

# Lambda UTILITY Project

## Photonic technologies for Distributed Virtual Terabit LAN

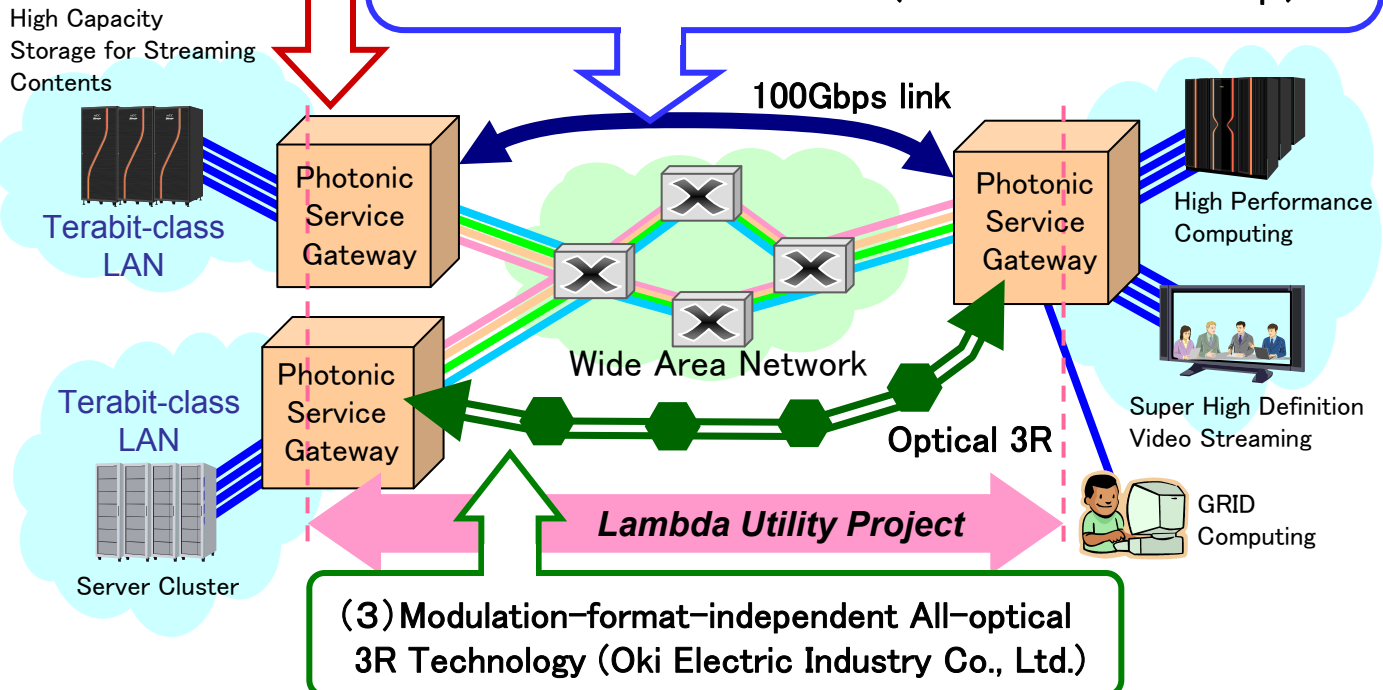
### Objective

This project aims at realization of Distributed Virtual Terabit LAN over wide area networks, which enables users to enjoy stress-free access to high bit-rate services, such as super high definition video.

(1) Borderless Optical Path Control and Management Technology (NEC Corp.)

(2) Highly-spectral-efficient Transmission Link Technology

- Multi-level modulation and demodulation technology at 100Gbps and beyond (Osaka Univ. and Fujitsu Ltd.)
- High-coding-gain forward error correction code for multi-level modulation format (Mitsubishi Electric Corp.)



### Companies research & University



NEC Corp.



Osaka Univ.



Fujitsu Ltd.



Mitsubishi Electric Corp.



Oki Electric Industry Co., Ltd.

