ITU-T Kaleidoscope Conference Innovations in NGN

An Alternative Access Technology for Next Generation Networks based on Full-Optical Wireless Communication Links

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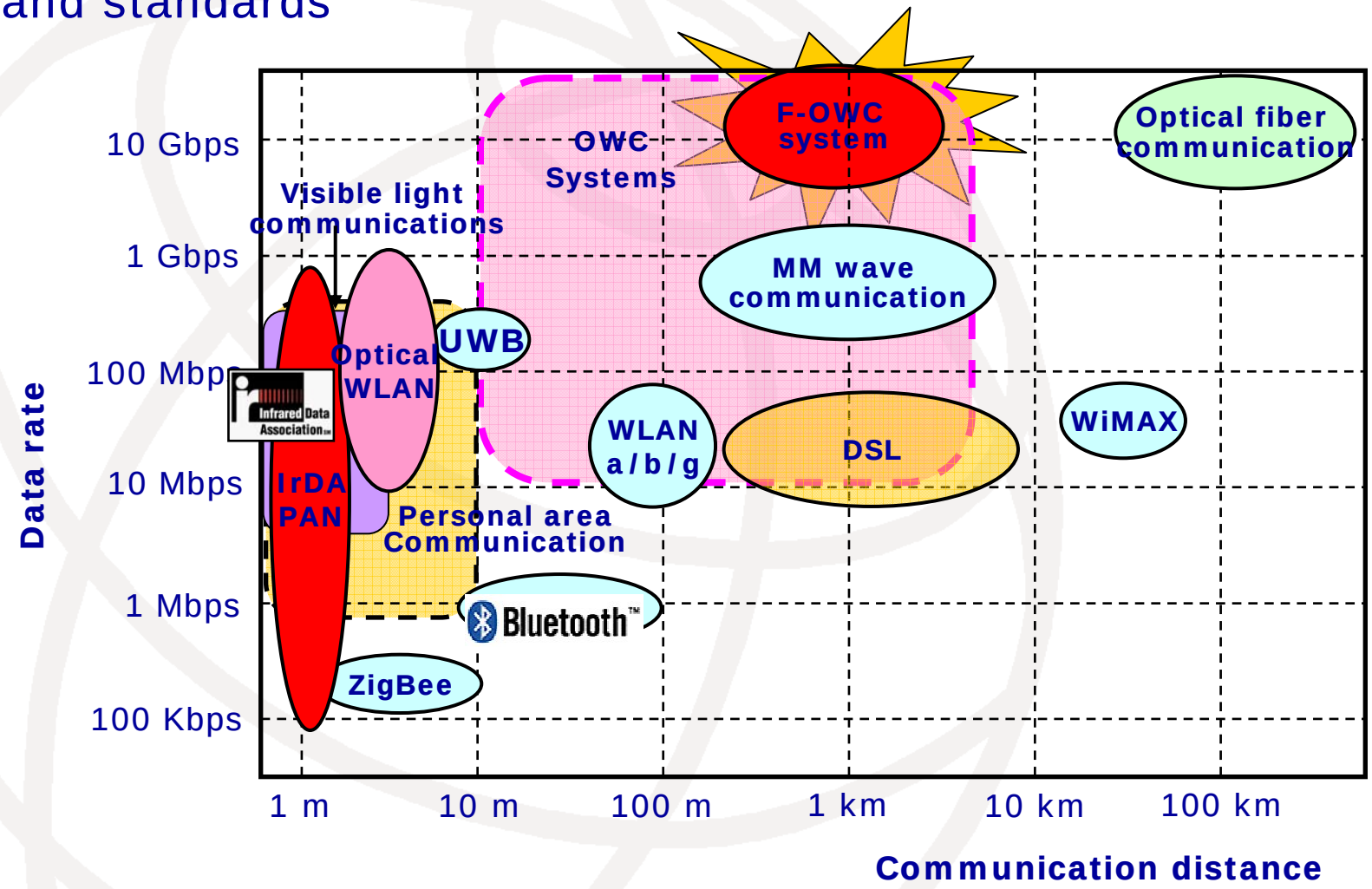
Contents

