# Feasibility Test on Photonic Technologies

## for developing Japanese Cyber Science Infrastructure


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# SINET and SuperSINET

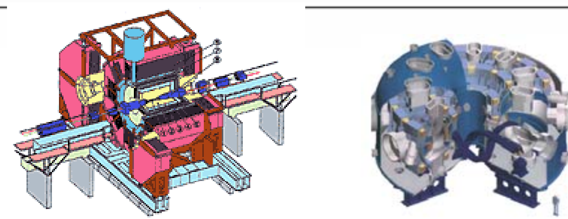
SINET

- started Jan.87 to operate network infrastructure
- 730 universities and research institutes are joined
- IPv4, IPv6 based network
- 40+ NOCs with 1G transport links

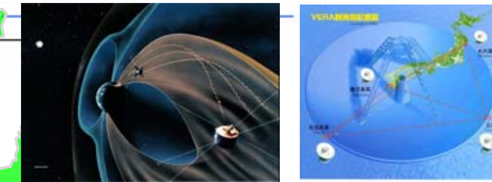
SuperSINET

- started Jan.02 to promote scientific research collaboration
- 30 universities and research institutes
- 4,000km fiber, 350+G, WDM transport with OXC
- 10G IP backbone, MPLS-VPN and lambda

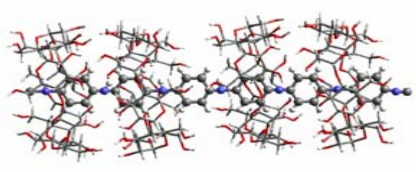
# SuperSINET and Applications



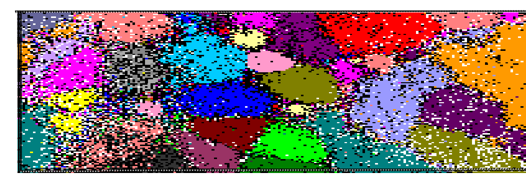
DataGRID for
High-energy Science



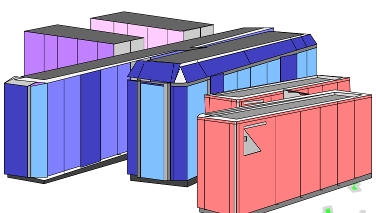
OC-48+ transmission
for Radio Telescope



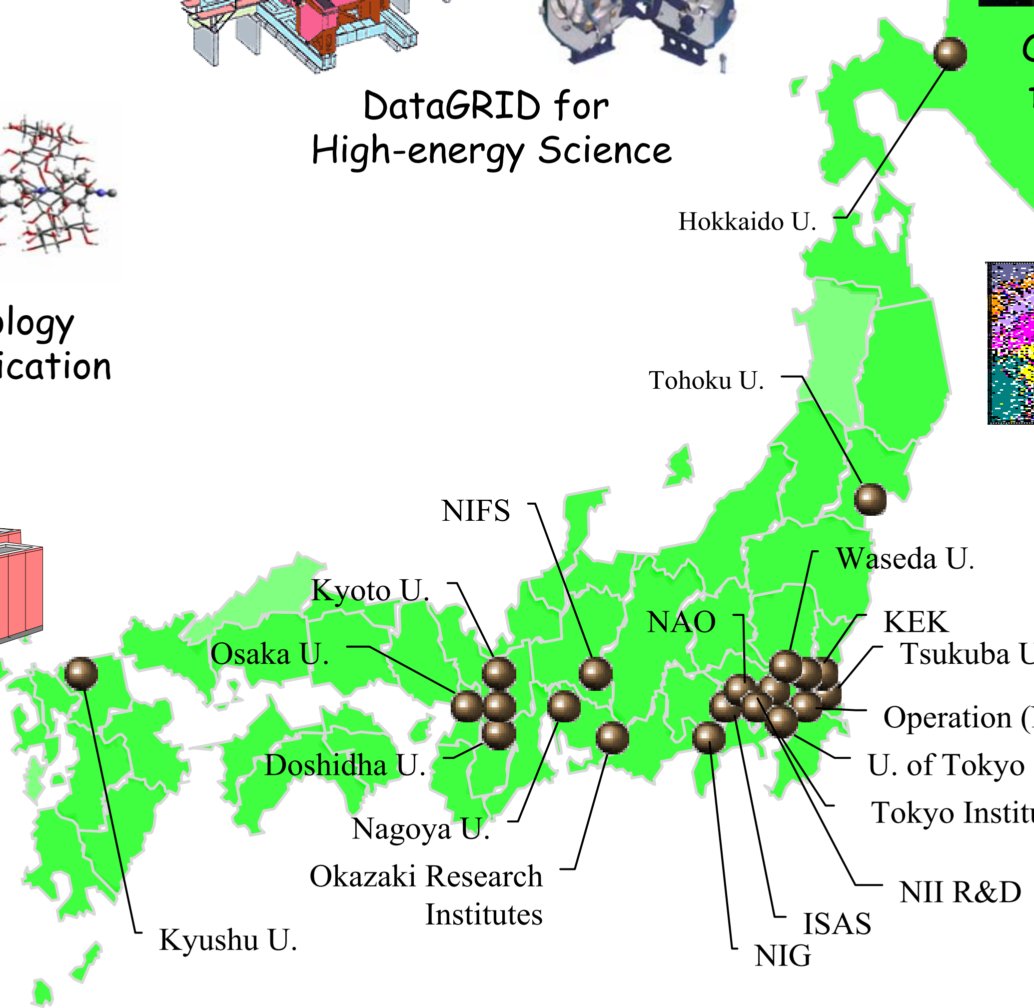
Nano-Technology
For GRID Application



Bio-Informatics



Middleware
for Computational
GRID



# SINETⅢ: Next Generation Network

| | SuperSINET | SINETⅢ |
|---|---|---|
| Technologies | IP over Optical<br>MPLS-VPN, v4/v6 | Optical, IP over everything<br>MPLS/GMPLS, v4/v6 |
| Lambda provisioning | Static with protection | Dynamic with protection, restoration on CoS basis |
| Platform | Standard control / forwarding plane | Multi-layer integration with management plane |
| Transport service | LSP without TE,<br>OC192/OC48/GbE lambda | LSP with TE, bundling,<br>OC768/OC192/OC48/10GbE/<br>GbE lambda |
| Quality/Reliability | >10E-13, 99.9 | <10E-13, <99.99 |

# Technical Challenges

- Dynamic control of transport core
  - integrated control of {lambda, LSP, L2 resource}
  - integration of L0/1(transmission devices)
  - CoS/QoS based control
  - end-to-end provisioning with protection/restoration
- Management plane
  - integrated resource management
  - dynamic topology management
  - fast provisioning
  - Protection recovery(<50ms), restoration(<2~3sec)
- Interface to management plane
  - Corba/XML based
  - co-operation with GRID management

# Responding Science Requirements

## Flat budget

- efficient use of network resources in order to;
  - increase collaborated projects / member institutes
  - satisfy the use of bandwidth
  - gain higher evaluation for scientific use, and
  - reduce operational cost

## Reliability

- reliable network operation;
  - to maintain national cyber science infrastructure
  - responsible as national public infrastructure, and
  - also responsible as infrastructure for international scientific collaboration

## Others

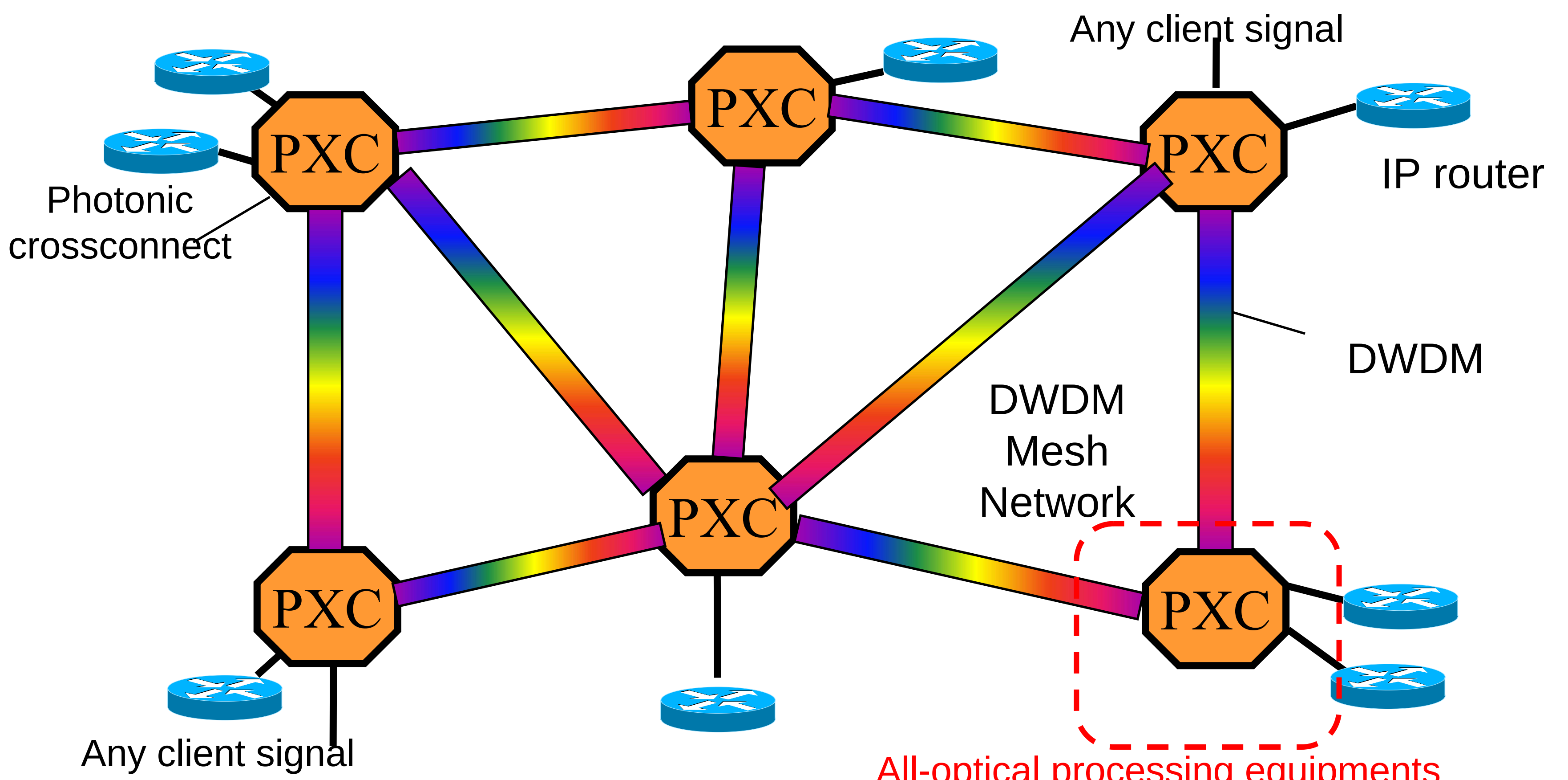
- Shift from communication to science information infrastructure

