1,000 Lambda WDM and Beyond

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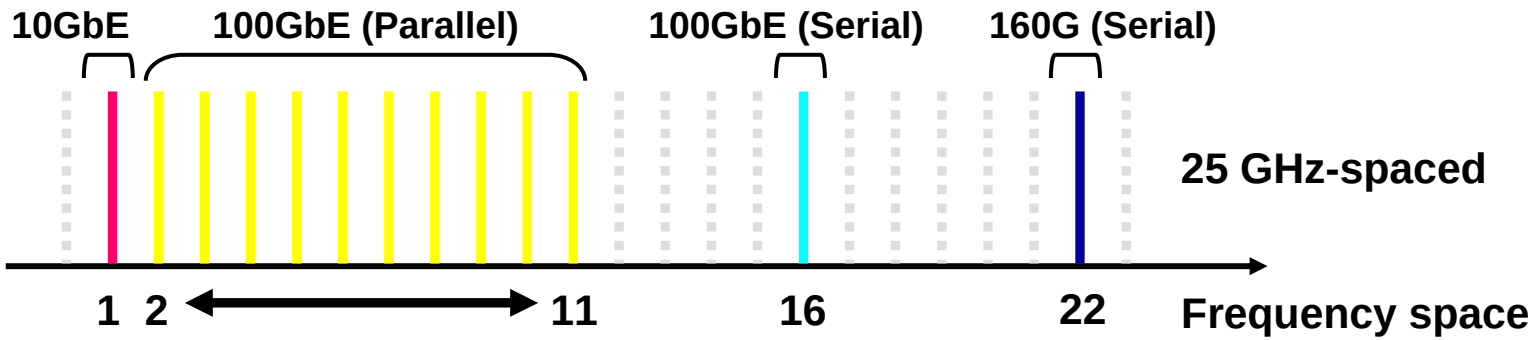
Outline

- ***Super Lambda NW***
  - ***Features and Issues***
  - ***Technologies***
- ***Recent JGN II Testbed Demonstration***
  - ***1000 λ Transmission***
  - ***640 Gbit/s Virtual Waveband Path Switching***
- ***Conclusion***

Super Lambda NW : Features

- ***Consists of Super Lambdas:***
  - **1,000 ~ 10,000 λs (used for Core, Metro, PON)**
  - **2.5 GHz ~ 25 GHz-spaced over 25 THz bandwidth**
  - **Well-defined with absolute accuracy of ~10 MHz (0.00008nm @1.55 μm)**
- **Dynamic λs assignment**
  - **Bandwidth (multi λs) on demand up to Tbit/s**
  - **10 G x n, 40 G x n, 100 GbE (Serial or Parallel) x n**



Super Lambda NW : Features (con'd)

- **Waveband Path Routing**
  - **All-optical Waveband Conversion**
- **Large-scale Multi-domain λ Connection**
  - **Possible by accurately defined λs**
- **Processing in *Optical Frequency ν domain***
  - **Optical Frequency conversion**
  - **Frequency monitoring**

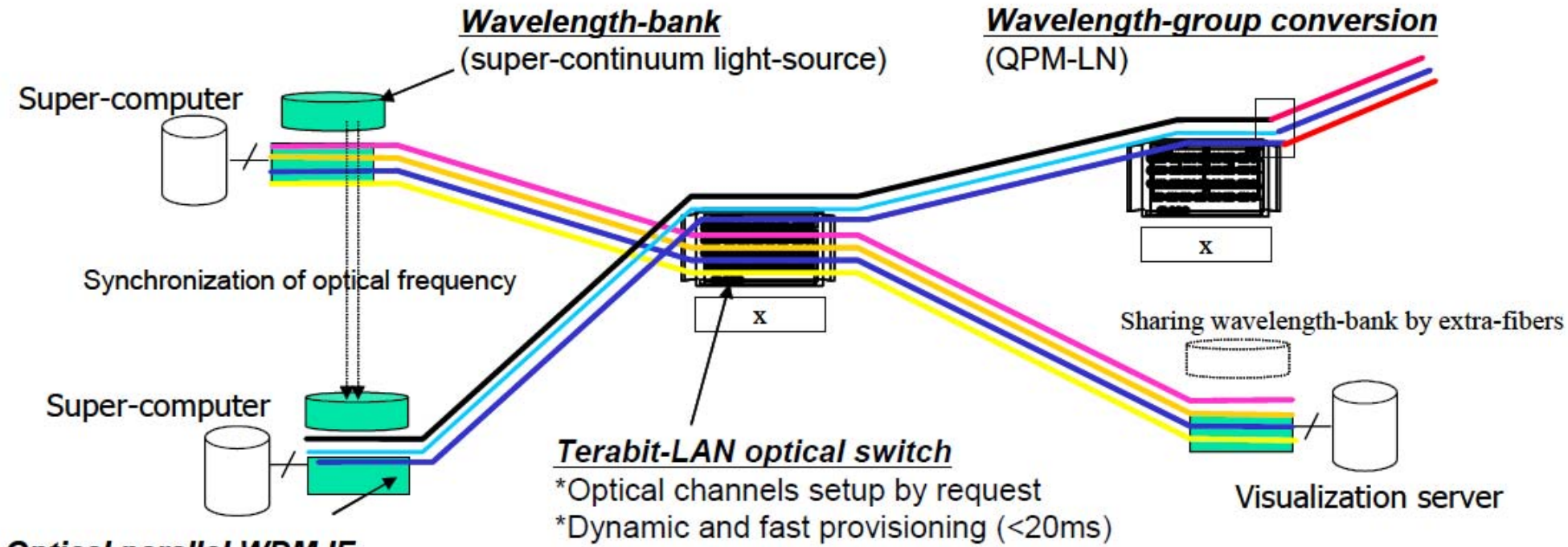
Super Lambda NW : Issues

- **Sources**
- **Optical Filters**
- **Transmission Technologies**
  for super DWDM
- **All-optical Waveband Conversion**
- **Frequency Measurement**
- **Control & Management**
- **Standardization**

Terabit-LAN Concept

"Terabit LAN with optical virtual concatenation for Grid applications with super-computers"

*Tomizawa, Hagimoto (NTT) et al, OFC**(2005)***



Optical parallel WDM IF
*Bit-phase controlled WDM
*De-skewing of parallel signals
*Distributed setup of channels