# Borderless Optical Path Control and Management Technology

## Achievements

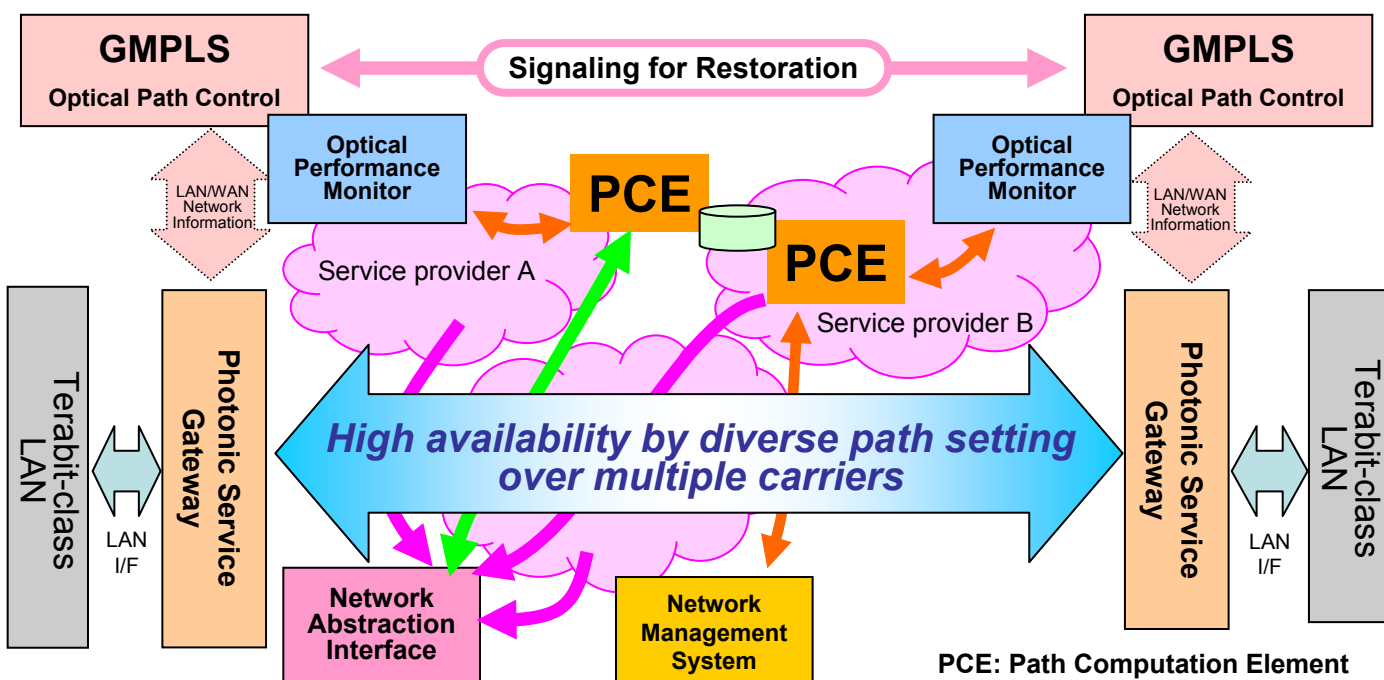
### ◆ NEC has developed automatic path control technologies for large-scale optical networks

We have successfully developed the automatic path control technology for a large-scale multi-domain Generalized Multi-protocol Label Switching (GMPLS) optical network, which consists of thousands of nodes. A key enabler is a Path Computation Element (PCE) technology which calculates the optimal path over multiple domains by using our novel path computation algorithm.

### ◆ NEC has successfully completed initial interoperability testing for PCE.

We have performed interoperability tests of Path Computation Element (PCE) among several research organizations, and confirmed its interoperability and fundamental operation of PCE in January 2008 at Kei-Han-Na Open Lab.

Furthermore, we have enhanced PCE with a functionality of inter-domain diverse path computation with confidentiality, and confirmed its interoperability in September 2008.