# Key technologies

- Technologies to realize optical network

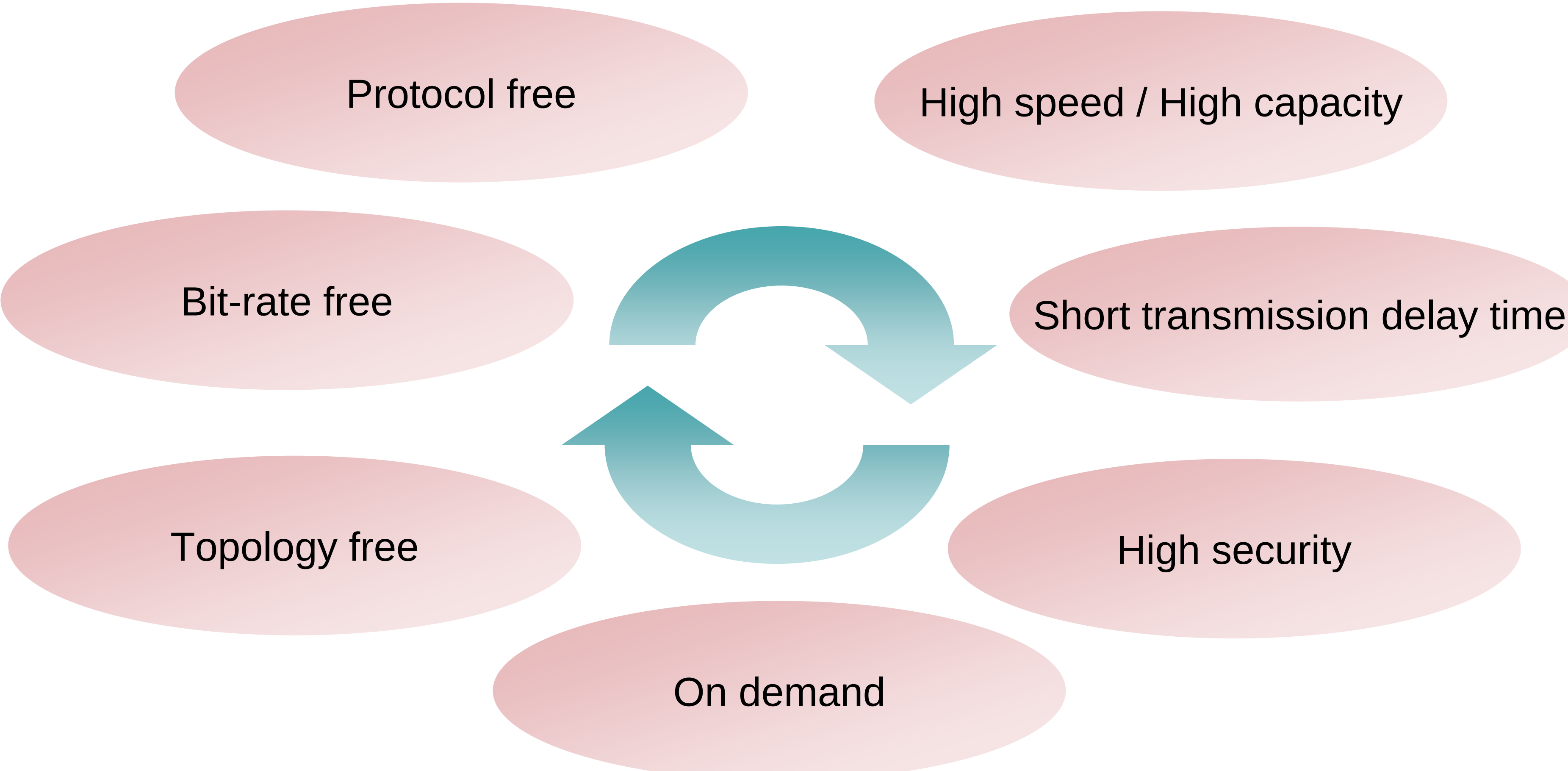
- Our recent activities
  - Field trial 1 : Application of all-optical regeneration system
  - Field trial 2 : Application of automatic chromatic dispersion compensator

# Model for optical network




GMPLS:
Generalized Multi-Protocol Label Switching

# Features of all-optical network



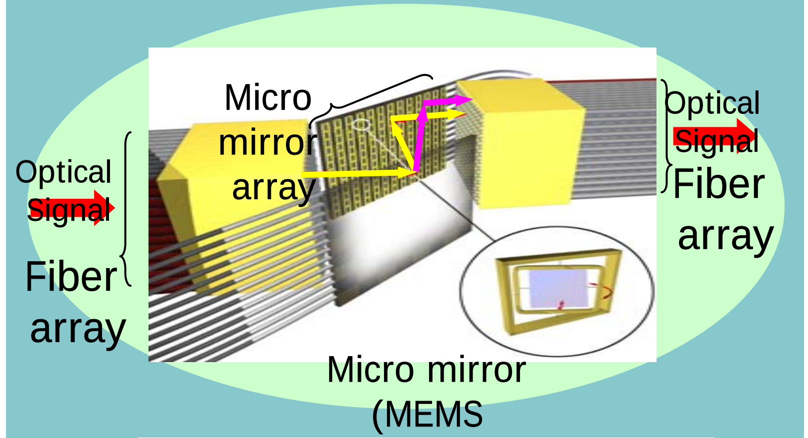

These functions are essential for the future network applications.

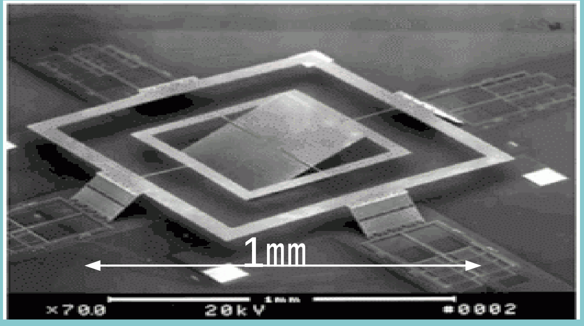
# Physical layer

- Switching technologies on repeater node
  - Optical crossconnect (OXC)/Photonic crossconnect (PXC)

- High-speed Switching
  - Link aggregation
  - Optical add/drop multiplexing (OADM)
  - Optical queuing