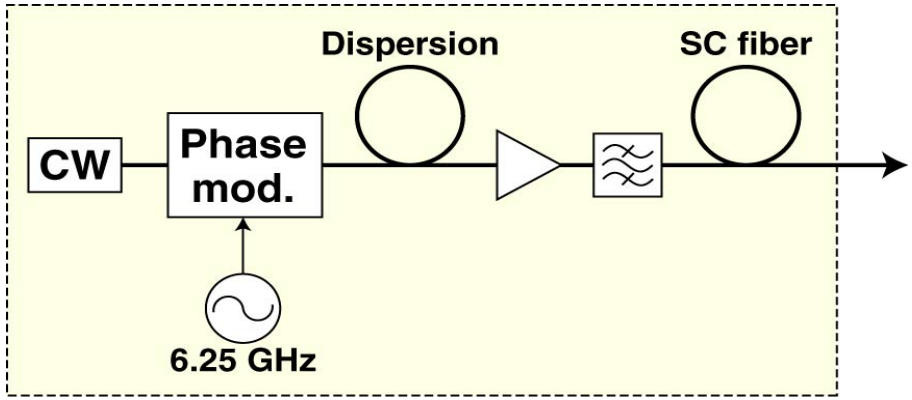
Optical Virtual Concatenation
*Number of wavelengths are assigned arbitrarily by latency requirement.
*Parallel data streams are handled as if virtually contiguous data.

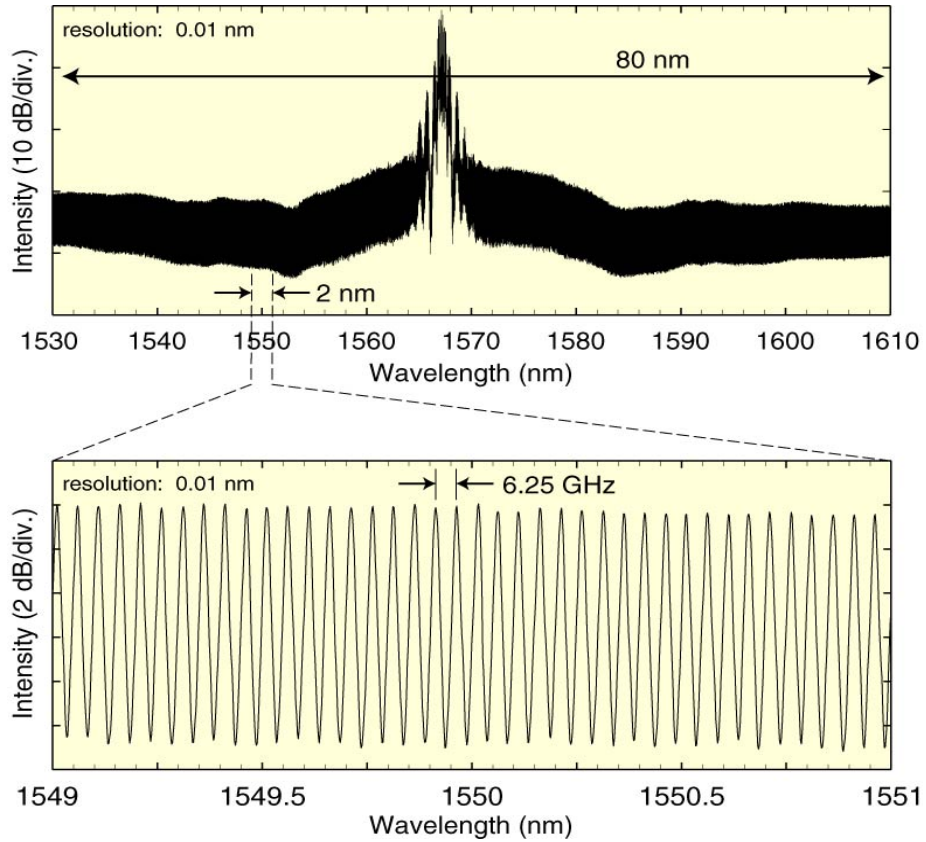
Fig. 1 Network configuration of terabit-LAN