- Broadband access technologies
- Optical wireless technologies
  - Overview and application areas of OWC
  - Conventional OWC systems
  - New F-OWC systems
  - Advanced DWDM RoF-OWC systems
- Experiments results and analysis
- Conclusion

Broadband Access Technologies

Broadband access technologies and other wireless technologies and standards



Overview of Optical Wireless Communications

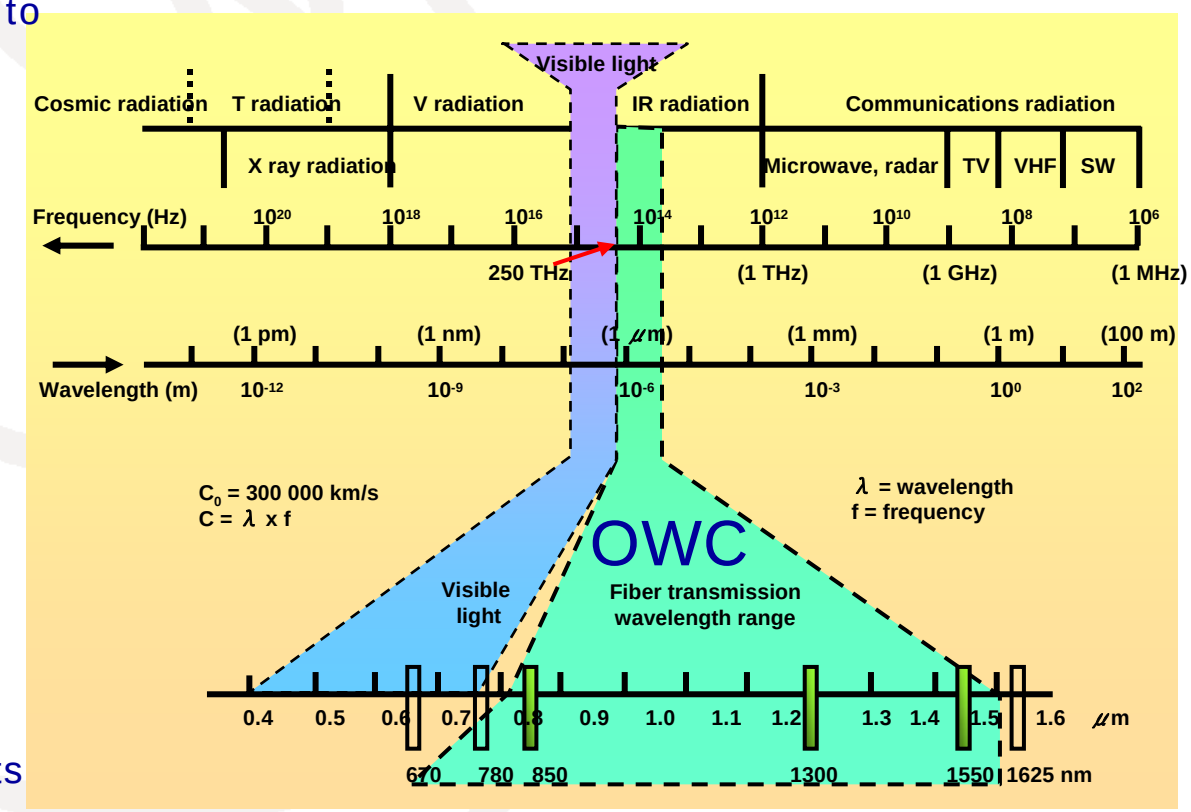
OWC is the transmission of modulated visible or infrared (IR) beams through the atmosphere to obtain broadband communications.