# Multilevel Modulated Signal Based Transmission System

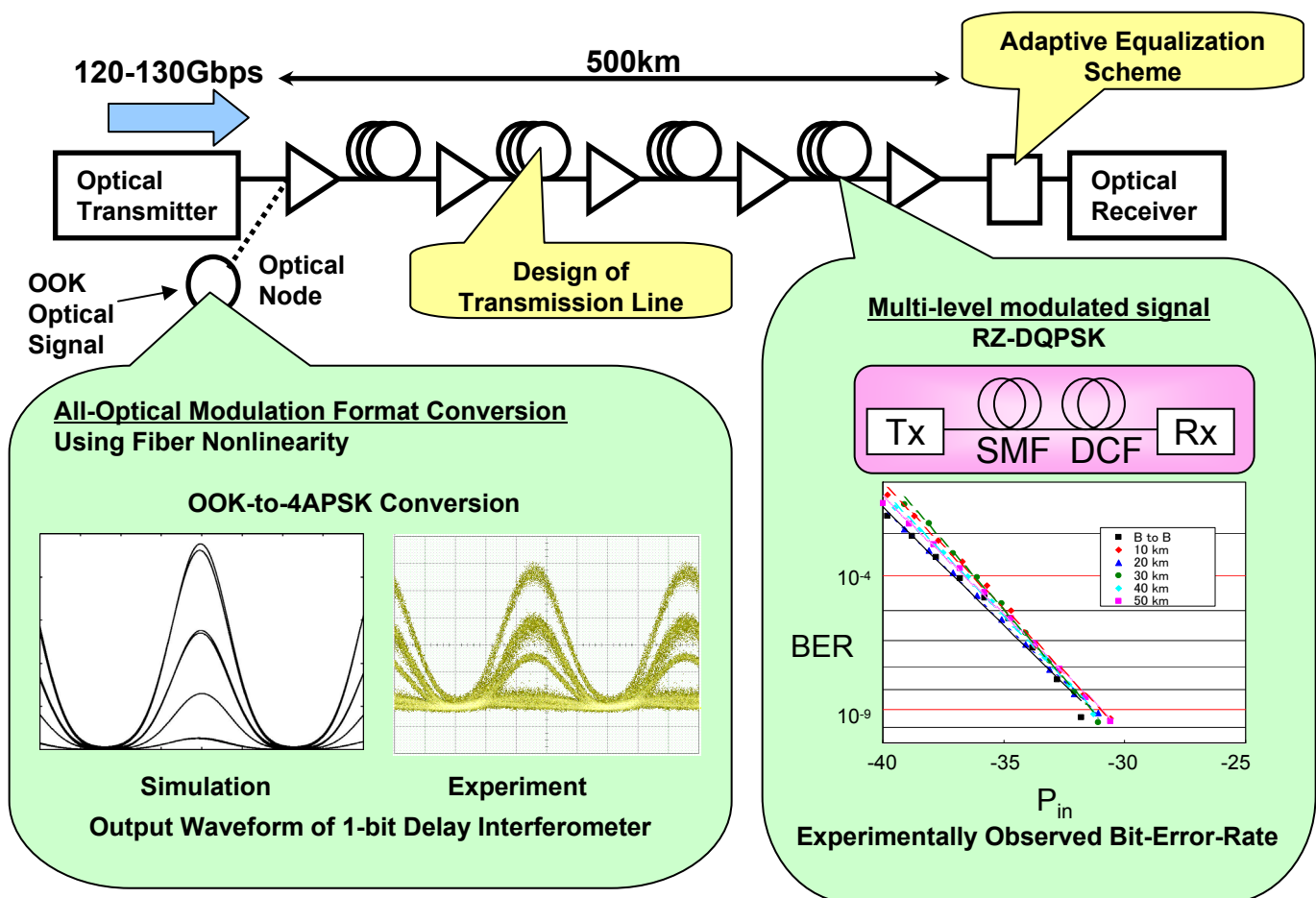
## Achievements

- ◆ Cooperating with Fujitsu and Mitsubishi Electric Corp., Osaka University has selected the optimal multilevel modulation format in terms of realizability for highly efficient link transmission technology.

We have selected the optimal modulation format which is a dual polarization return to zero differential quadrature phase shift keying (DP-RZ-DQPSK) for over 100Gbps, 500km transmission system.

- ◆ Osaka University has developed an all-optical modulation format converter for smoothly introducing the advanced modulation format in the conventional system.

We have proposed and demonstrated an all-optical OOK-to-APSK modulation format conversion scheme based on fiber nonlinearity.