(1-1) 1,000 λ multi-carrier source

H. Takara et al., Electron. Lett. Vol. 41, pp.270 ***(2005)***
T. Ohara et et al., IEEE JLT, Vo24, pp.2311 ***(2006)***

- **Generation of over 1000 carriers with 6.25 GHz spacing**



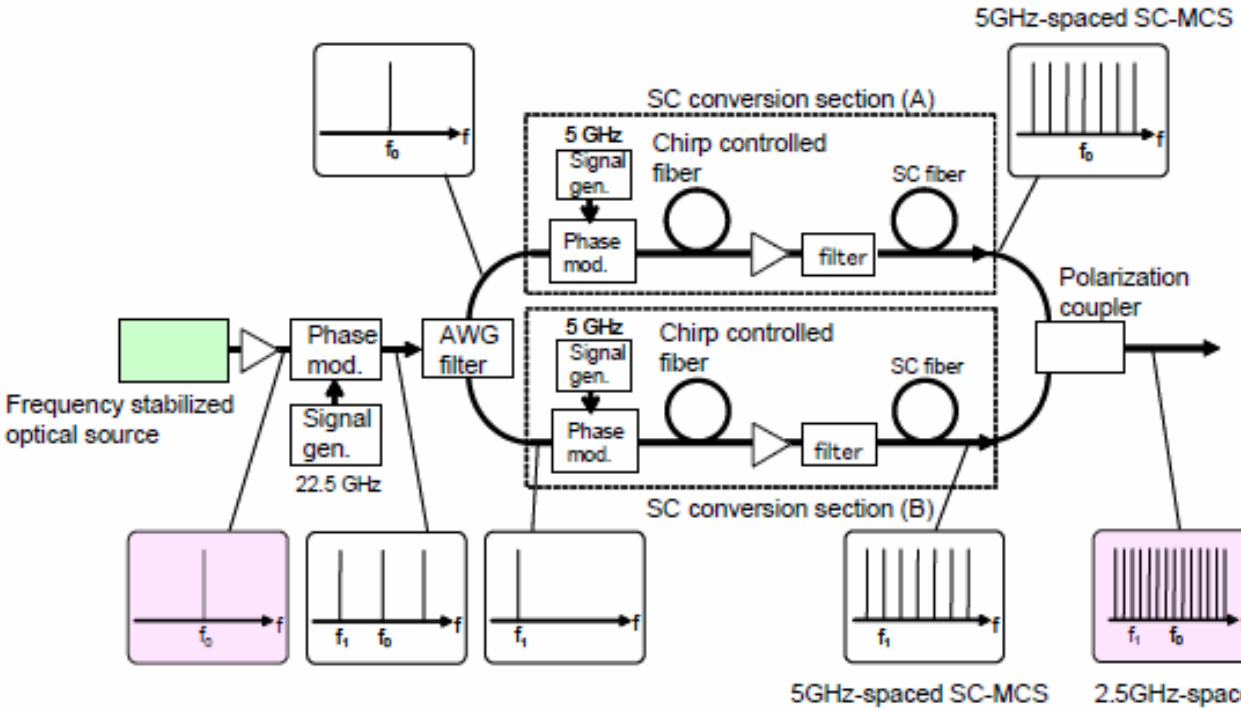


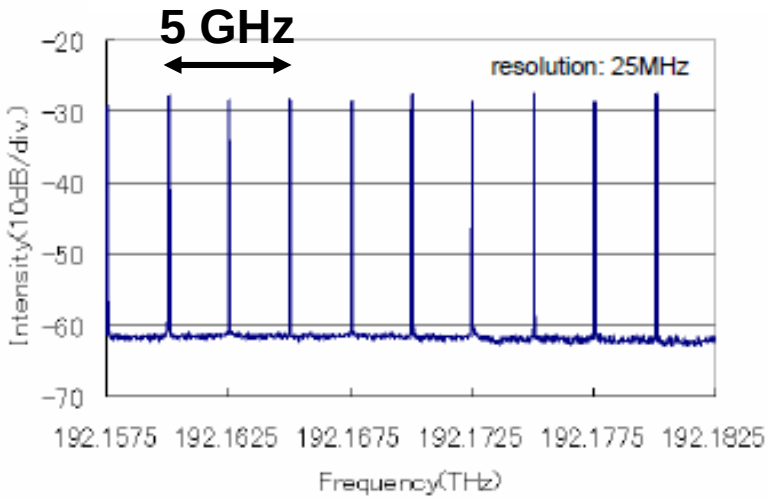
- **Seed pulse: phase mod. + dispersion**
  - **Low repetition rate pulse**
  - **High SNR**
- **SC fiber: dispersion decreasing fiber**
  - **Super-broadened spectrum**

(1-2) 10,000 λ multi-carrier source

Y. Miyagawa et al., Electron. Lett. Vol. 42, p.655 ***(2006)***

- **Generation of over 10,000 λs with 2.5 GHz spacing**
  - **3,100 λs having enough SNRs for GbE Transmission**
  - **<30 MHz (0.00025 nm; Instrument limited) absolute accuracy**
  - **Can be used as NW wavelength (frequency) reference as well**

