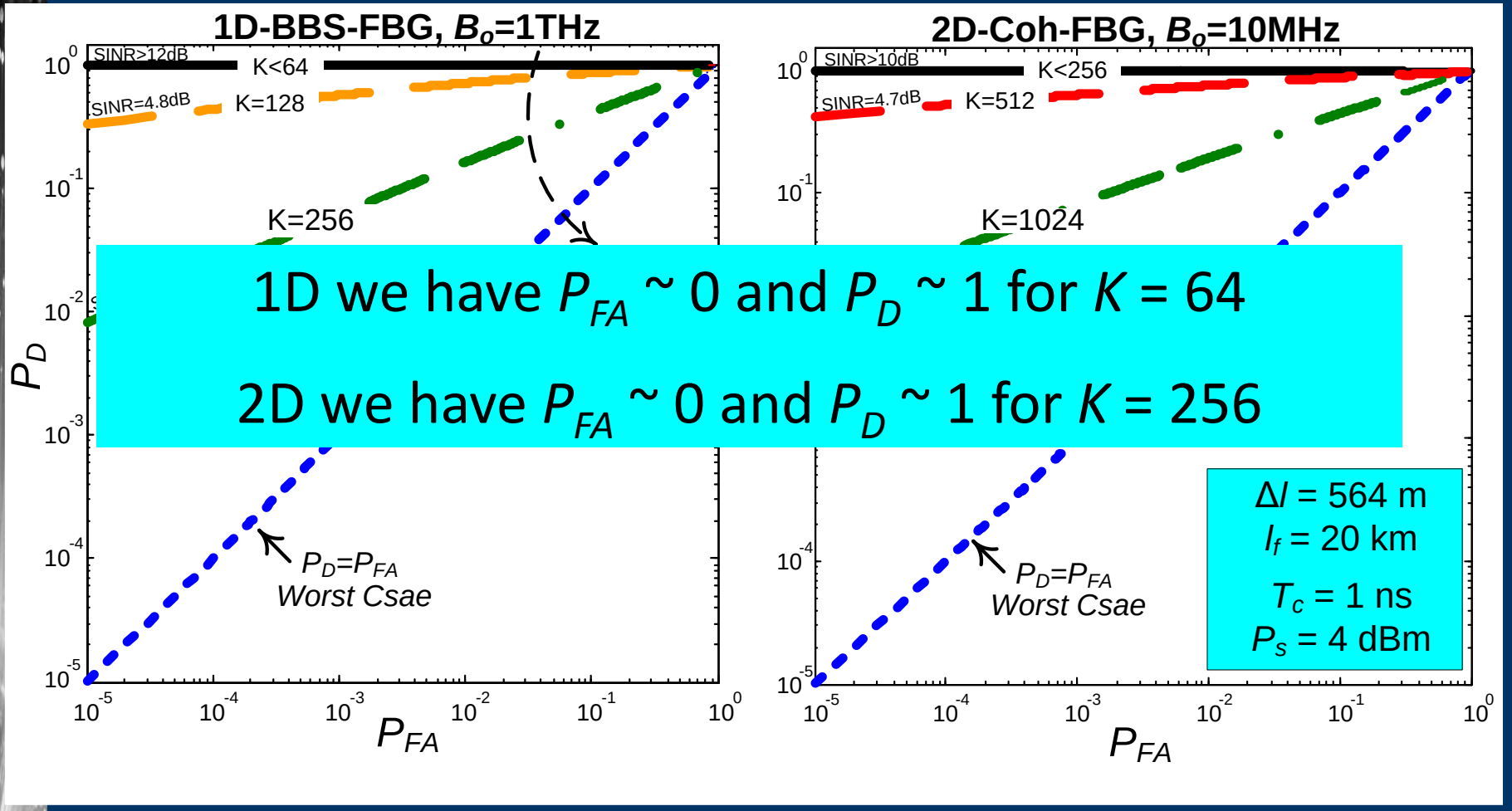
P_D = The probability we correctly declare a healthy fiber

Neyman-Pearson Test:

A plot of P_D *vs.* P_{FA} *(ideal case:* $P_D = 1$, $P_{FA} = 0$*)*

OC Monitoring: Neyman-Pearson Test





1D we have P_{FA} ~ 0 and P_D ~ 1 for K = 64

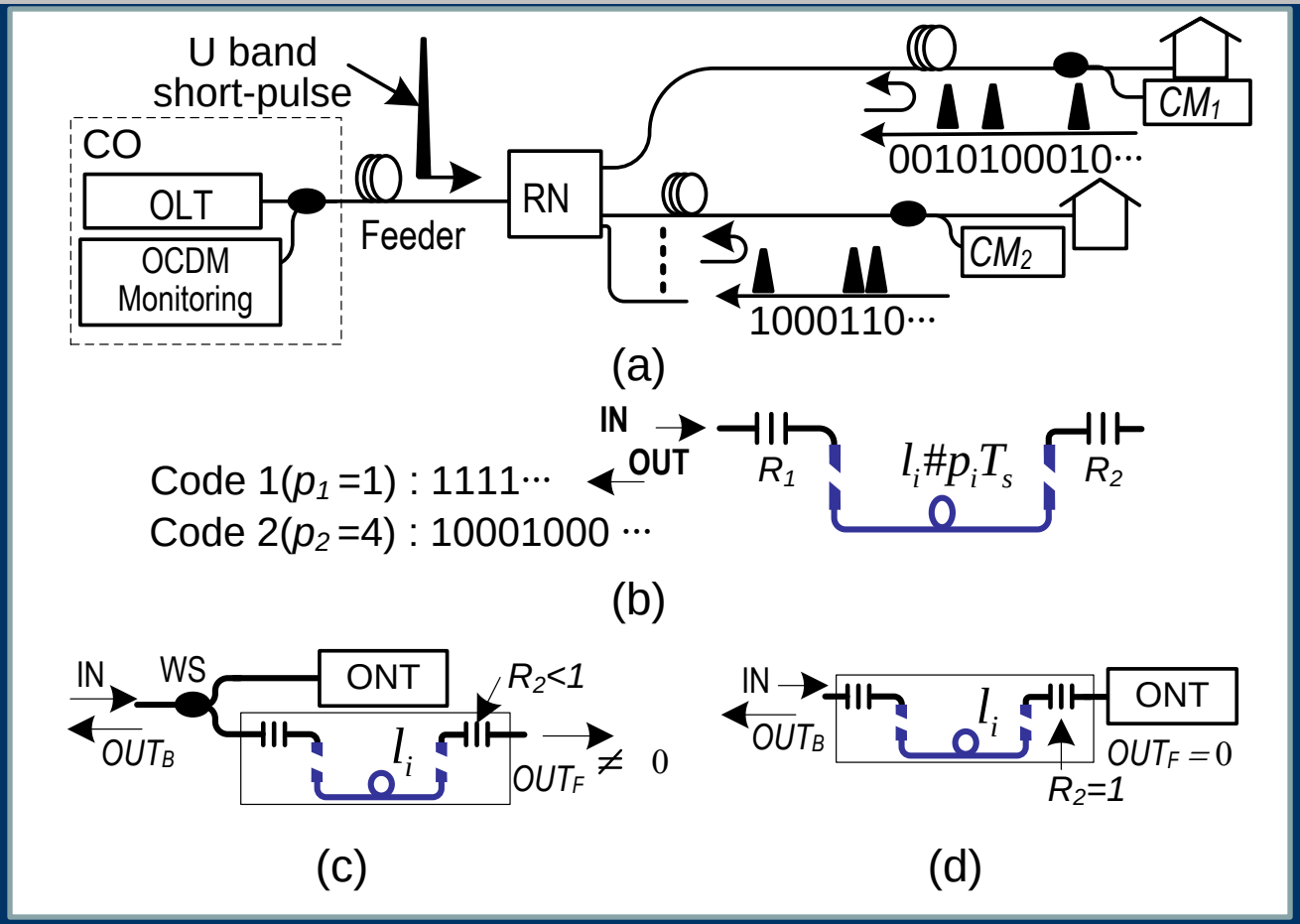
2D we have P_{FA} ~ 0 and P_D ~ 1 for K = 256