Advantages

- Secure wireless system not easy to intercept
- Easy to deploy, avoid huge costs involved in laying cables
- License free
- Possible for communication up to several kms
- Can transmit high data rate

Disadvantages

- High dependence on weather condition (rain, snow, fog, dust particles etc)
- Can not propagate through obstacles
- Susceptible to atmospheric effects (atmospheric fluctuations)

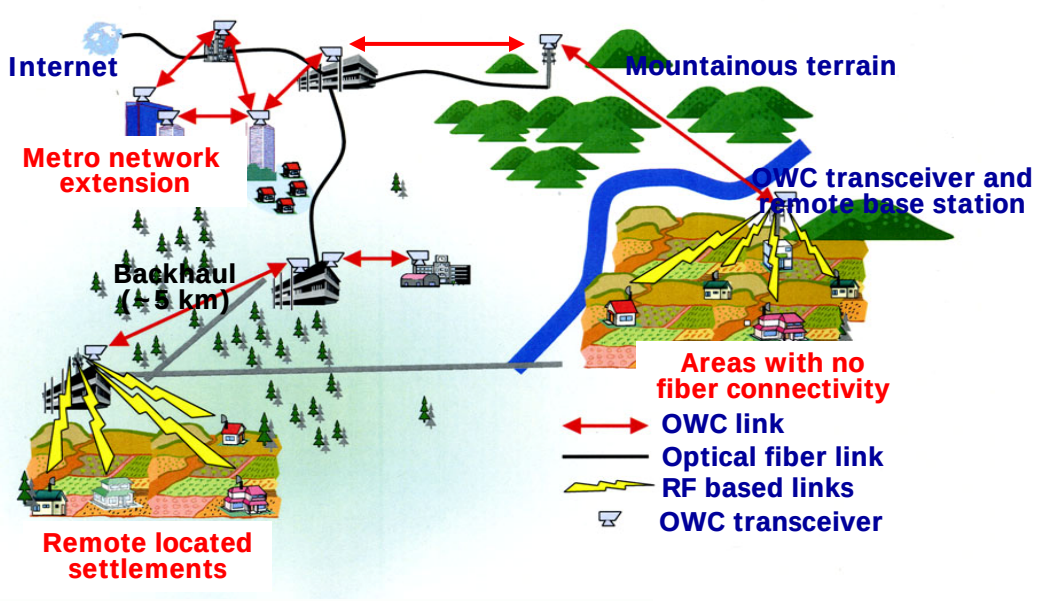


Electromagnetic spectrum

OWC technology application scenarios

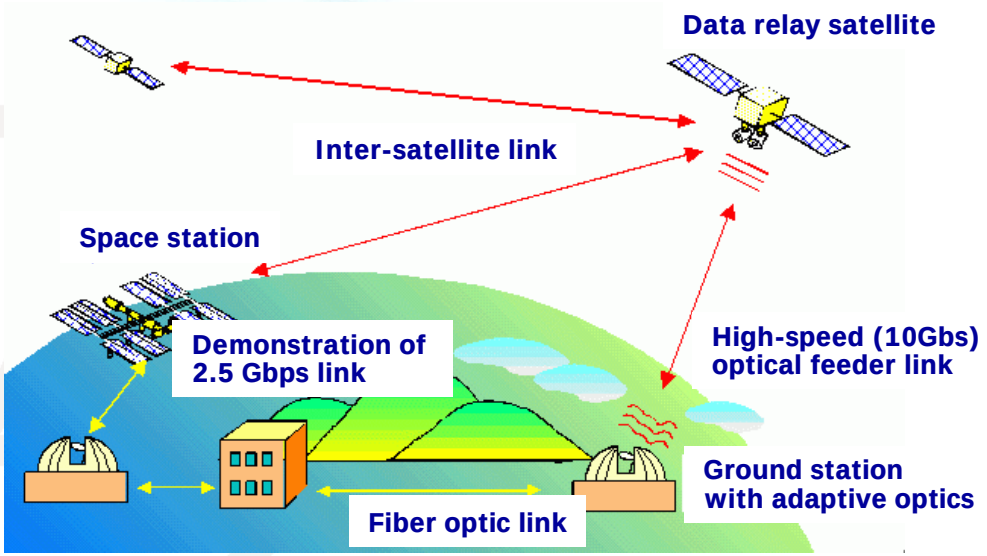
Terrestrial

- Metro network extension
- Last mile access
- Enterprise connectivity
- Fiber backup
- Transmission of heterogeneous wireless services