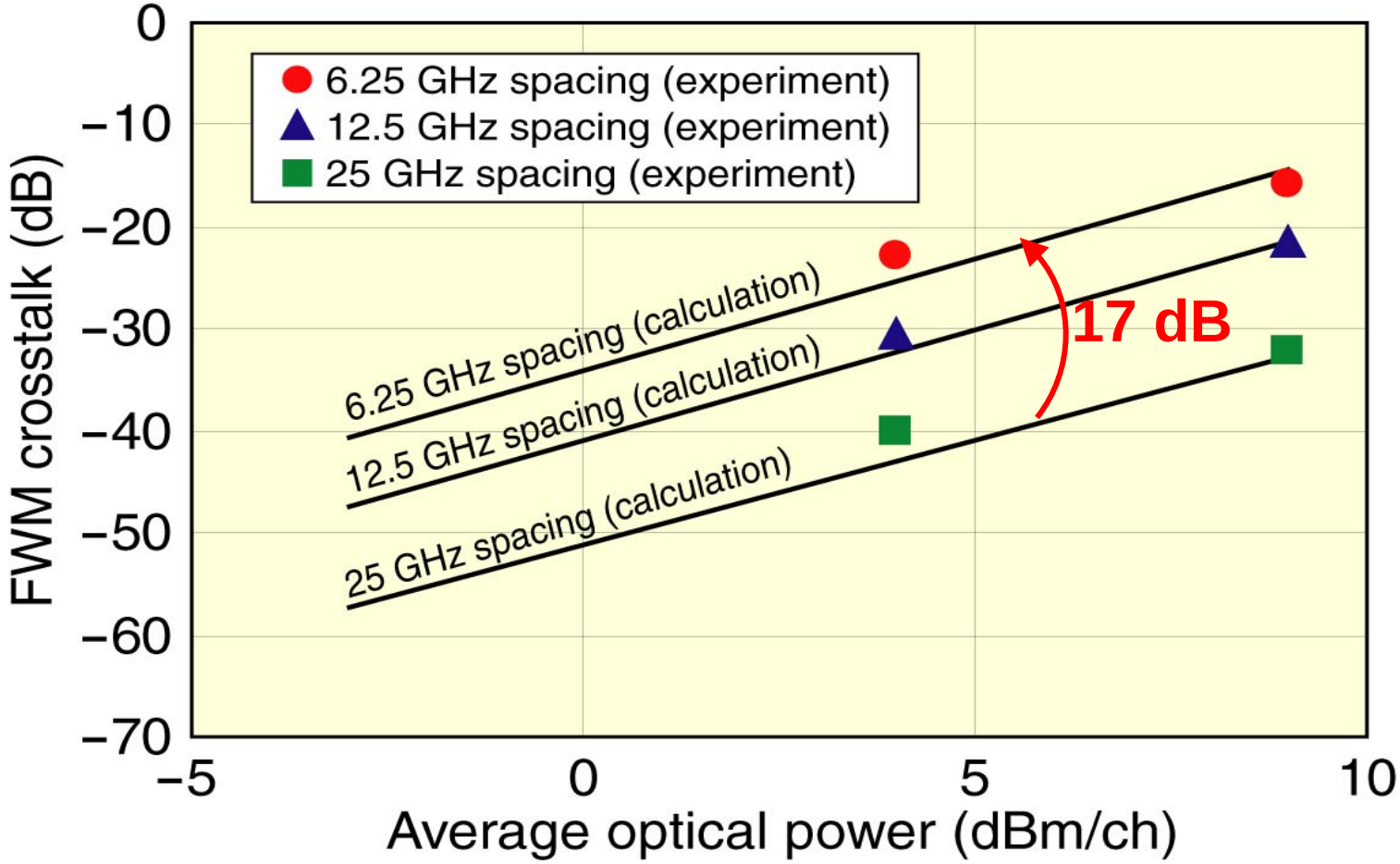




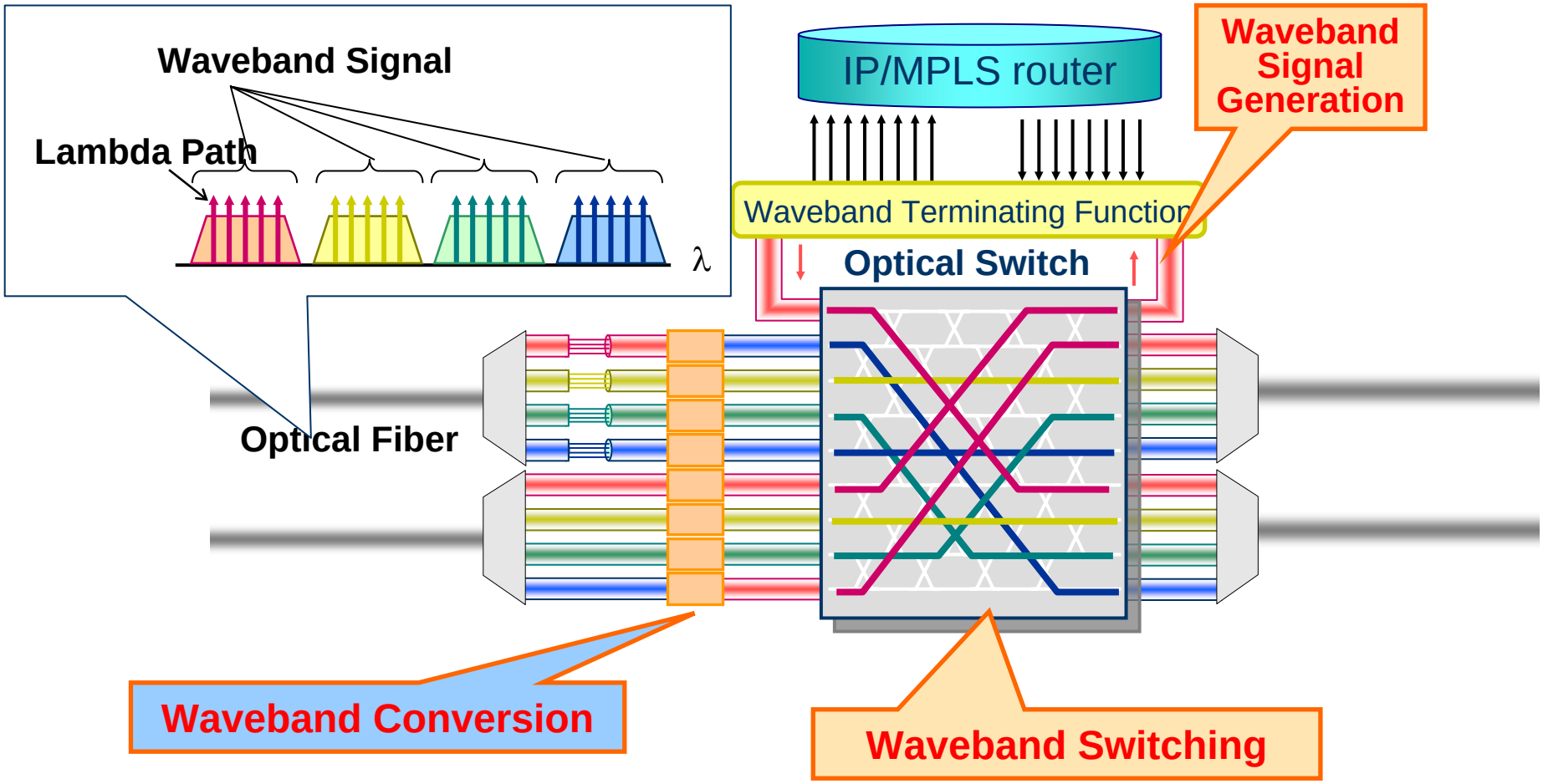
(2) Transmission Issue

T. Ohara et et al., IEEE JLT, Vo24, pp.2311 ***(2006)***

- FWM Crosstalk even in SMF (16 ps/nm/km)



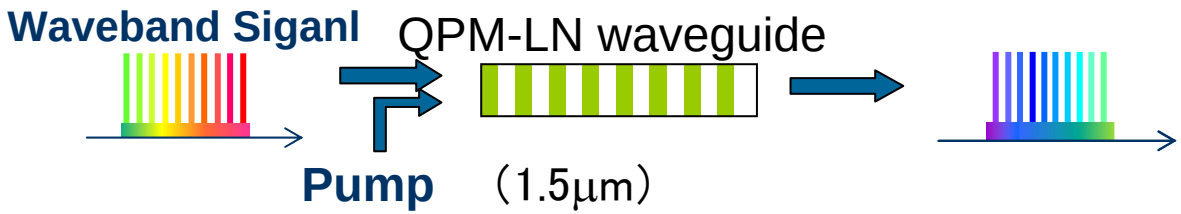
(3-1) Waveband Path Routing



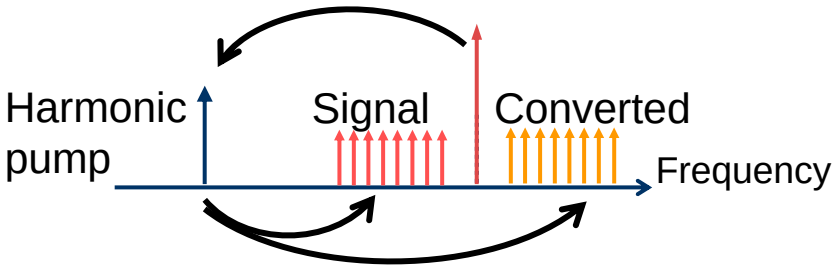
(3-2) Waveband Conversion

・Features of QPM-LN Waveband Converter

- Ultra-wideband all-optical waveband conversion (bps/format indep.)
- Low crosstalk
- Small size, high conversion efficiency (~0 dB)