Δl = 564 m
l_f = 20 km
T_c = 1 ns
P_s = 4 dBm

Presentation Outline

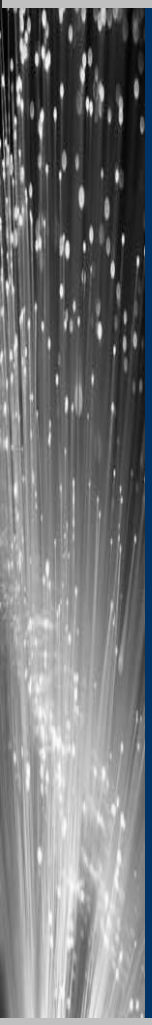
- Introduction:
  - FTTH PON evolution/ Optical performance monitoring
- PON monitoring challenges
  - Limits of OTDR / Existing alternative approaches
- Our Optical Coding (OC) System approach
  - 1 D , 2 D, and hybrid 1D/2D encoders
  - Our OC system *vs* Standard OCDMA
- Performance analysis and results
  - Power budget /Geographical distribution and Source effects
  - System capacity/Signal to Noise Ratio/Probability of False Alarm
- Mirror Cavity based New Coding
- OC system for WDM & TDM/WDM PONs
- Summary and future work

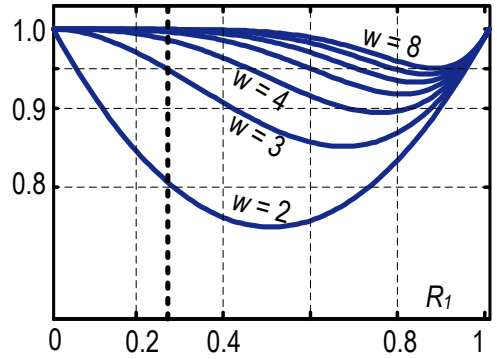
Periodic Coding: *Cavity based Encoder*



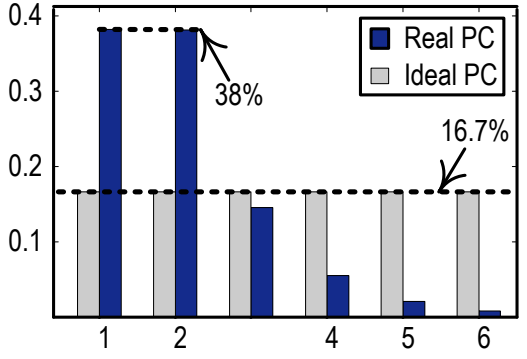
Two grating cavity: simple, low cost, the length fixes the code, etc.