# Optical transceiver technology for multi-level modulation format

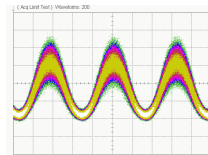
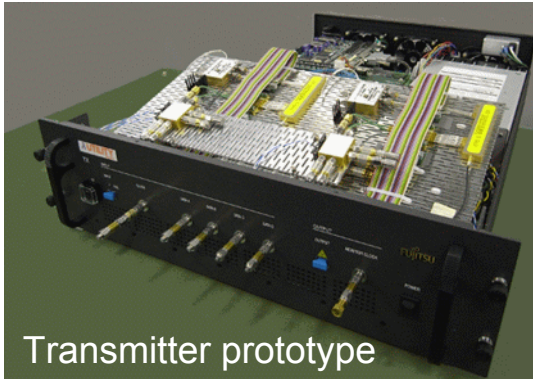
## Achievements

### ◆ Fujitsu has developed a prototype of over 100Gbps optical transceiver with DP-RZ-DQPSK modulation format

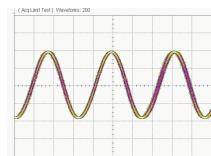
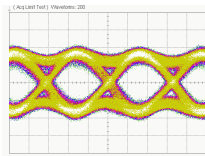
- Stable transmitter and receiver output signals by the feed-back control circuits for optical modulators and demodulators

### ◆ Fujitsu has developed an integrated DP-RZ-DQPSK LiNbO<sub>3</sub> modulator

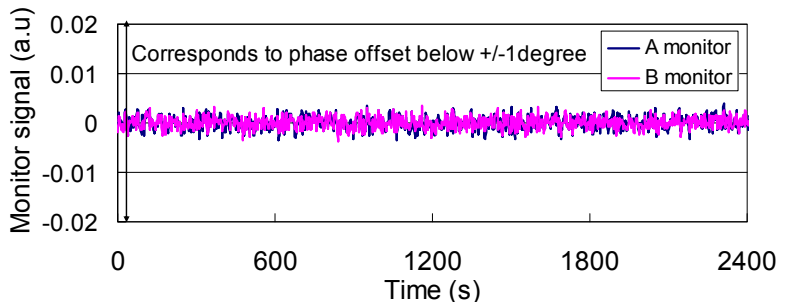
- The design with our intersecting U-turn waveguide structure enables low PDL of less than 0.3 dB and low optical crosstalk of less than -24 dB.



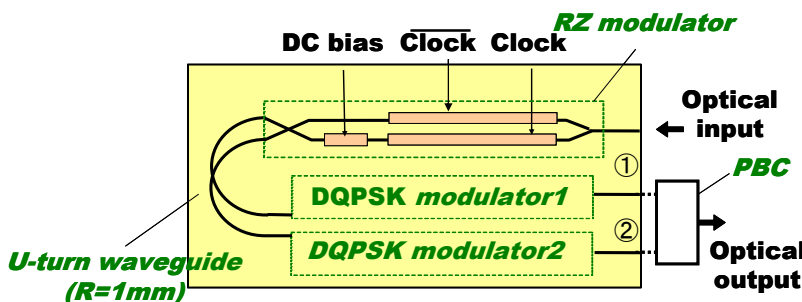
Transmitter output (125Gbps DP-RZ-DQPSK)



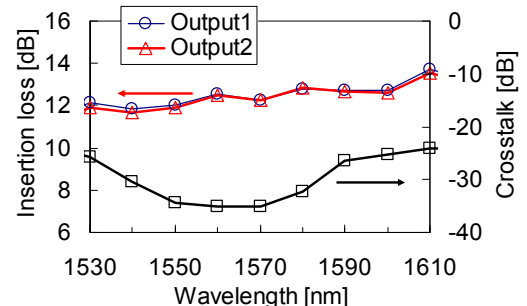
Receiver output (left: data signal, right: clock signal)



Phase stability of optical demodulators



Device design of the developed DP-RZ-DQPSK modulator



Characteristics of the developed DP-RZ-DQPSK modulator

DP-RZ-DQPSK: Dual Polarization Return to Zero Differential Quadrature Phase Shift Keying