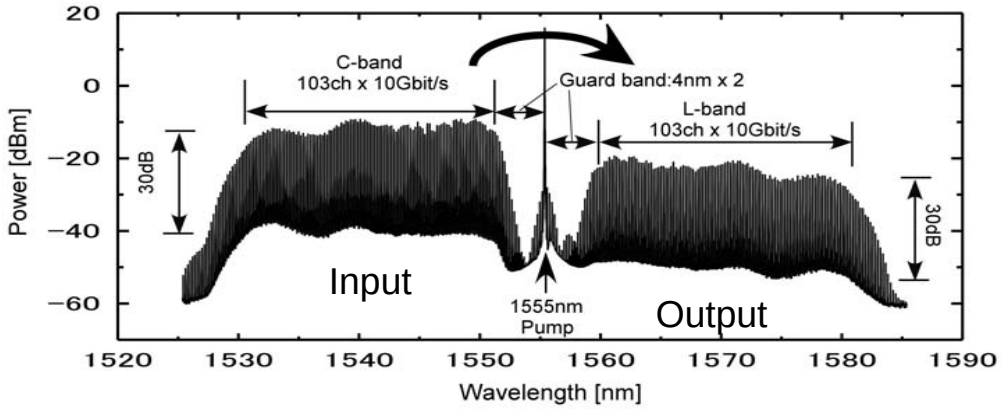


Sum Frequency Generation（SHG）



Difference Frequency generation（DFG）

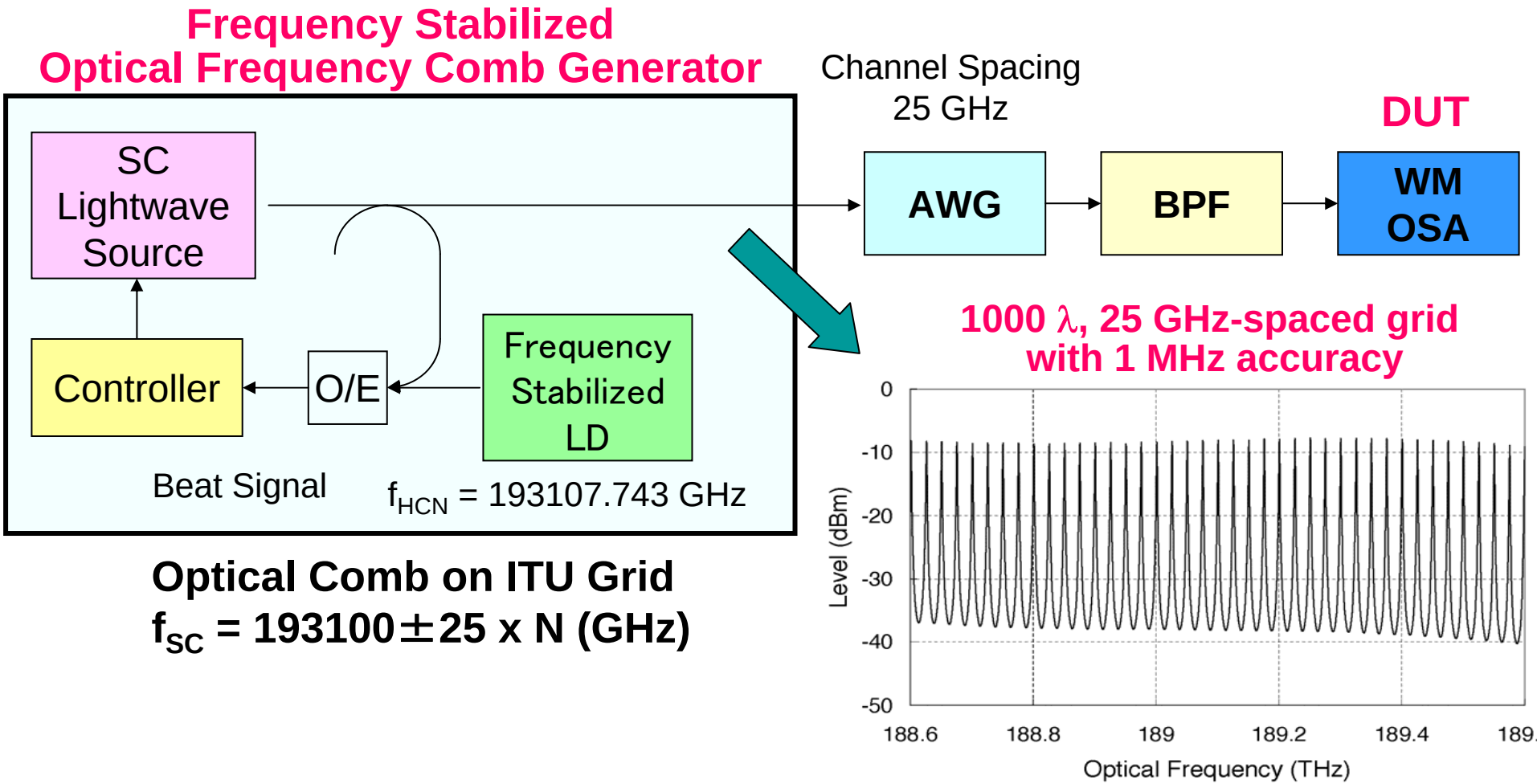
Waveband Conversion (10 Gbps x 103 ch)



Yamawaku, Electron. Lett. Vol39, pp.1144-(2003)

(4) Optical Frequency Measurements by Frequency Grid with 1 MHz Accuracy

*K. Suzuki et al., Electron. Lett., vol. 40, pp.1078 (**2004**)*

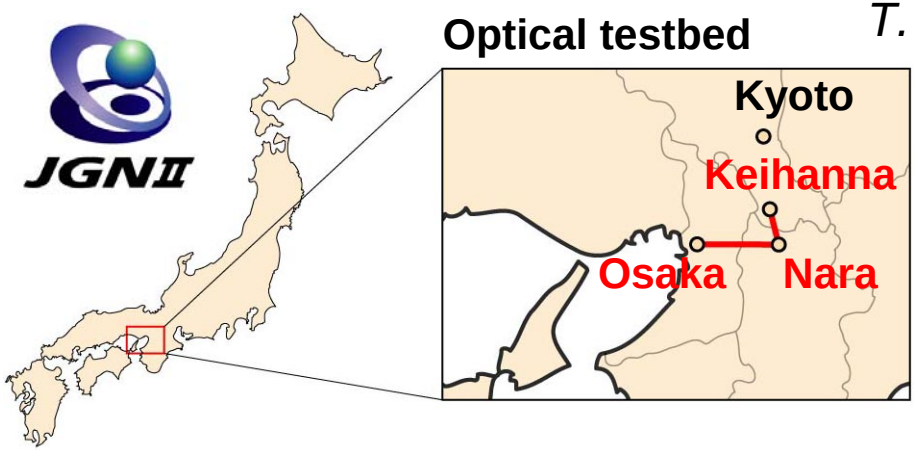


Optical Comb on ITU Grid

f_{SC} = 193100±25 x N (GHz)