Periodic Coding

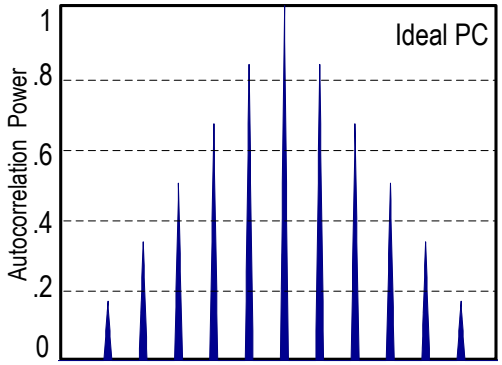


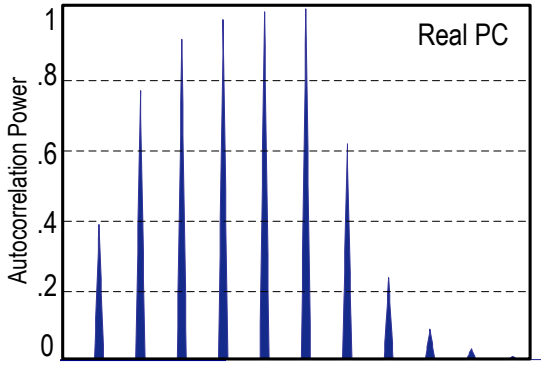


(a) Total code power

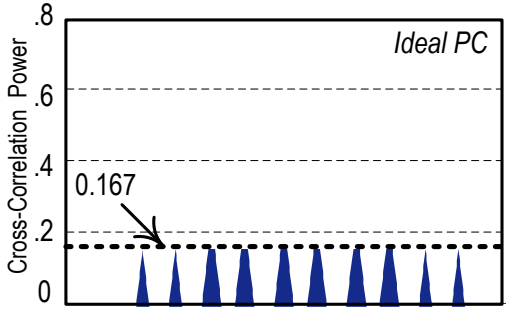


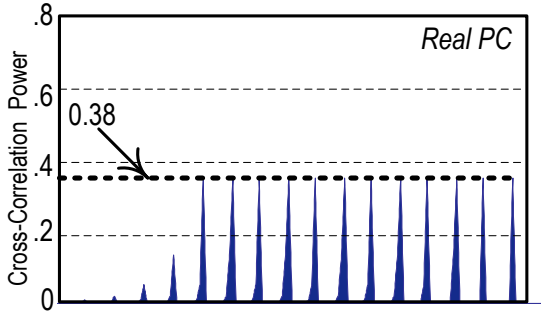
(b) Ideal vs. Real code pattern





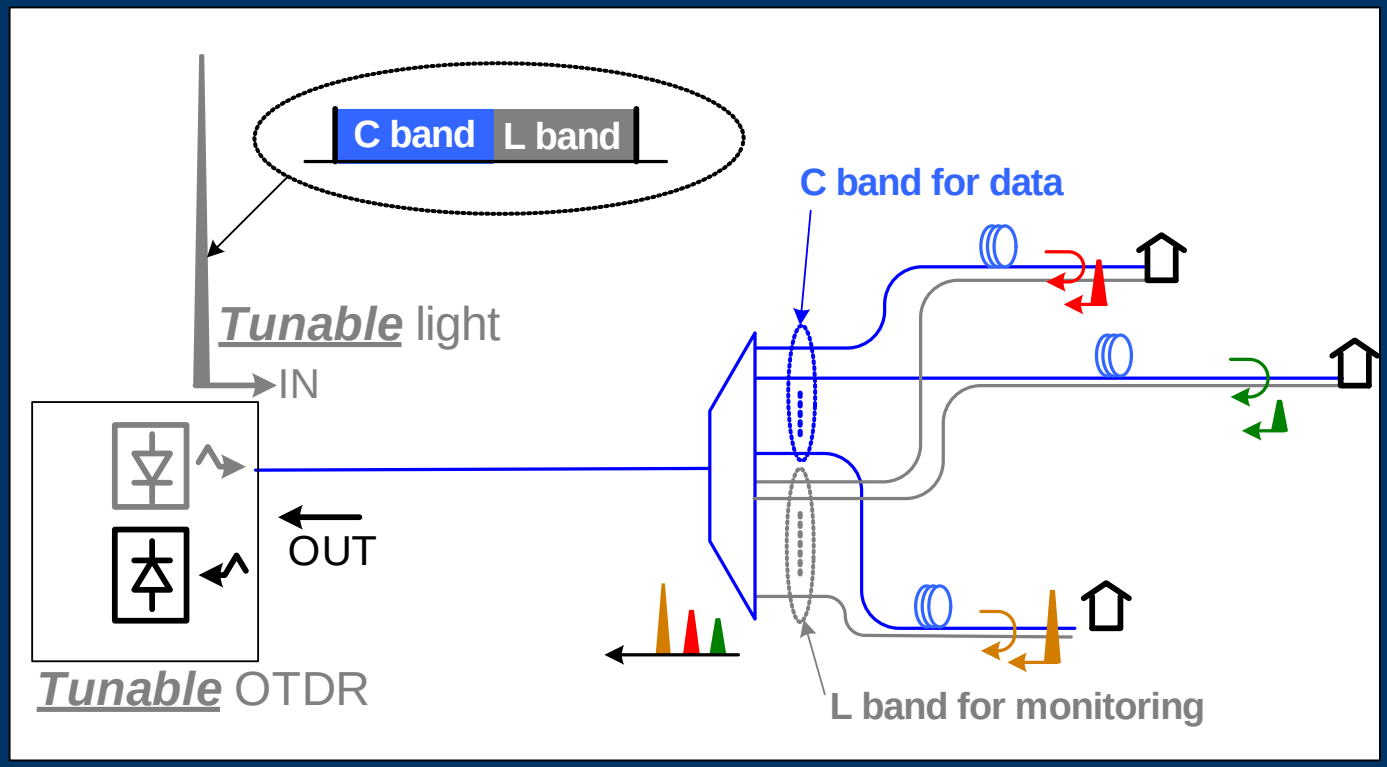
(c) Ideal vs. Real PC normalized autocorrelation for the code: [0, 9, 18, 27, 36, 45]