3 Dimension Micro Electro Mechanical Systems (3D MEMS)



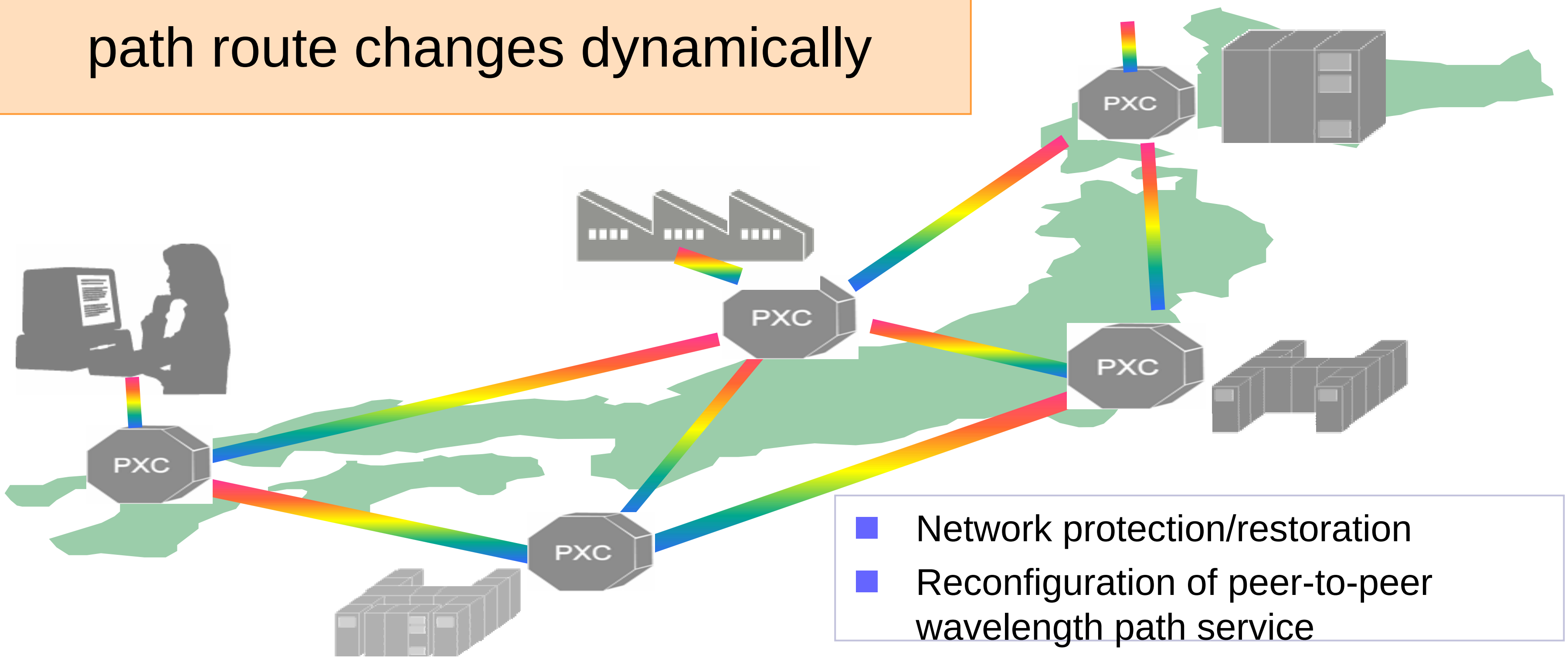
# Physical layer (cont.)

- All-optical signal processing technologies
  - All-optical regeneration
    - 2R regeneration (regeneration and reshaping)
    - 3R regeneration (regeneration, reshaping, and retiming)
  - Optical wavelength conversion
  - Compensation of fiber parameter effect (Chromatic dispersion / Polarization-mode dispersion)

- Optical signal quality measurement technology

# What's problem on physical layer ?

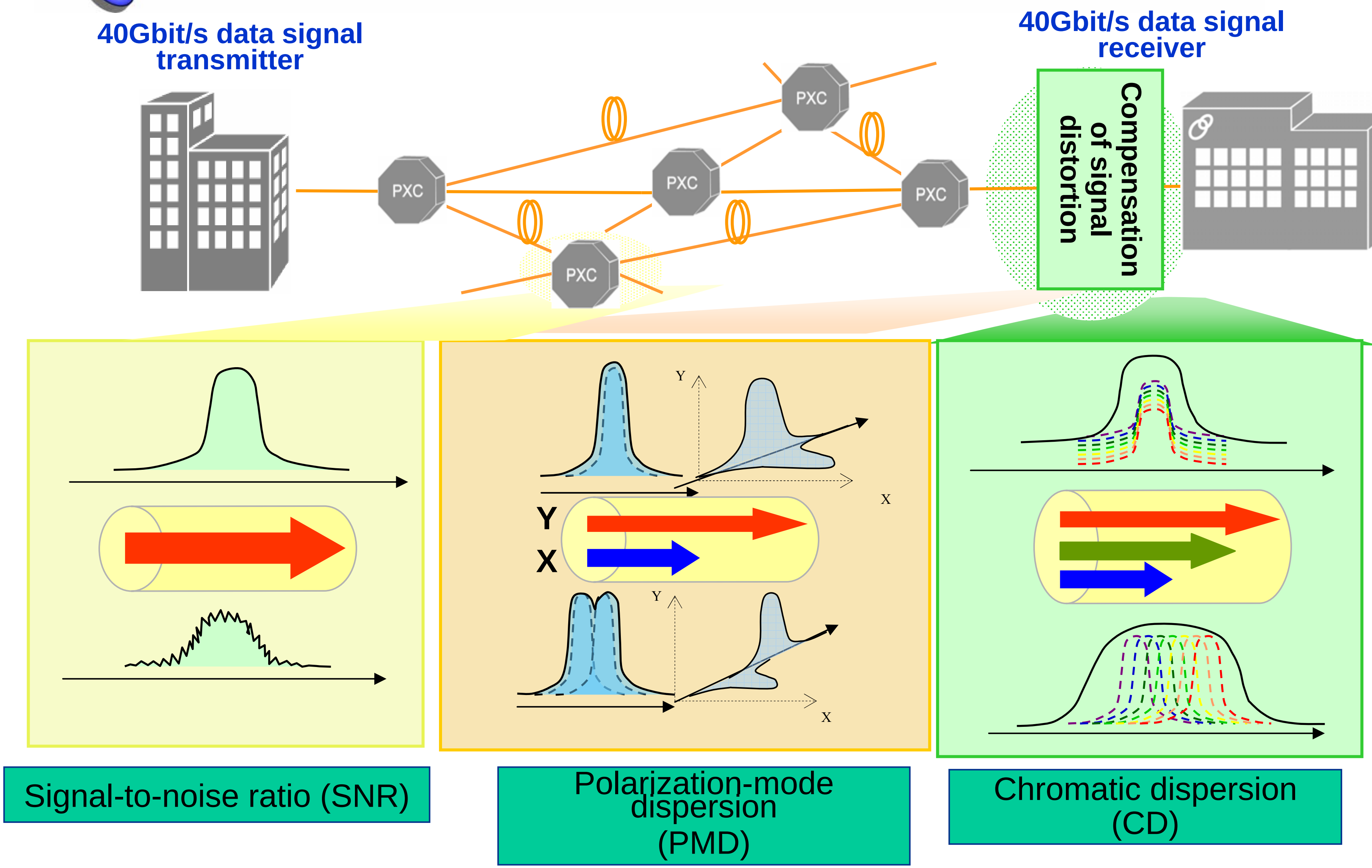
path route changes dynamically



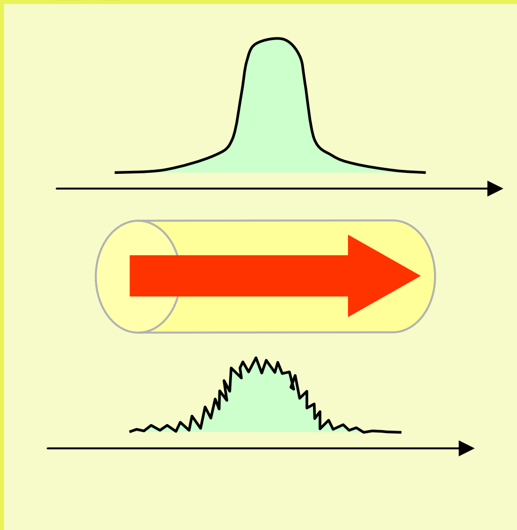

- Network protection/restoration
- Reconfiguration of peer-to-peer wavelength path service

Fiber parameters along the path are changed after reconfiguration.

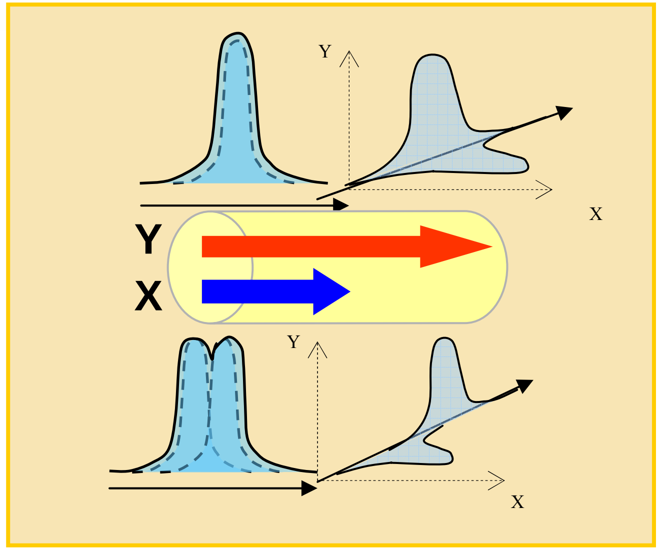
# Signal degradation



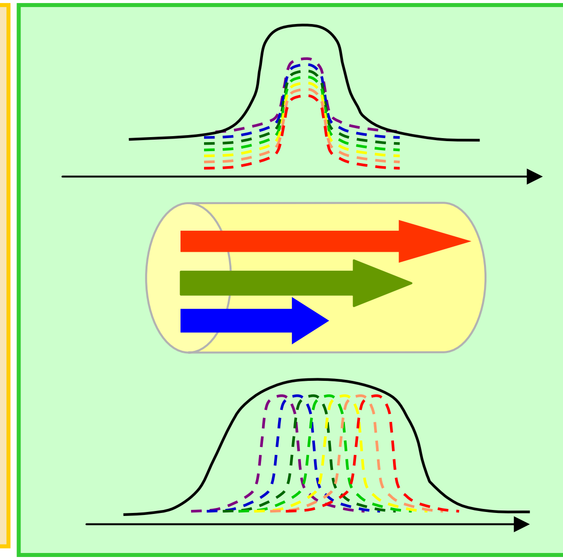
# Compensation technologies



Signal-to-noise ratio (SNR)