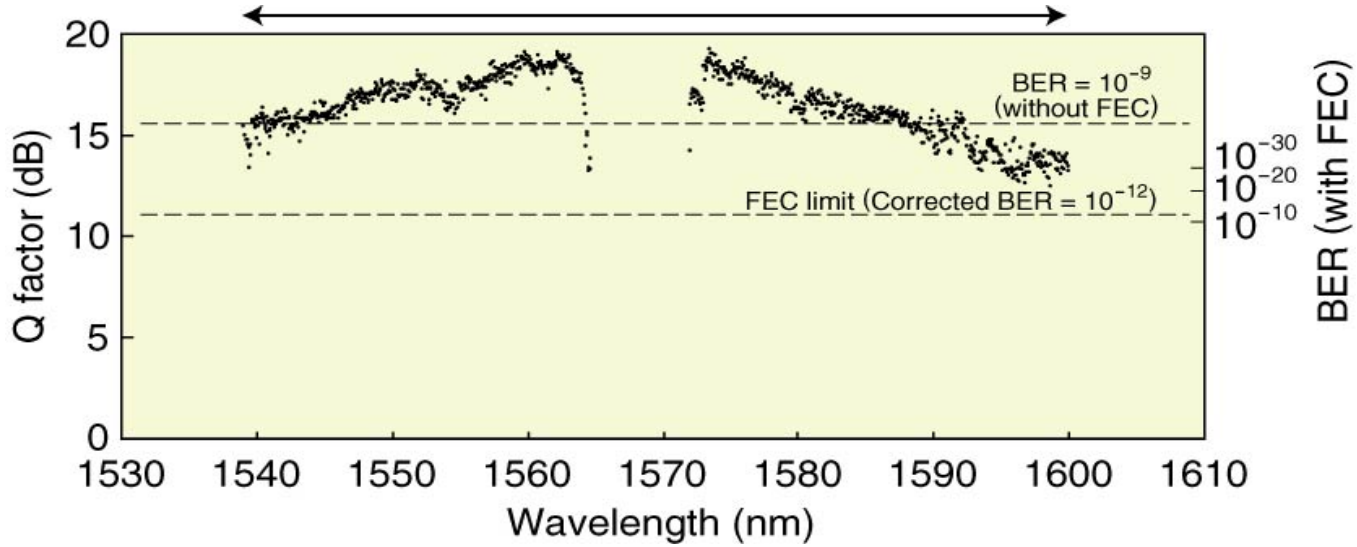
1000 λ Transmission over 126 km with 6.25 GHz spacing

H. Takara et al., Electron. Lett. Vol. 41, p.270 ***(2005)***
T. Ohara et al., IEEE JLT Vol. 24, pp.2311 ***(2006)***



Distance	**126 km (SMF)**
Bitrate/ch	**2.67 Gbit/s**
Ch spacing	**6.25 GHz**
No of Ch	**1046**
Band	**C-L band**

1046 ch



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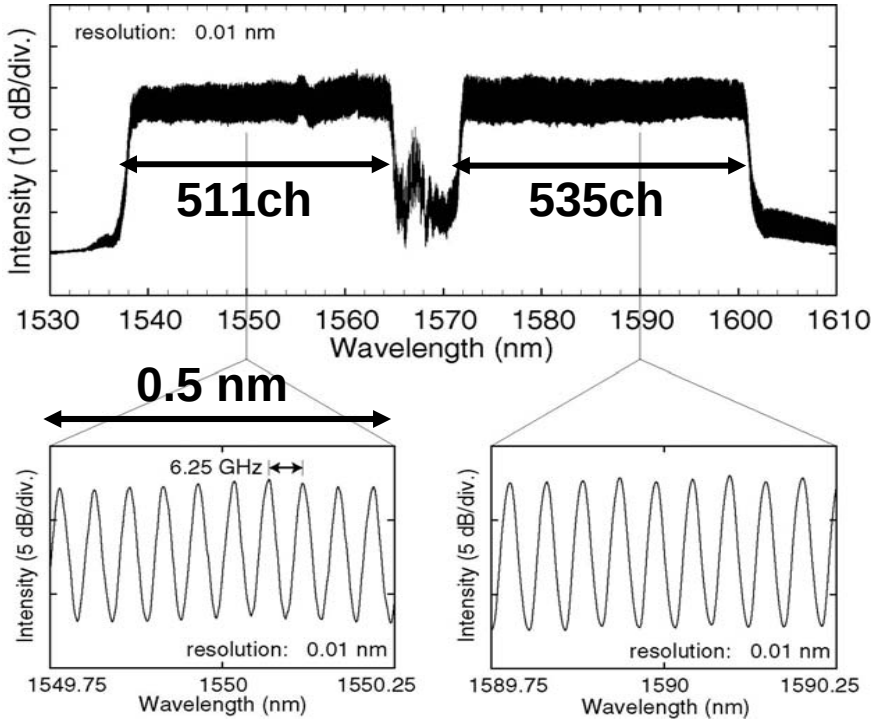
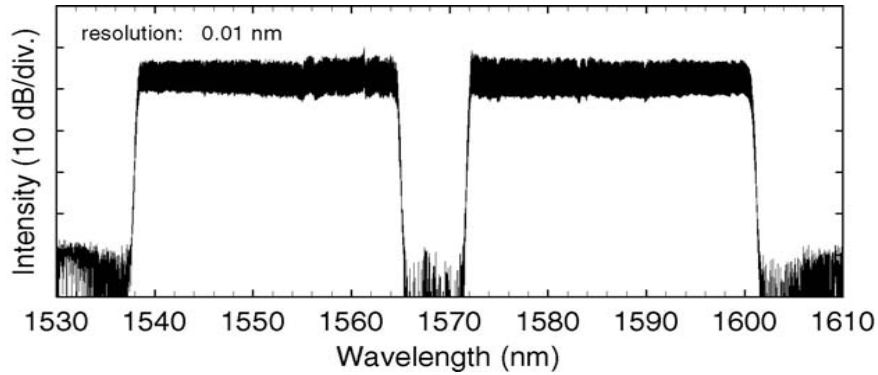
Before Transmission