(d) Ideal vs. Real PC normalized cross-correlation between [0, 9, 18, 27, 36, 45] and [0, 17, 34, 51, 68, 85]

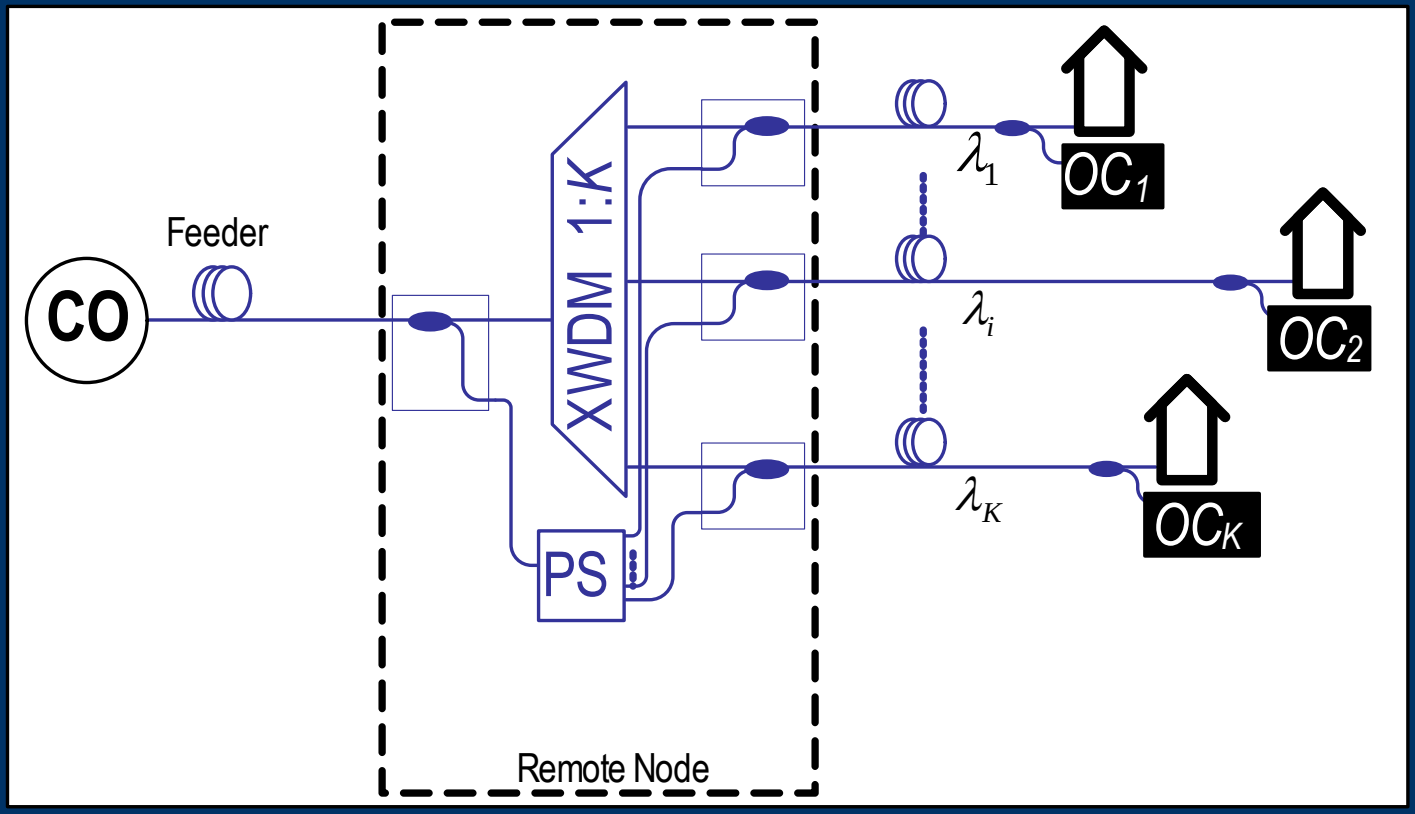
OC Monitoring of WDM PON



2 λs per customer: ***1 for data + 1 for monitoring***