Polarization-mode dispersion (PMD)



Chromatic dispersion (CD)

All-optical signal regeneration

- All-optical 2R regeneration
- All-optical 3R regeneration

All-optical signal regeneration
• All-optical 2R regeneration
• All-optical 3R regeneration

PMD compensator

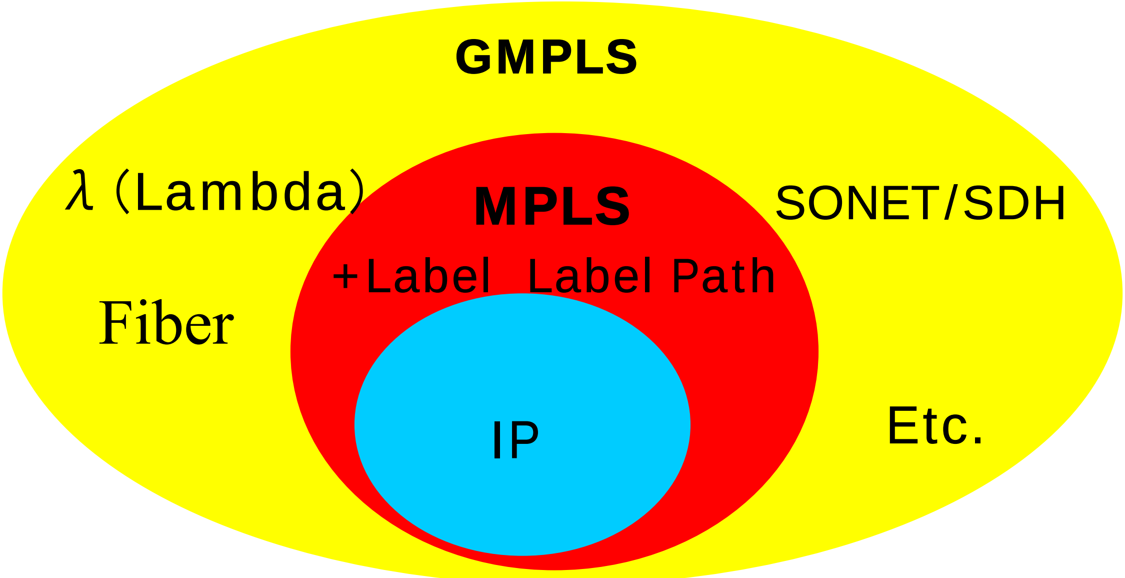
PMD compensator

CD compensator

CD compensator

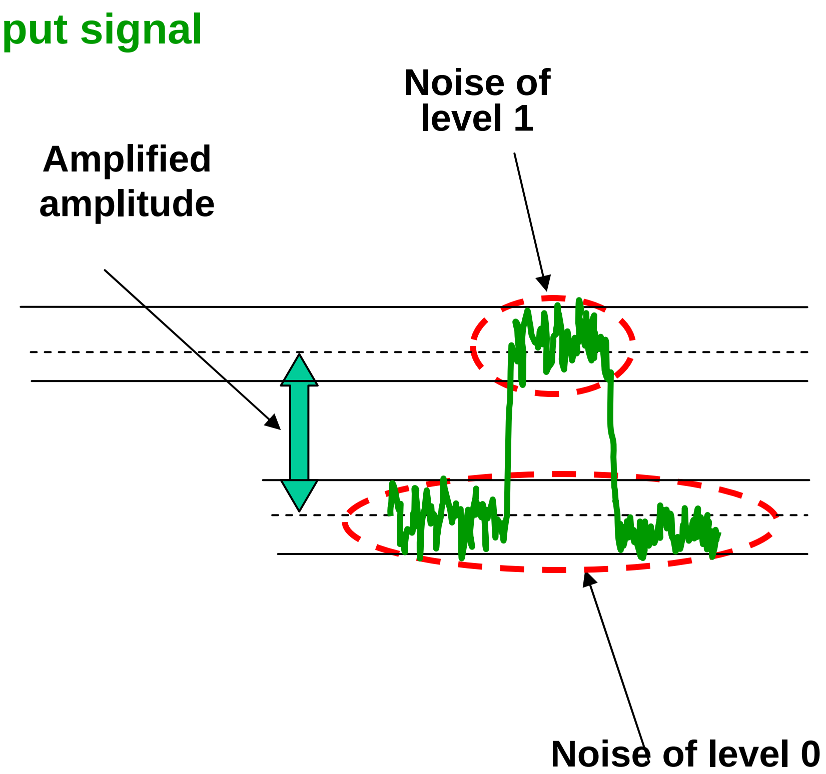
# Control plane

- Generalized MPLS (Multi-Protocol Label Switching)
  - Control and signaling mechanisms of MPLS label path have been extended in order to apply those mechanisms to not only label paths, but also SONET/SDH paths, lambda paths and etc.
- ***MPLS*** is the set of extensions to OSPF, IS-IS, and RSVP to support the routing of *paths*
- ***MPλS*** is a concept that says the MPLS control plane can be leveraged to support routing of lambda paths
- ***GMPLS*** is the realization of the MPλS concept, created by extended MPLS to support *non-packet* paths (λ's, time-slots, fibers)



# How can all-optical 2R regeneration be realized?

- 2R regeneration :
  - regeneration and reshaping




Input v.s. output characteristic of an optical device that has non-linear effect

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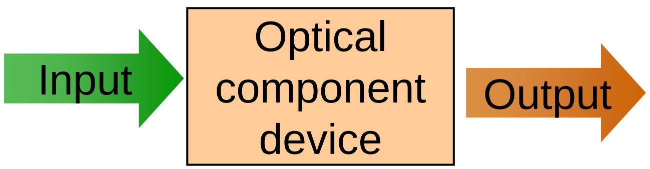
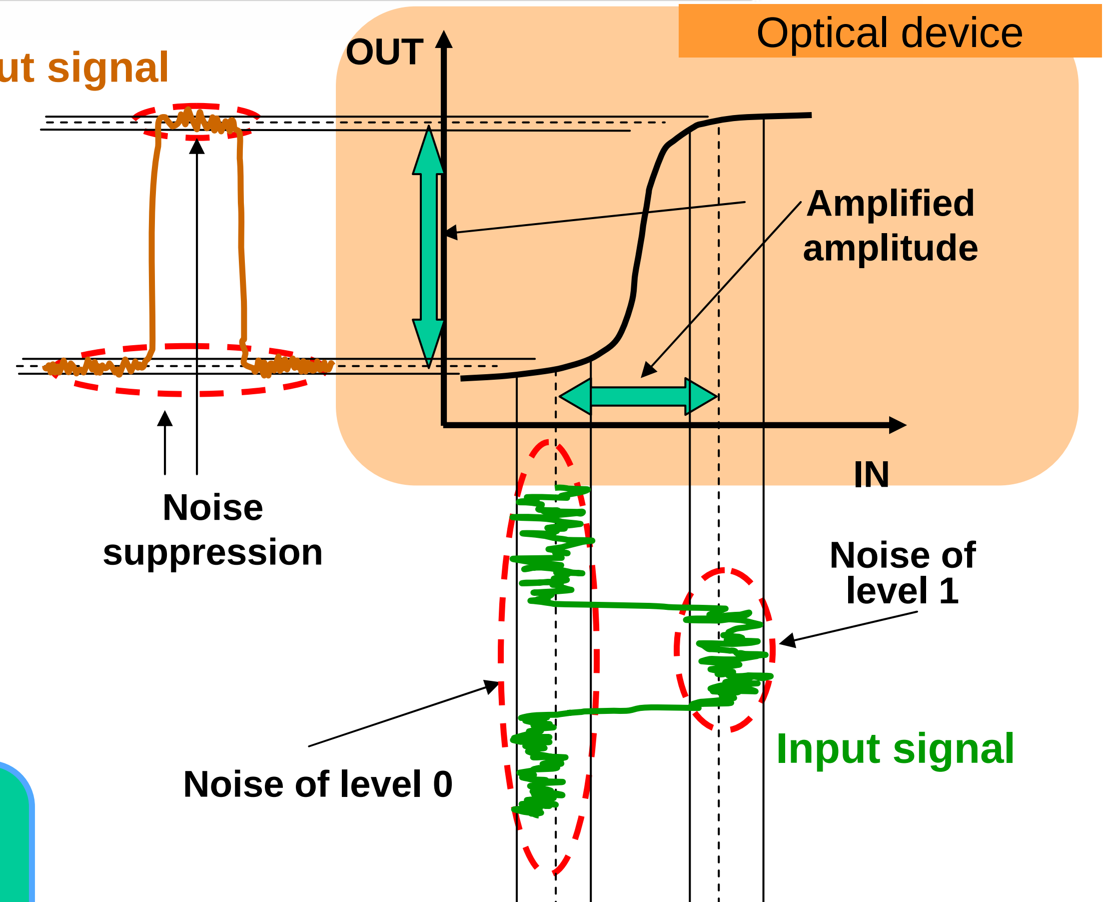
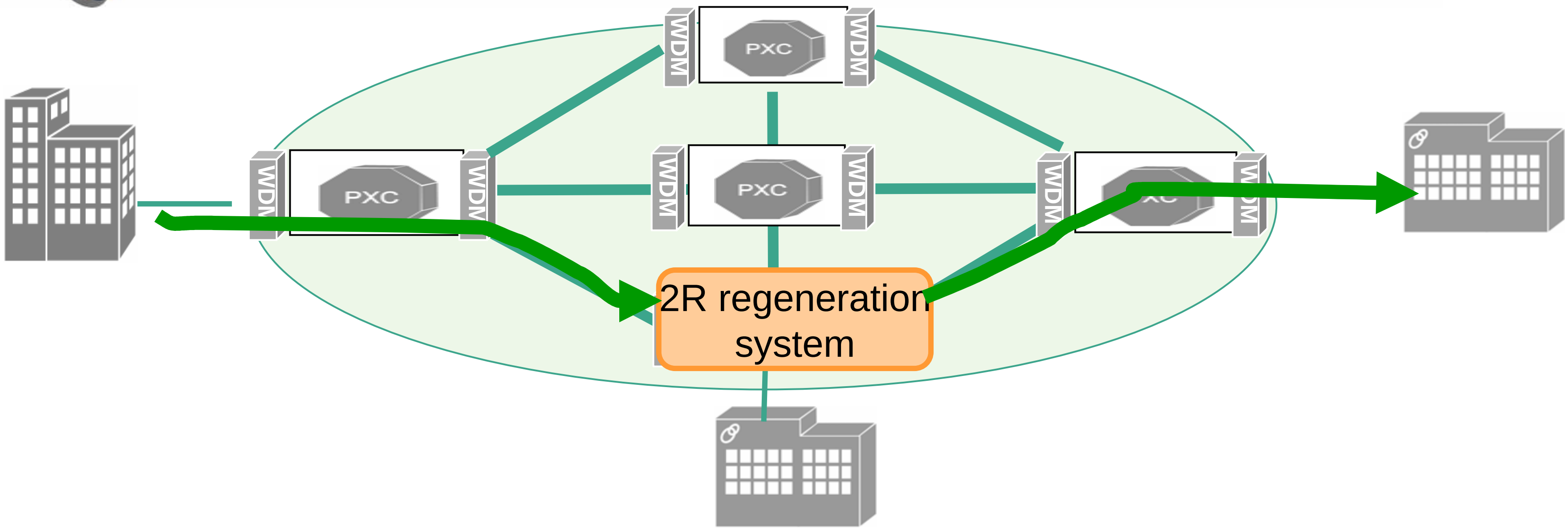