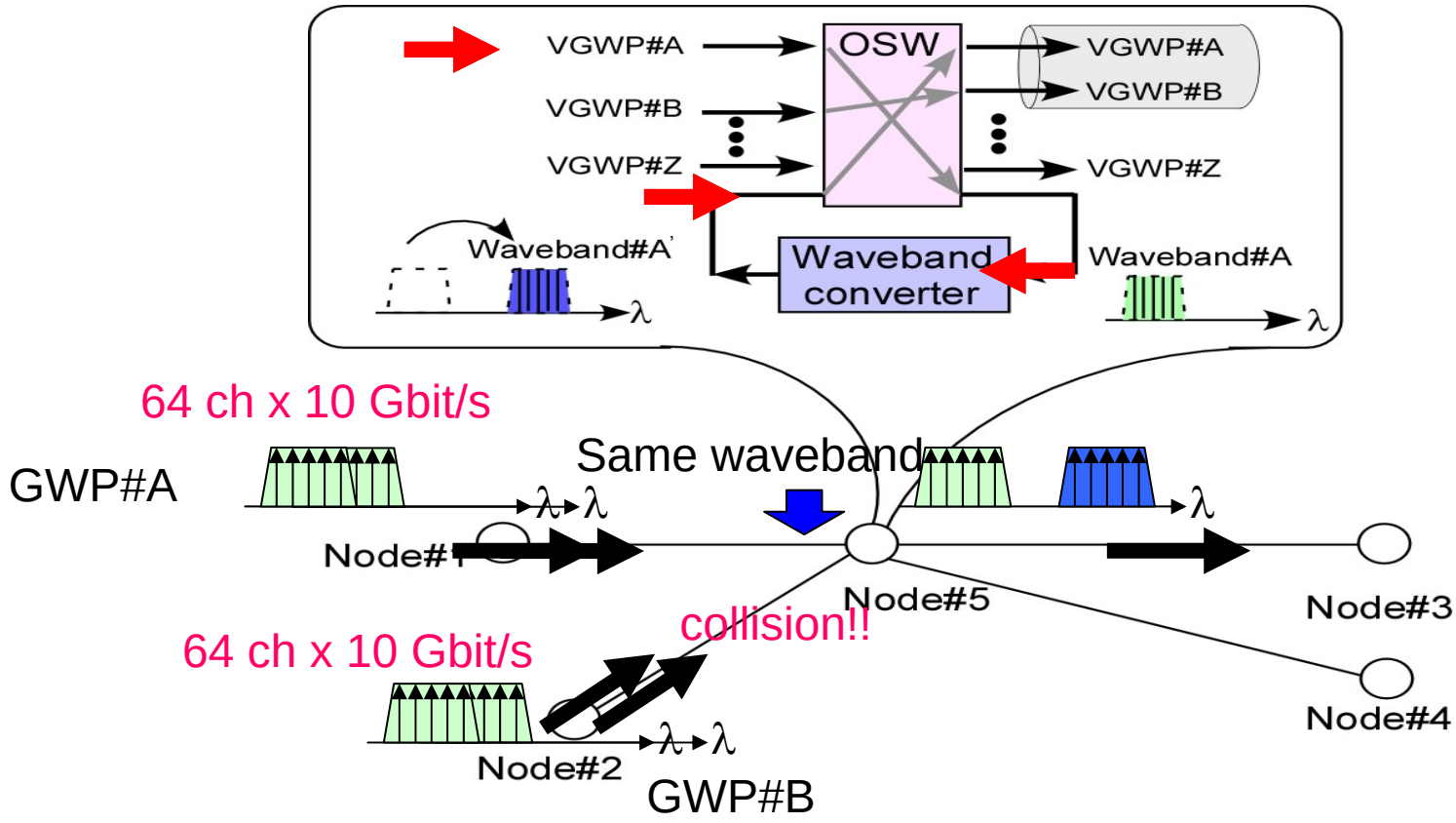
After 126 km Transmission



640 Gbit/s (64ch x 10 Gbit/s) Virtual Waveband Path Switching

J. Yamawaku et et al., IEEE JSAC, Vo12, pp.529 ***(2006)***

Mechanism: ***Contention Resolution***



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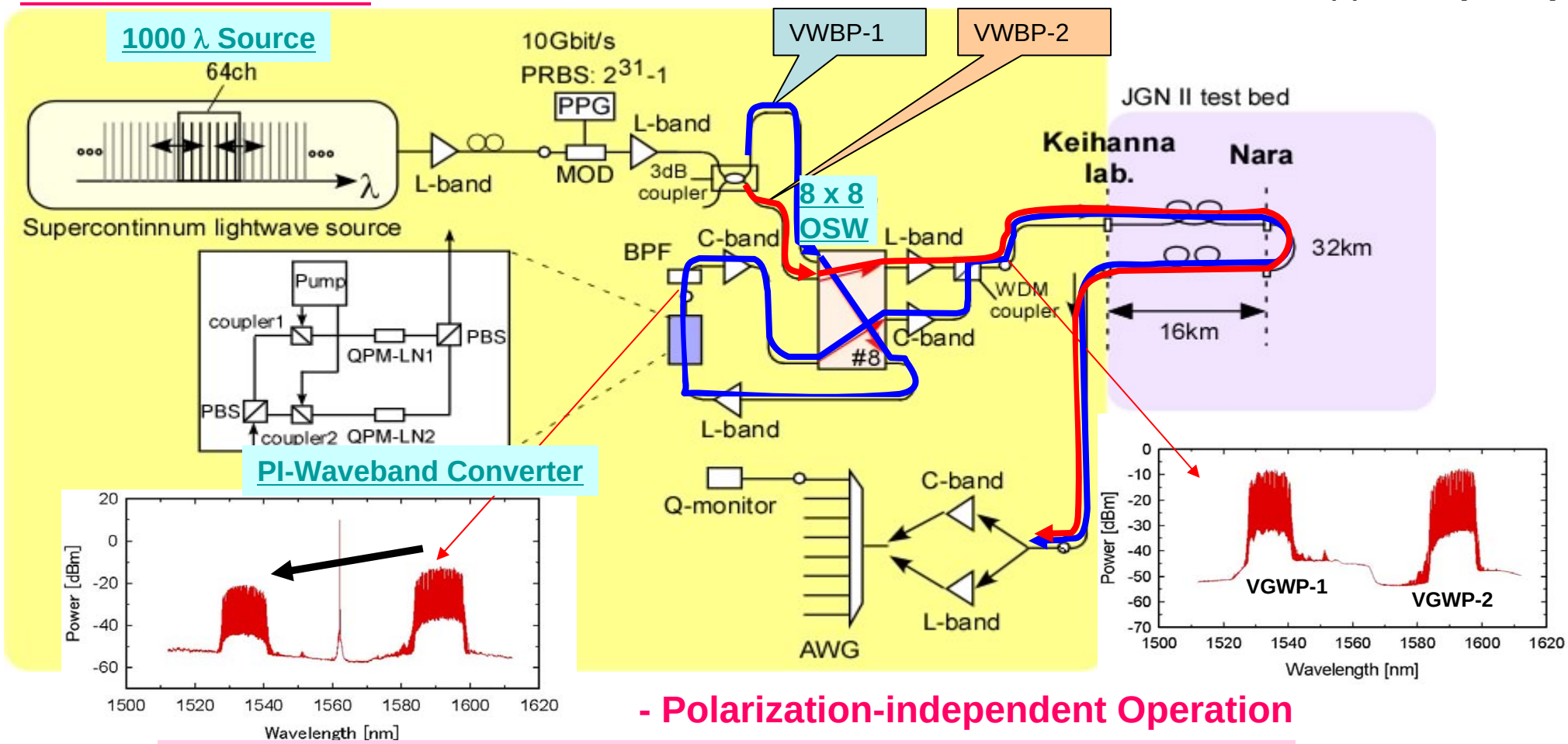
Demonstration