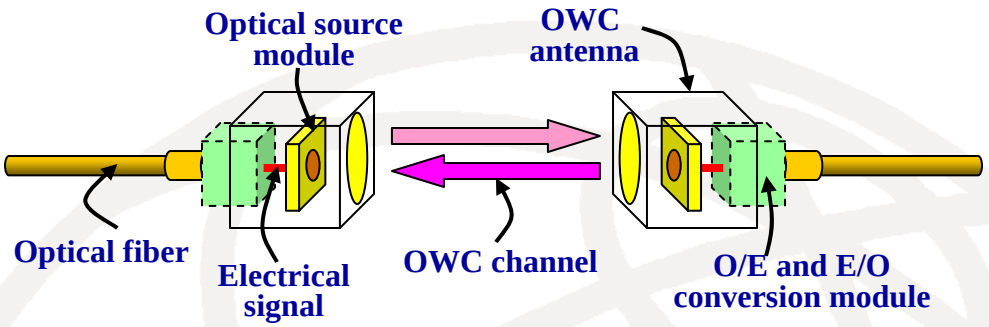


Space

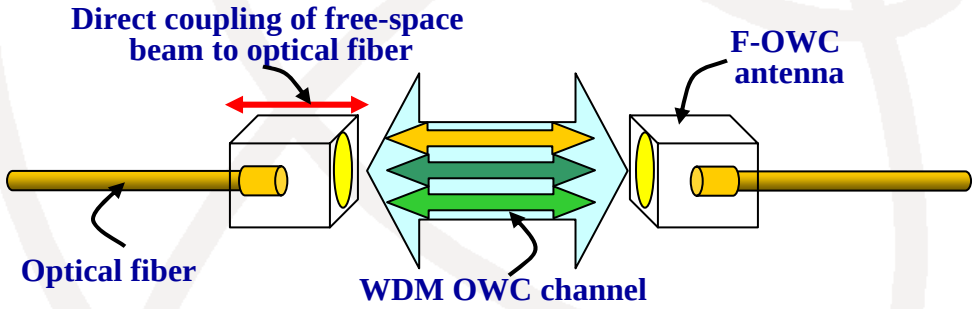
- Inter-satellite communication (cross link)
- Satellite to ground data transmission (down link)
- Deep space communication



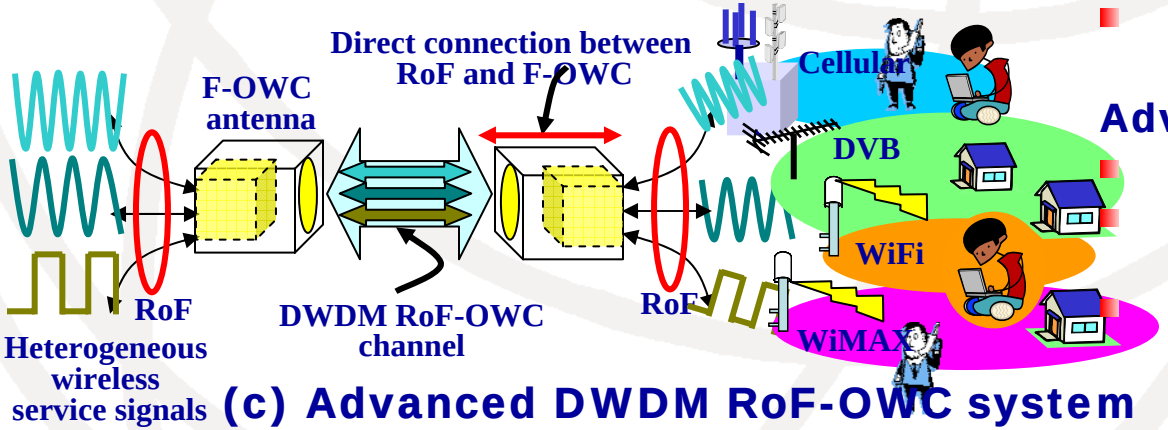
OWC technology



(a) Conventional OWC system



(b) New F-OWC system



(c) Advanced DWDM RoF-OWC system

Conventional OWC system

- Operate near the 800nm wavelength band
- Uses O/E & E/O conversion
- Data rates up to 2.5 Gbps
- Bandwidth and power limitations