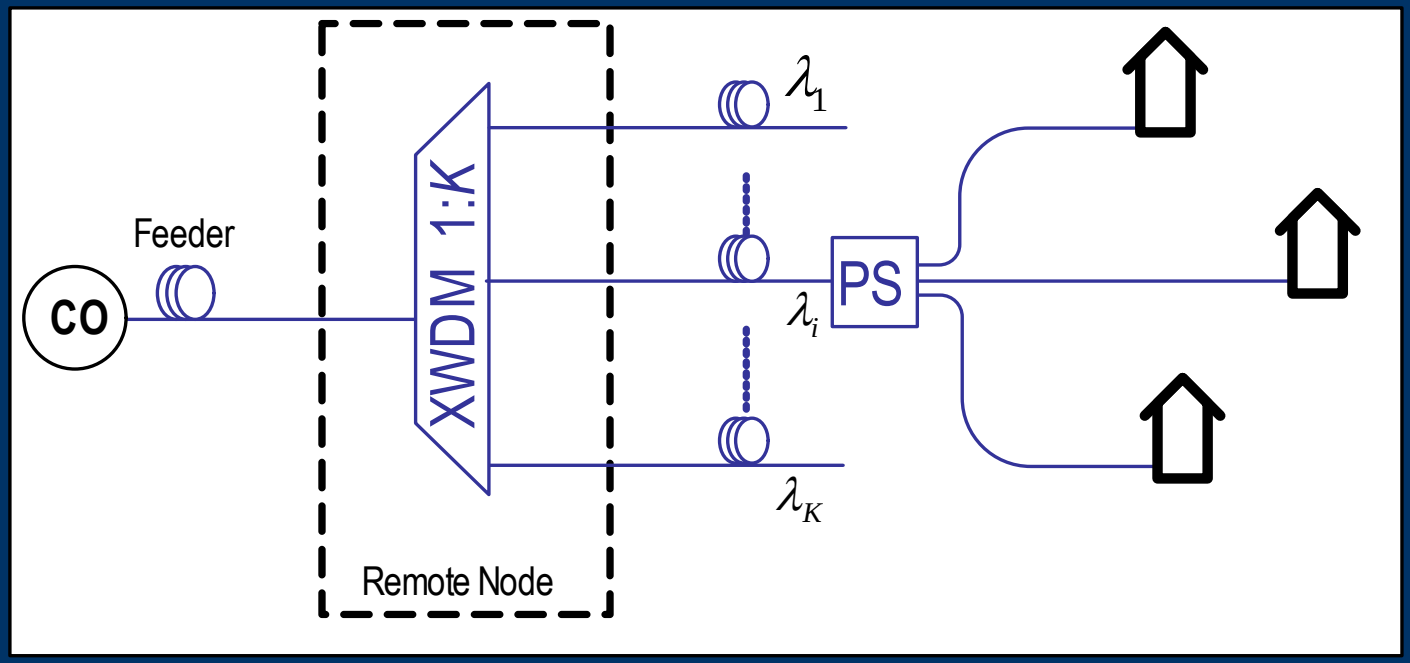
➔ ***Monitoring consumes 50% of the spectral capacity***

OC Monitoring of WDM PON



- Uses standard U band for live monitoring even for WDM-PON
- Saves 50% of the spectrum resource