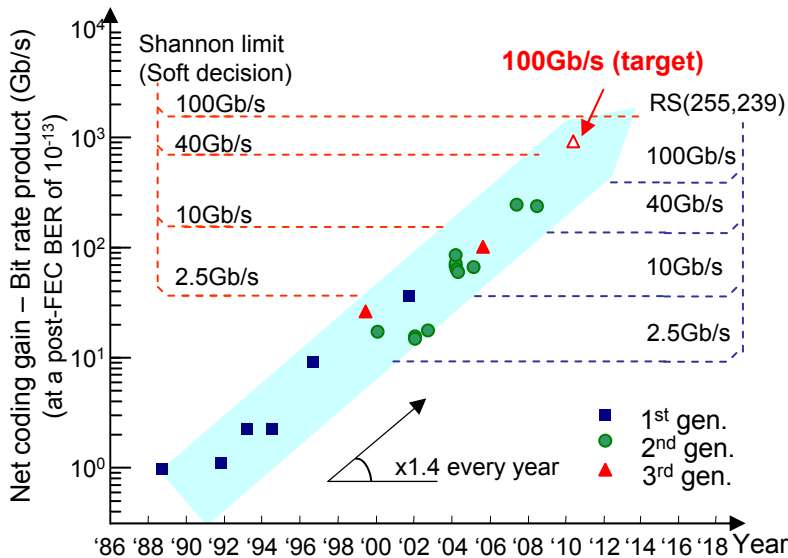
# Forward Error Correction for 100Gbps Transport Network

## Achievements

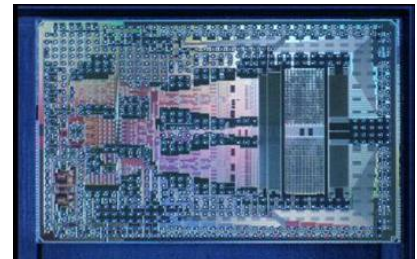
### ◆ Seek for more powerful FEC for multi-level modulation

- Concatenated LDPC+RS codes with 20% redundancy
- ITU-T recommended OTU4V compatible FEC framing
- Novel FEC decoding algorithm to reduce the circuit size
- High speed FPGA emulation boards with world-fastest 32Gsamples/s 2-bit soft-decision LSI
- Anticipated net coding gain of 9.4dB (Q-limit of 7.1dB)