New F-OWC system

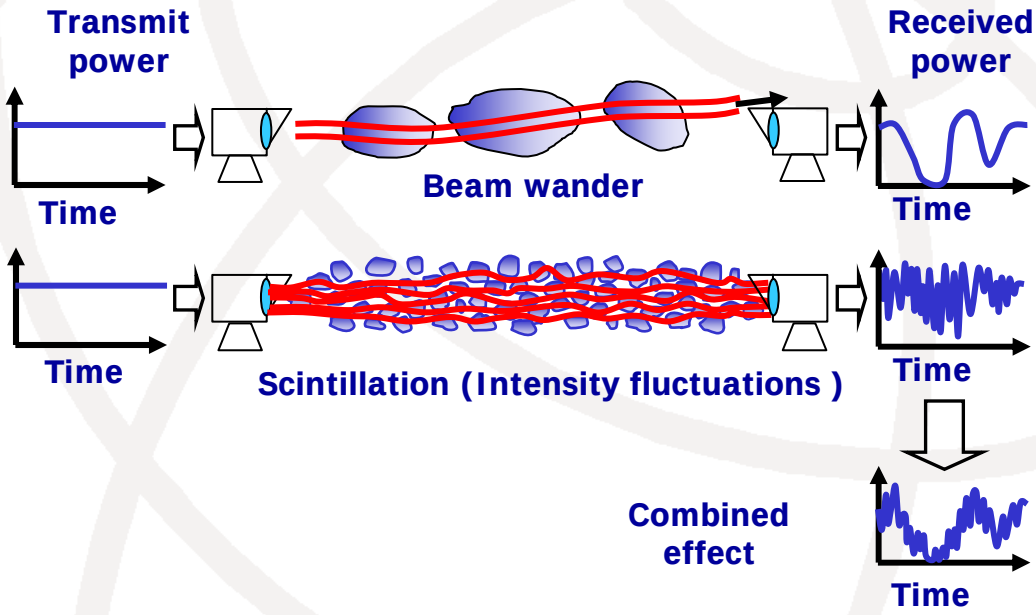
- Uses 1550nm wavelength
- Seamless connection of optical wireless beam and fiber.
- Multi gigabit per second data rates (using optical fiber technology)
- Compatible with existing fiber infrastructure
- Protocol and data rate independent

Advanced DWDM RoF-OWC system

- Uses 1550nm wavelength
- Transport multiple RF signals using DWDM OWC channels
- Realize heterogeneous wireless services e.g. WLAN, Cellular, terrestrial digital TV etc

Deployment environment characteristics

Atmospheric turbulence has a significant impact on the quality of the optical wireless beam propagating through the atmosphere.