An electro-absorption modulator (EAM) has the effect of noise suppression.

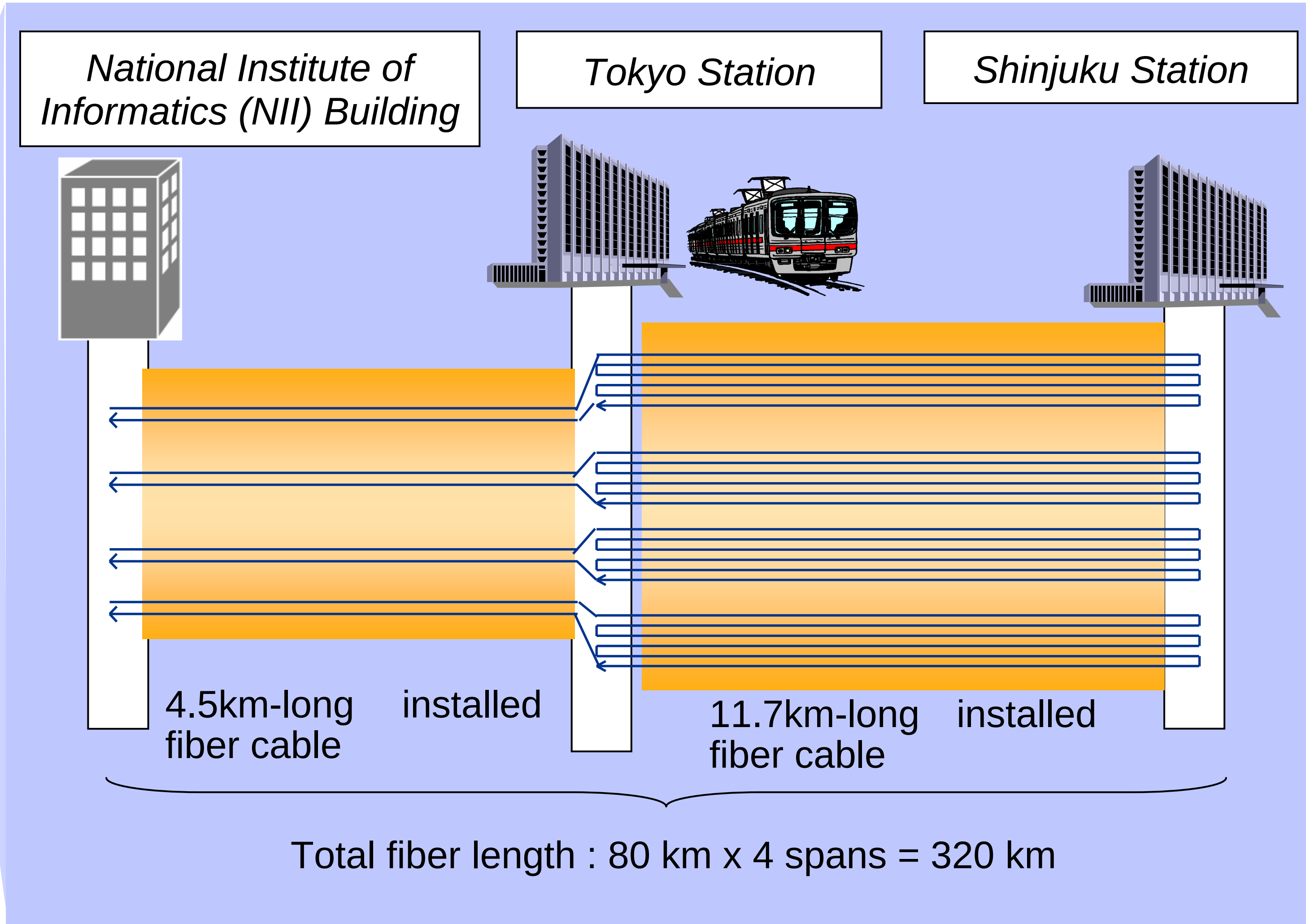
Input v.s. output characteristic of an optical device that has non-linear effect

# Research background




- This experiment
  - 40-Gbit/s 12-channel WDM field trial using an installed 320km-long fiber.
  - Applied OADM system with an all-optical 2R regeneration system.