## FEC Deployment in Opt. Commun.

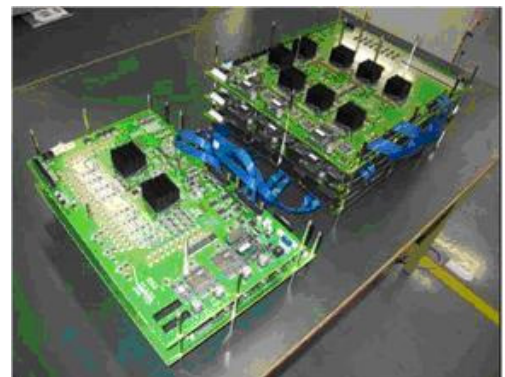


## Soft-Decision LSI Chip

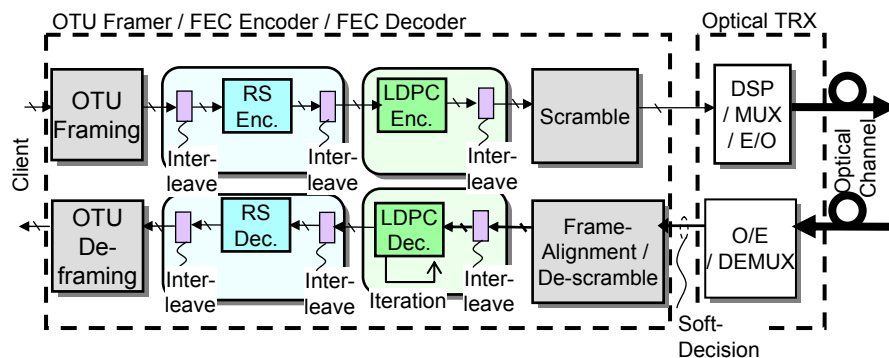


- 0.13 $\mu$ m SiGe BiCMOS ( $f_T=200$ GHz)
- 9.7mm x 6.9mm
- 14W

## FEC Emulation Boards



## Functional Block Diagram

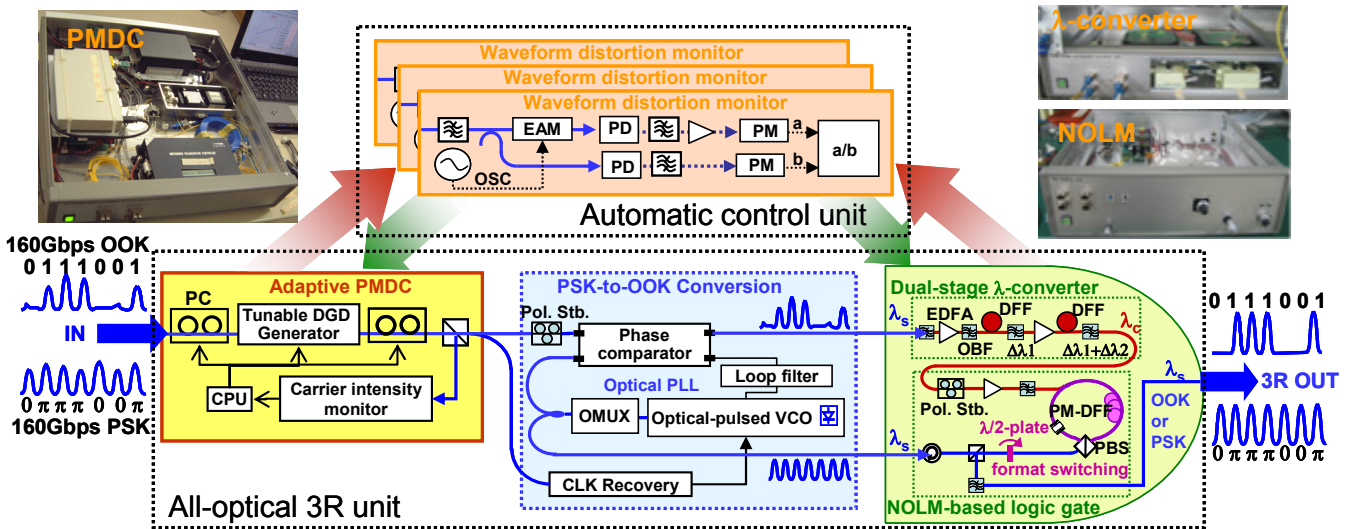


# Modulation-format-independent All-optical 3R technology

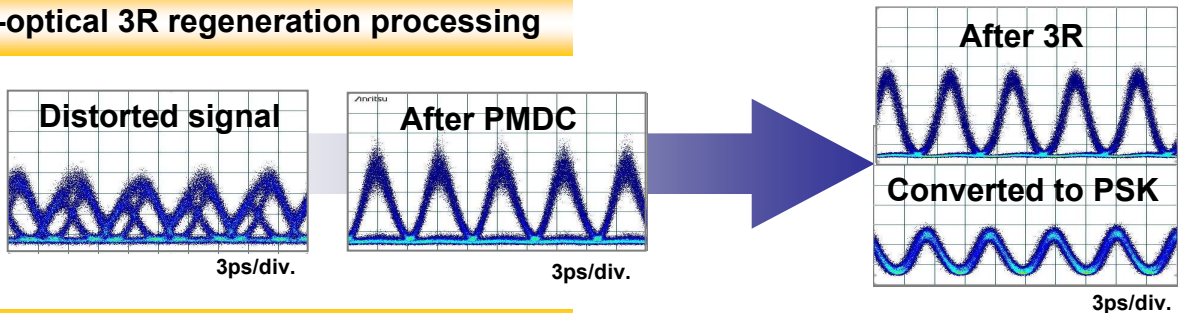
## Achievements

- ◆ OKI has developed all-optical 3R regeneration for 160Gbps OOK signal.
- We have successfully demonstrated all-optical 3R regeneration with a 3R interval of 380 km in field trial on JGNI optical test-bed.
- Unique automatic control ensured long-term stability of 3R regeneration.
- Switching capability of OOK-to-PSK is implemented in the optical logic gate based on NOLM.
- We have also developed the ultra-precise PMD compensator with a function of HOPMD mitigation based on carrier-intensity-monitoring.

## Schematic diagram of modulation-format-independent all-optical 3R



## All-optical 3R regeneration processing



## Field demonstration of All-optical 3R