Reduces the optical beam power at the receiver point and causes burst errors

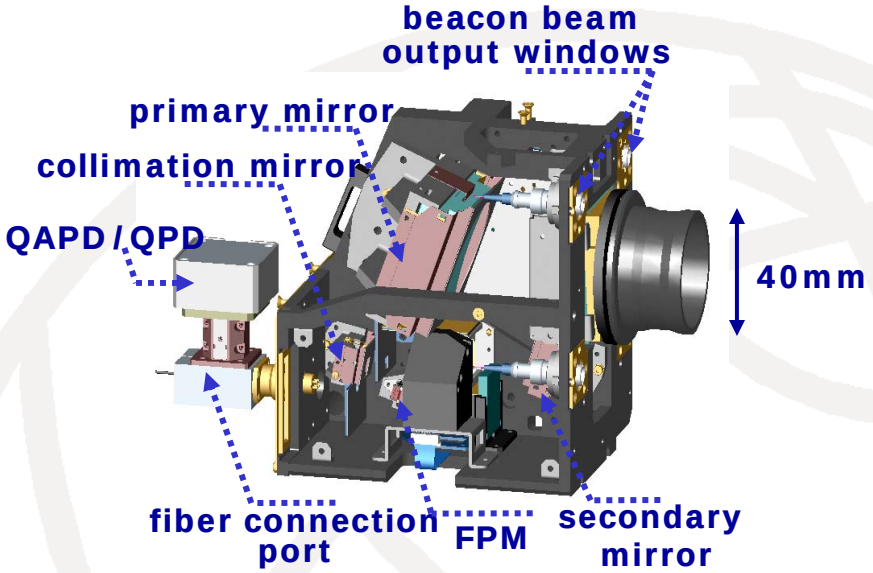
Other effects include

- Beam broadening and
- Angle-of-arrival fluctuations

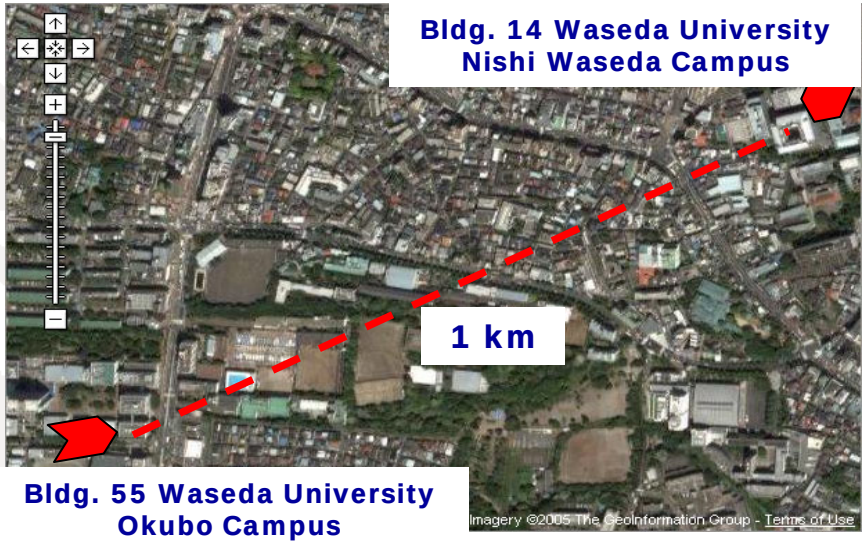
Mitigation techniques include:

- Aperture averaging
- Diversity techniques
- Adaptive optics
- Coding techniques