# 2R system field trial in Tokyo area

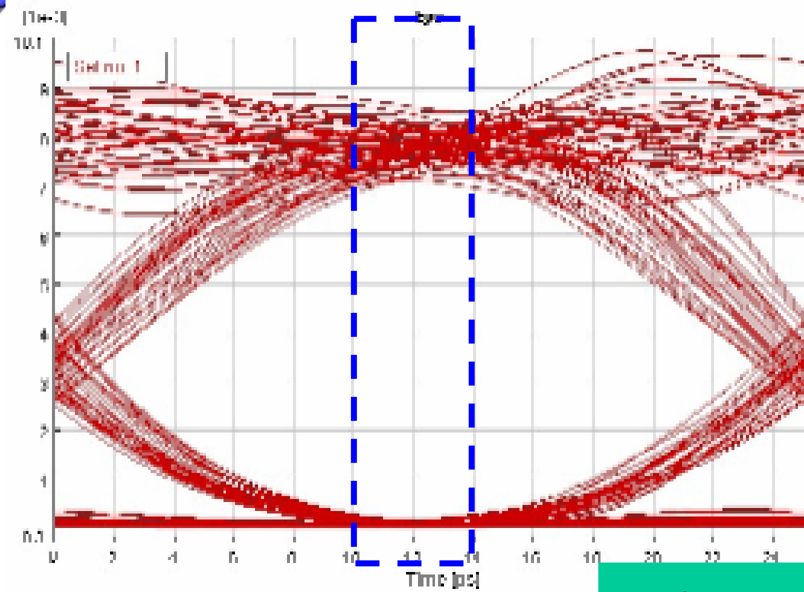



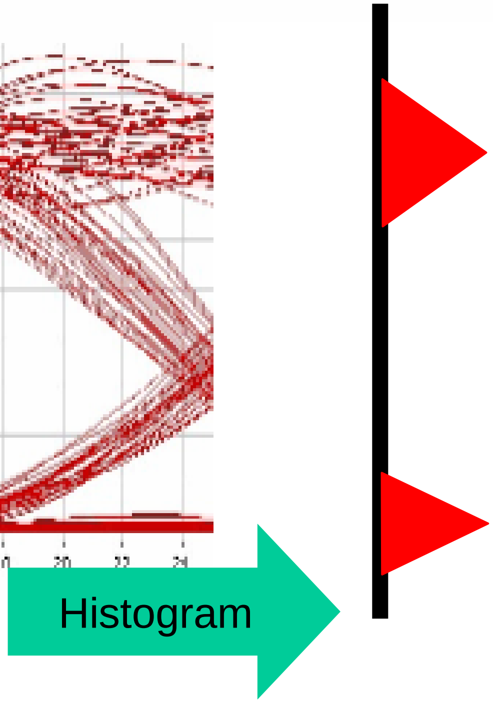

Fiber type : SMF

# Performance evaluation : Q-factor

on

off




$$Q = \frac{\mu 1 - \mu 0}{\sigma 1 + \sigma 0}$$

Q=20dB :: BER= $8 \times 10^{-24}$

Q=17dB :: BER= $1 \times 10^{-12}$

$\mu 1$: ON level average value

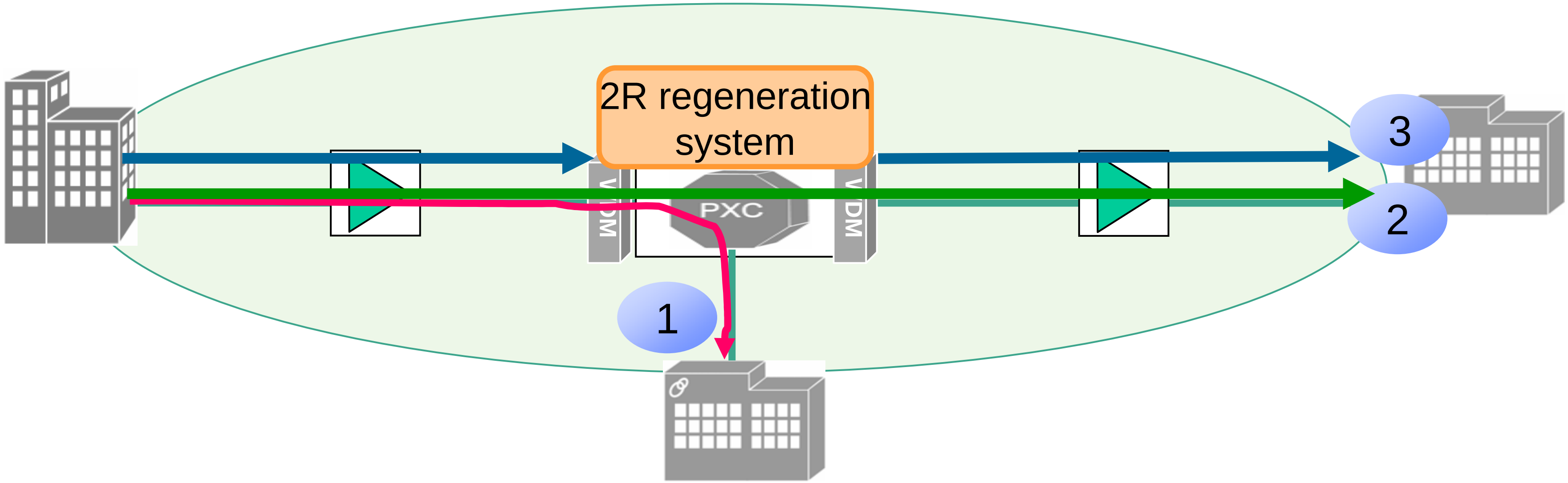
$\sigma 1$: ON level noise standard deviation

$\mu 0$: OFF level average value

$\sigma 0$: OFF level noise standard deviation

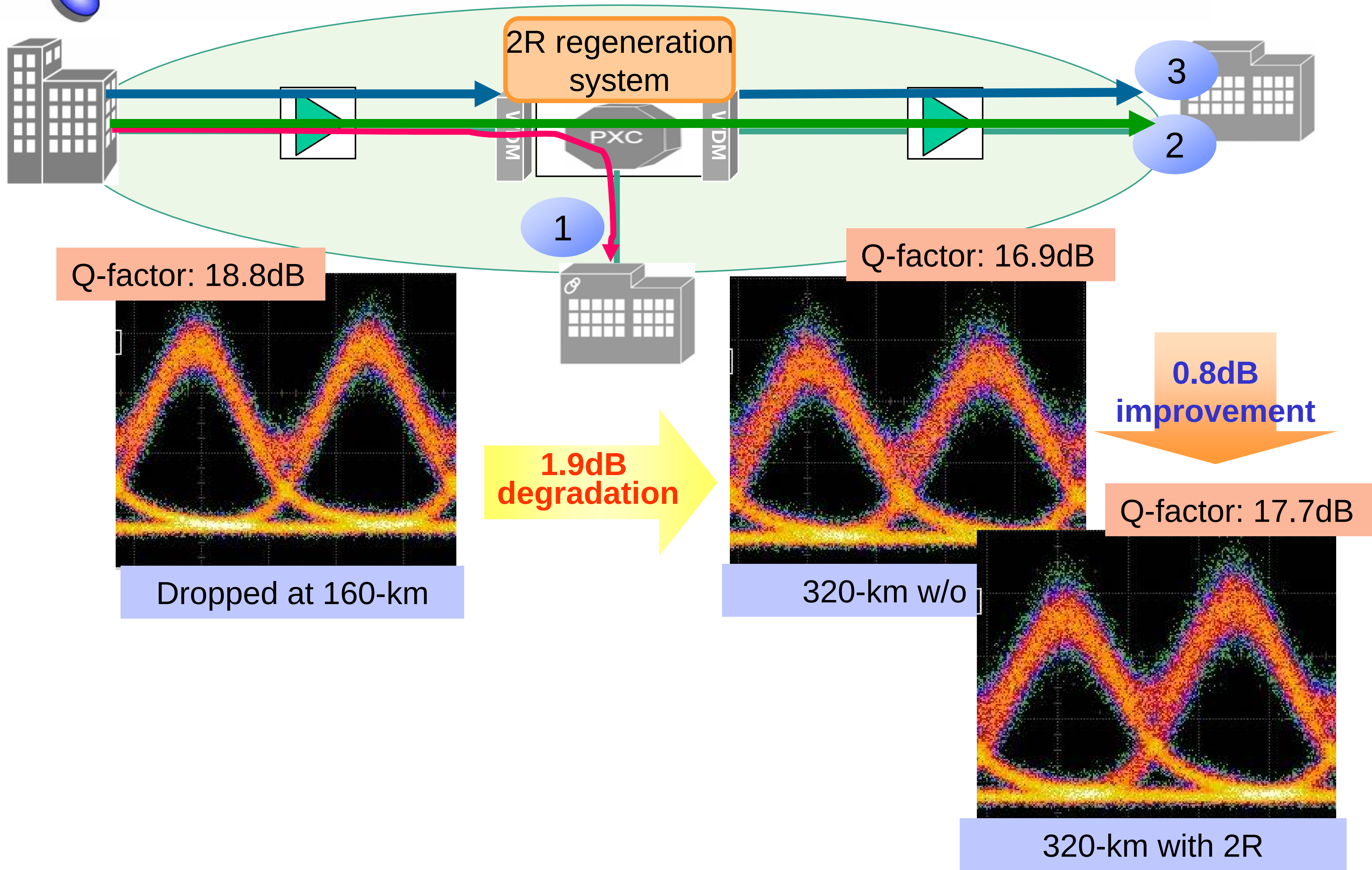
Q-factor ++ ⟶ Transmission quality ++

# Performance evaluation cases




1. Dropped at 160-km by the OADM ; “Dropped at 160km”
2. 320-km transmission without 2R; “320km w/o 2R”
3. 320-km transmission with 2R: “320km with 2R.”

# Result of 320km transmission with OADM / 2R system



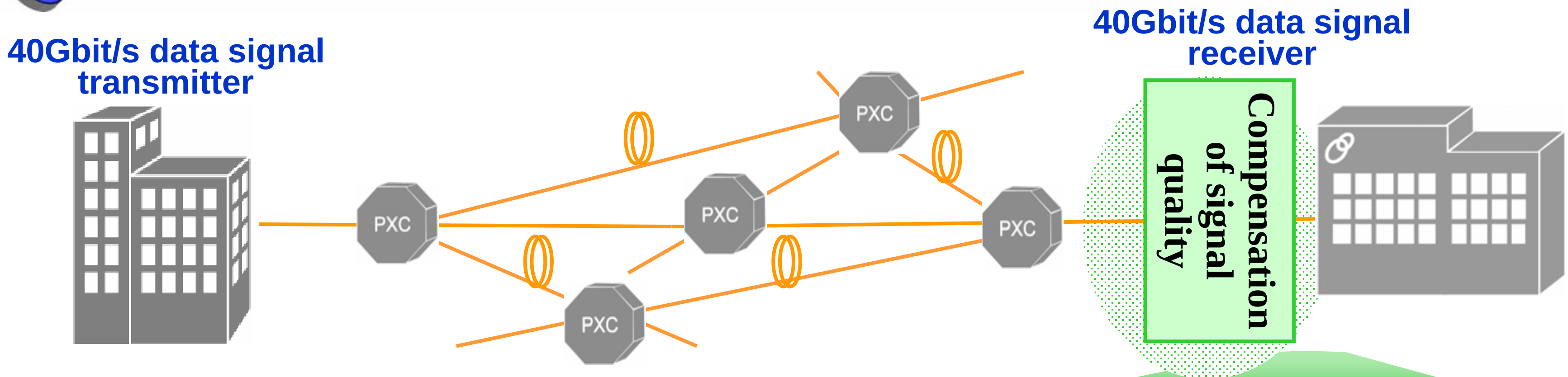
# Discussion

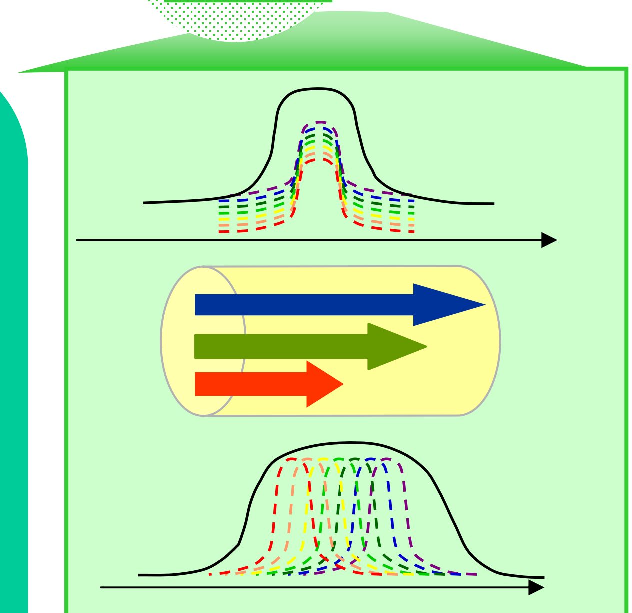
- **OADM system with/without 2R regeneration system**
  - 0.8dB improvement over 320km transmission with 2R
  - Nearly the same as the quality of the signal dropped at 160km.