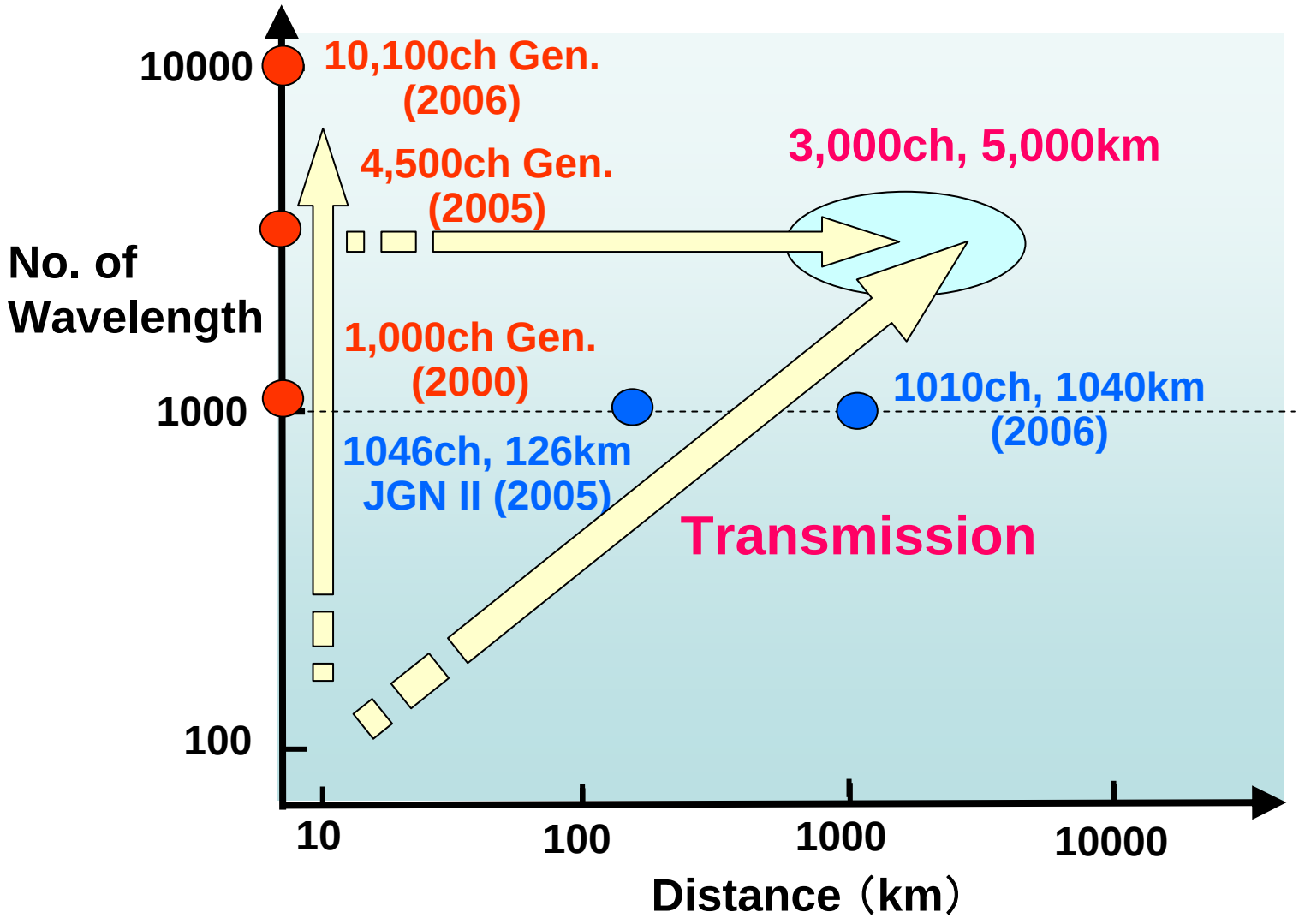
J. Yamawaku et et al., IEEE JSAC, Vo12, pp.529 ***(2006)***



- Polarization-independent Operation

8ports x 64ch x 10Gbit/s = 5.1Tbit/s throughput

Accomplishments



Summary

- ***Super Lambda NW : 1,000~10,000 λ***
  - ***Tbit/s BOD with Dynamic λs assignment***
- ***JGN II Field Demonstrations***
  - ***1000 λ Transmission***
  - ***640 Gbit/s Virtual Waveband Path Switching***
- ***Control & Management Issues***
- ***Standardization Issues***
  - ***Frequency Assignment***
  - ***Control & Management Protocol***