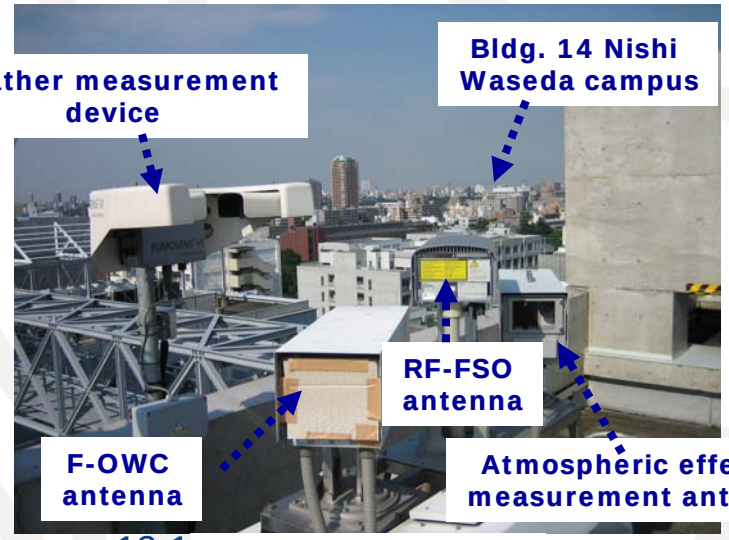
Experiment devices and setup



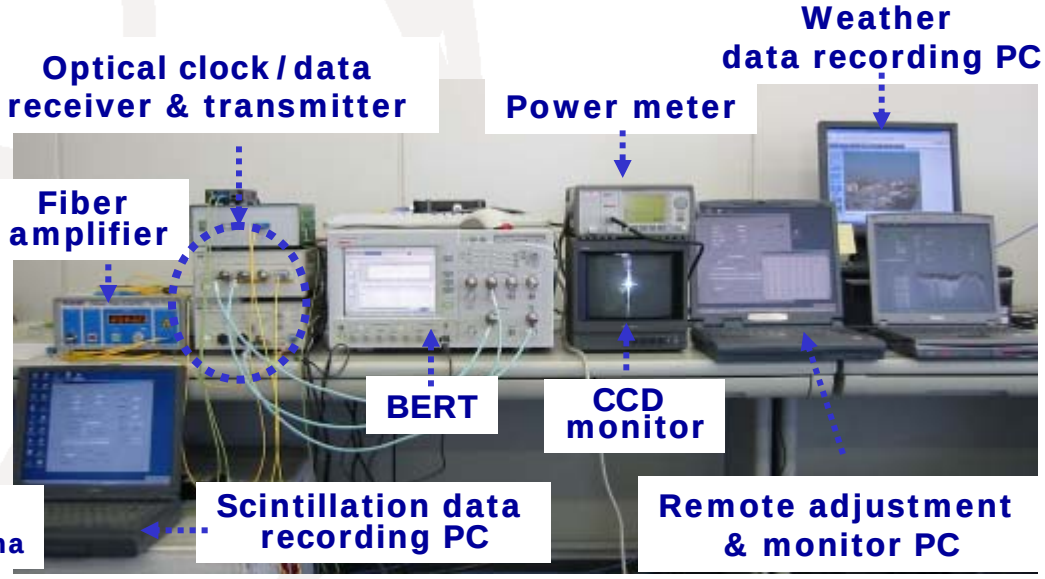
(a) Optical antenna internal structure



(b) Experiment field

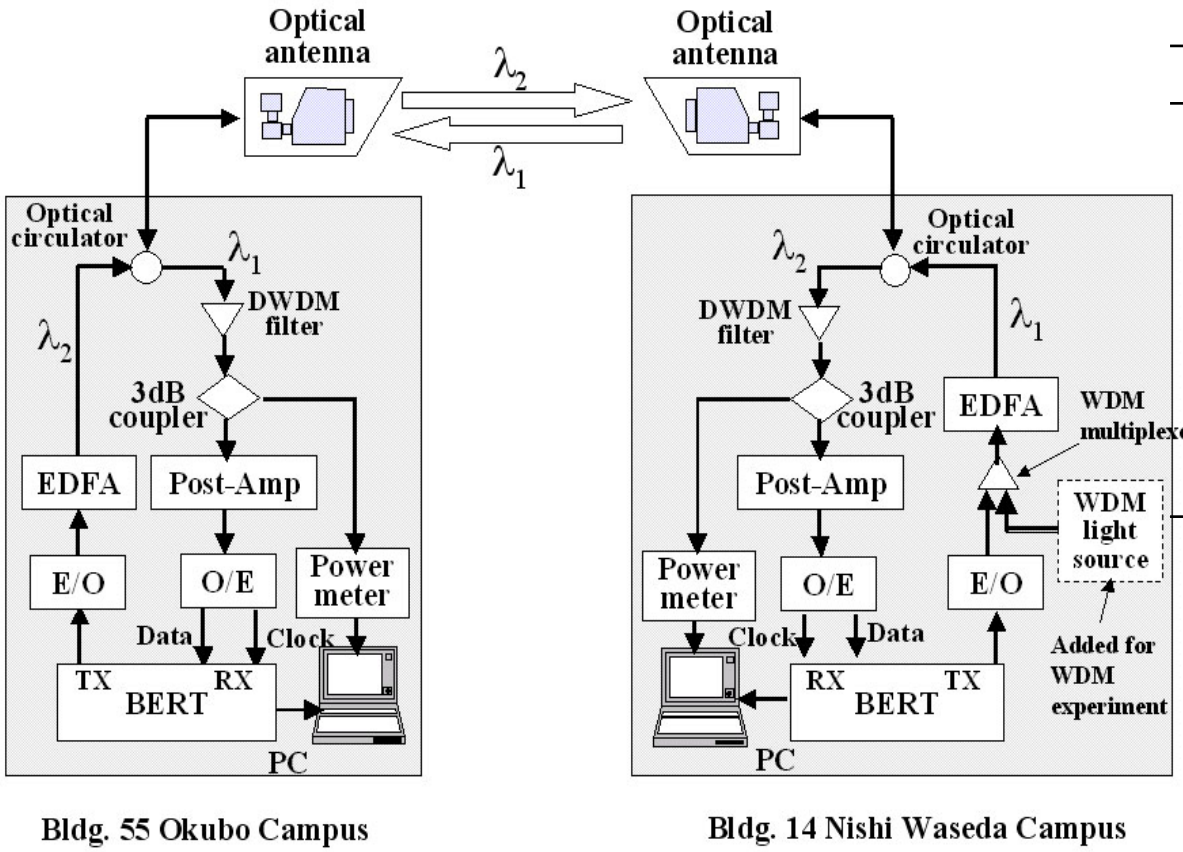


(c) Rooftop setup



(d) Experimental hardware setup

Experimental results and analysis



Bldg. 55 Okubo Campus

Bldg. 14 Nishi Waseda Campus

F-OWC system performance evaluation experimental setup

Specifications of equipment used in experiment