- **From a point of view of the system design,**
  - It is preferable that transmission characteristics of the express channel and the dropped channel are equal.

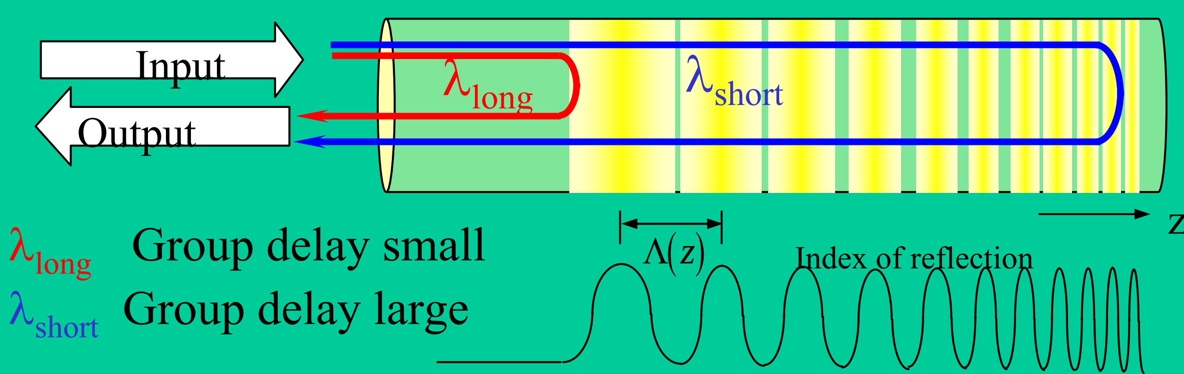
We have confirmed that the all-optical 2R system has the possibility to realize such a condition in an OADM system.

# Chromatic dispersion compensation



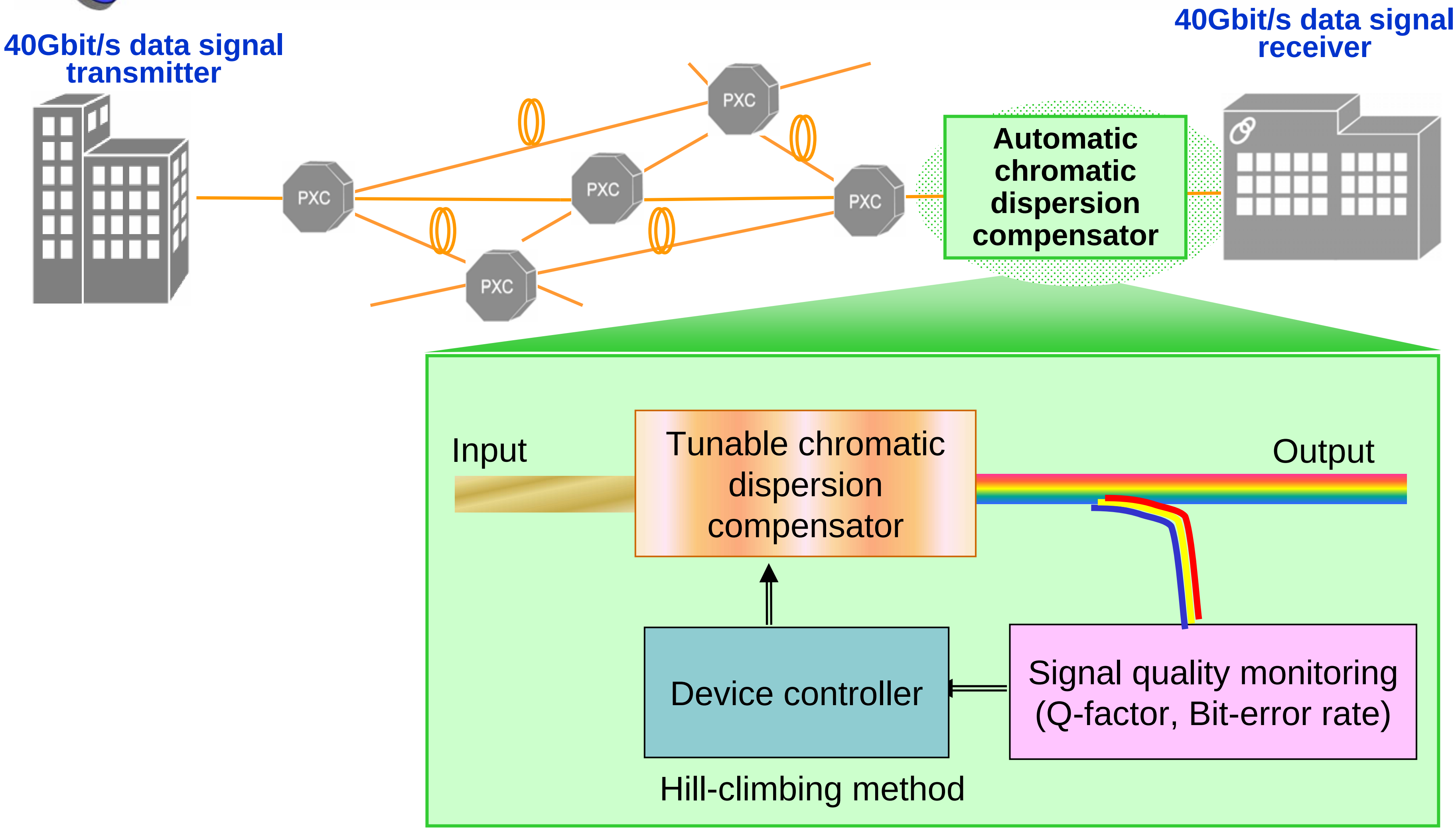



## Tunable chromatic dispersion compensator
## - Chirped fiber Bragg grating (CFBG) -



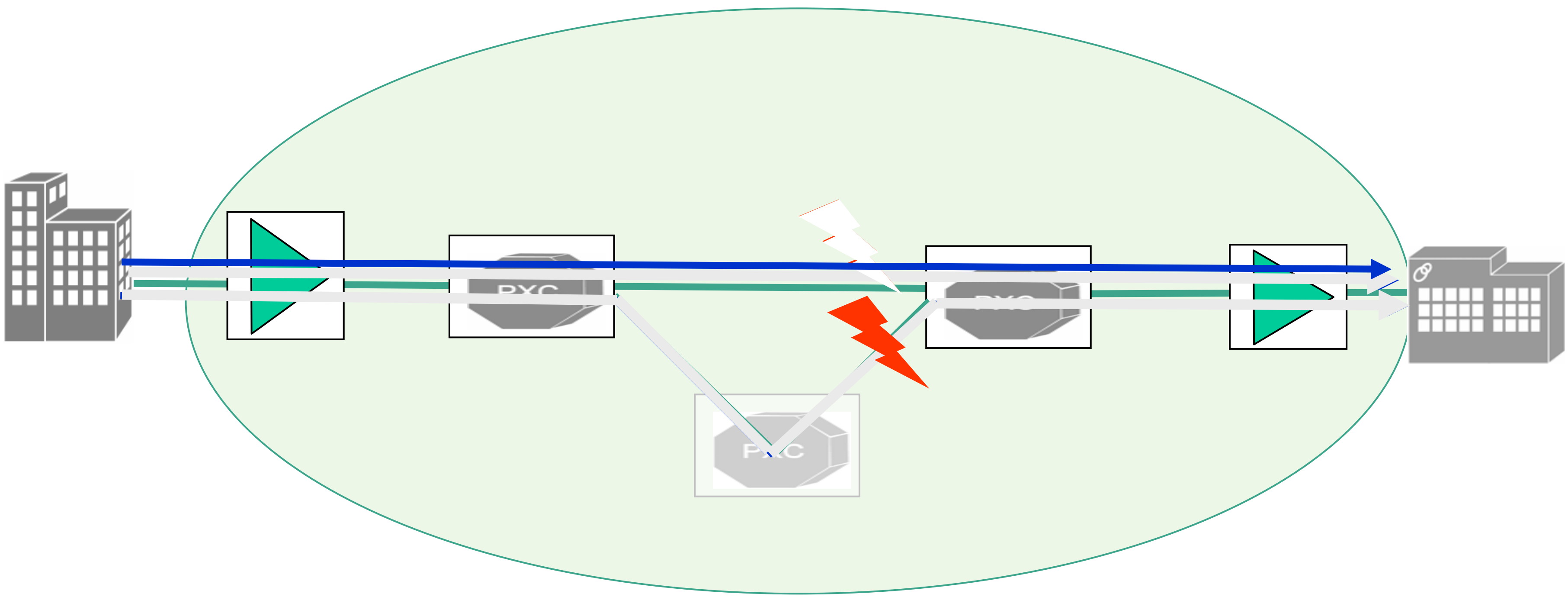

Reflect point of input signal depends on wavelength. It causes the difference of group delay.