OC Monitoring of TDM over WDM PON

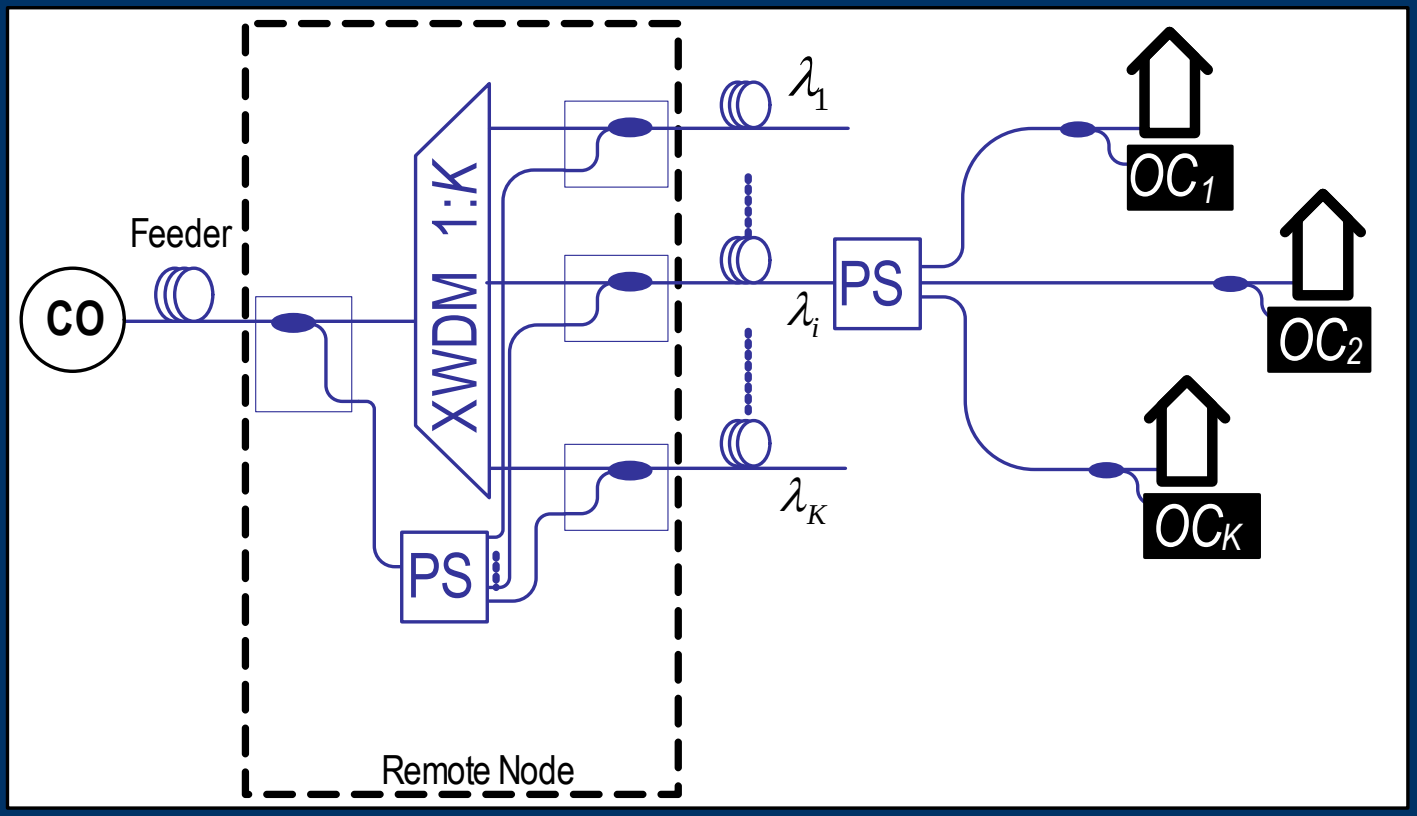


Still no effective solution is known!

Notes:

- Electronic embedded monitoring techniques in the ONT side are note addressed here.
- We focus on solutions 100% under the CO control.

OC Monitoring of TDM over WDM PON



➔ **Only one wavelength monitors the whole TDM/WDM PON**


Kimwipes