# Automatic chromatic dispersion compensator

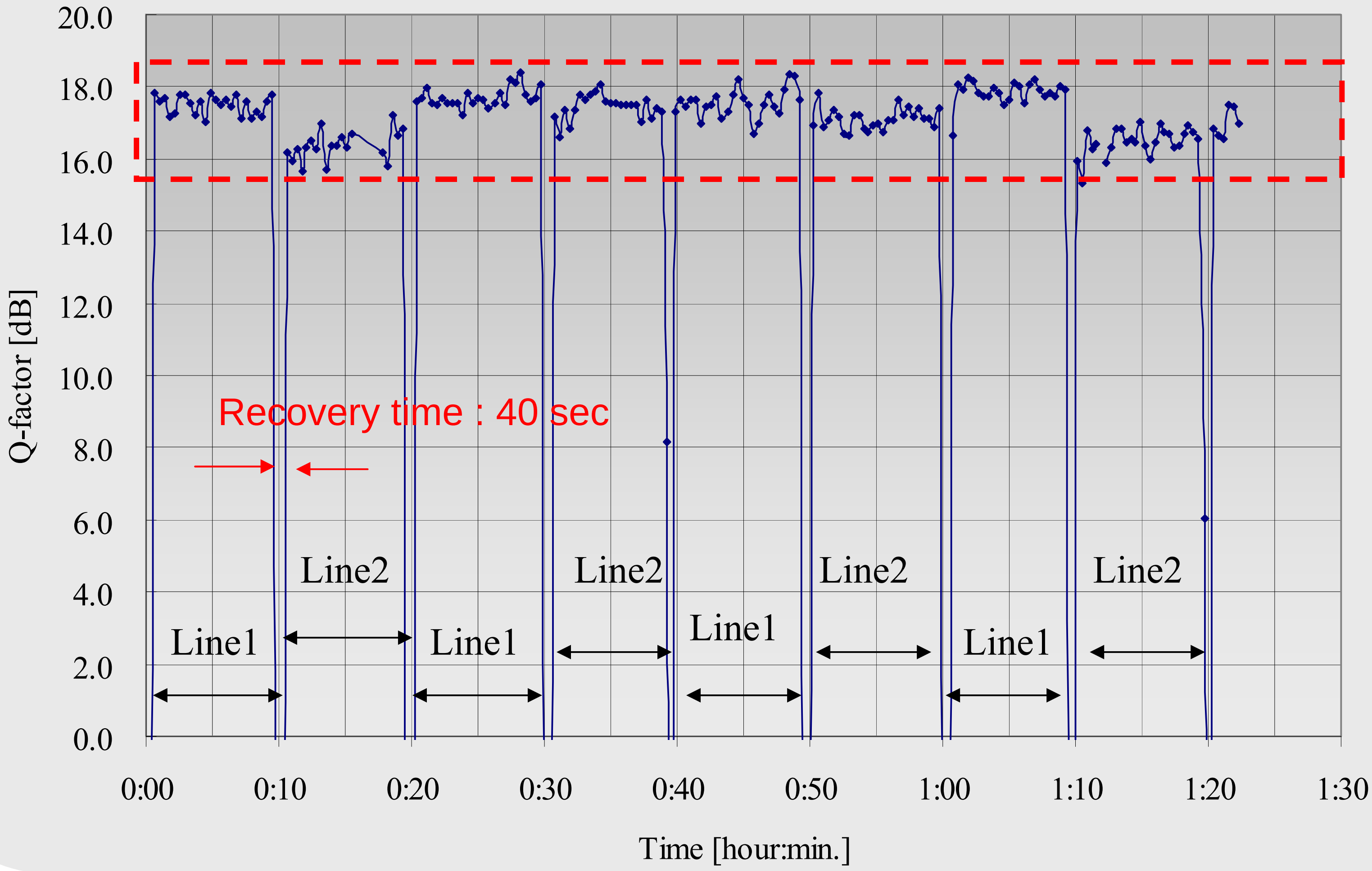


# Performance evaluation

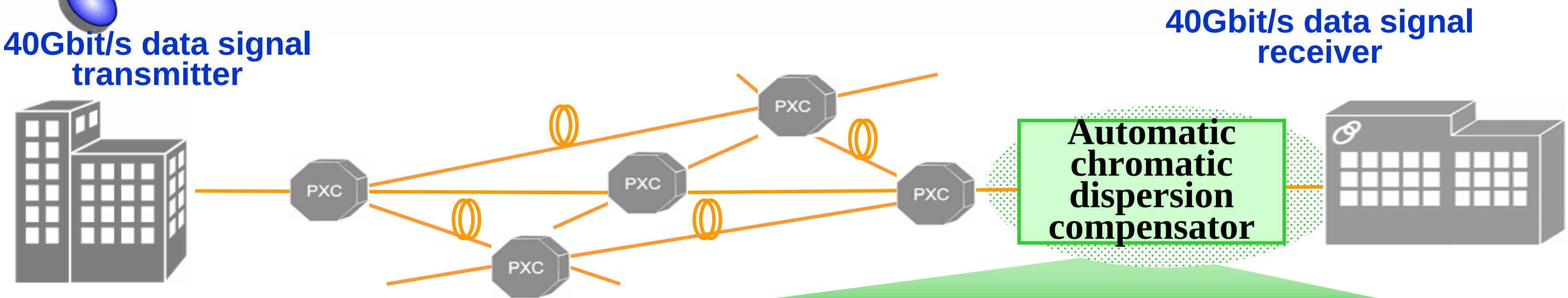
- Rerouting operation
  - GMPLS signaling
  - Operation of automatic chromatic dispersion compensator



# Variation of Q-factor in case of protection

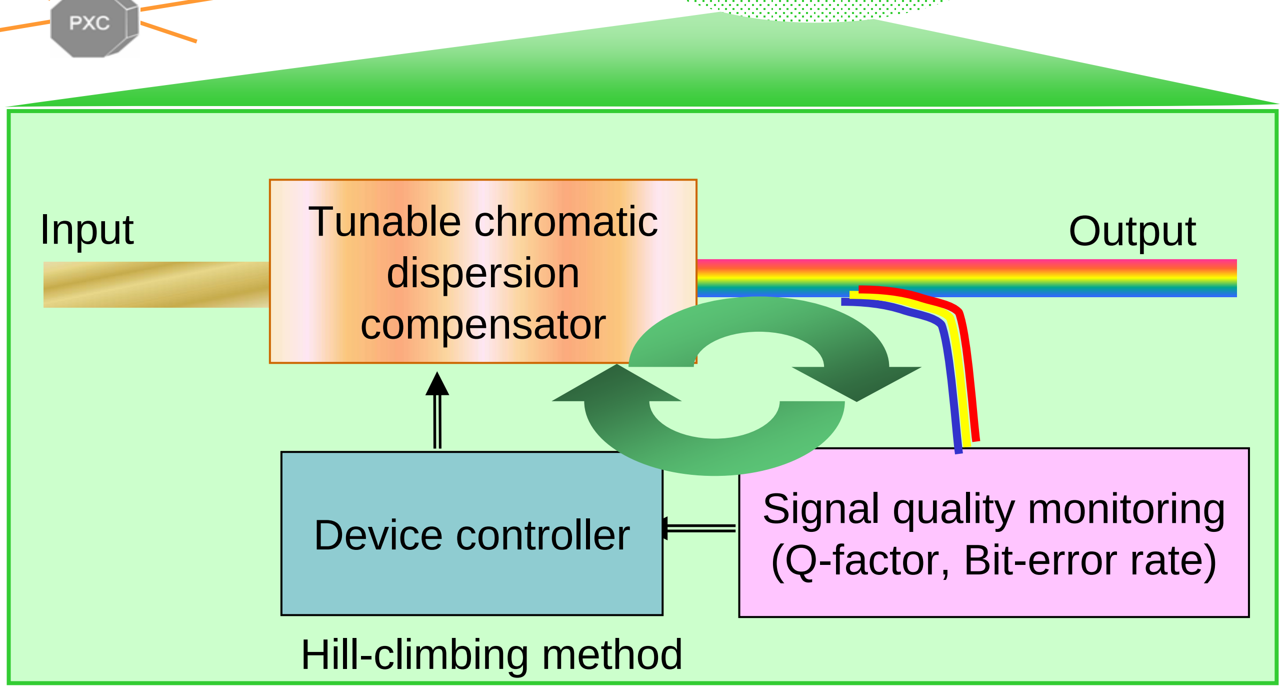


# Make the CD compensation faster




Quality measurement (Q-factor, BER) takes long time ( ~ 40 sec).

Measurement of CD makes path setup faster




The multilayer integration among a GMPLS control plane, a measurement plane, and a data plane is essential.

# Summary

| Requirements from scientific community | Technical Solution | Feasibility |
|---|---|---|
| ■ Transport Quality<br>■ High-speed Transport for Research Projects | ■ Dynamic Quality Control<br>■ 40G Transport in real environment | ■ Demonstrated in Field Trials |
| ■ User's Involvement in Operation<br>■ Dynamic Provisioning | ■ Development of Control / Management Plane with Multiple Instances<br>■ Implement PCE and TED | ■ Implementing |
| ■ Economical Solution | ■ Deployment of Full Optical integrated Solution | ■ More than 300% Efficiency is expected |