Parameter Specification	*Value*
Data rate (Gbits/s)	2.5 & 10
E/O (directly mod. DFB laser)	OOK/NRZ
Test data pattern	2^{23}-1 & 2^{7}-1 PRBS
Boost EDFA output (mW)	100
Receiver opt. filter 0.5dB BW	±11 nm
Antenna aperture (mm)	40
Rec. sensitivity (BER = 10^{-12})	**-30 dBm**

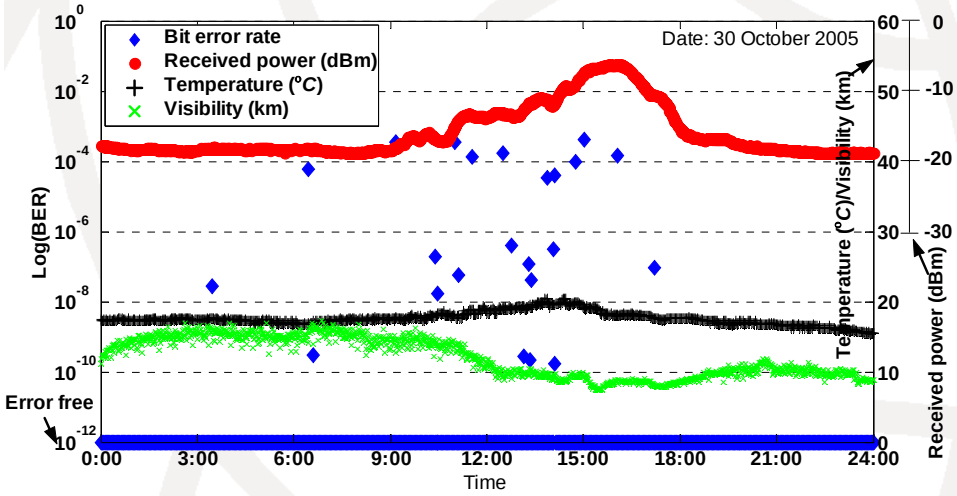
Experiments

- BER and received power characteristics
- WDM transmission characteristics
- Application data performance characteristics

Experimental results and analysis cont.

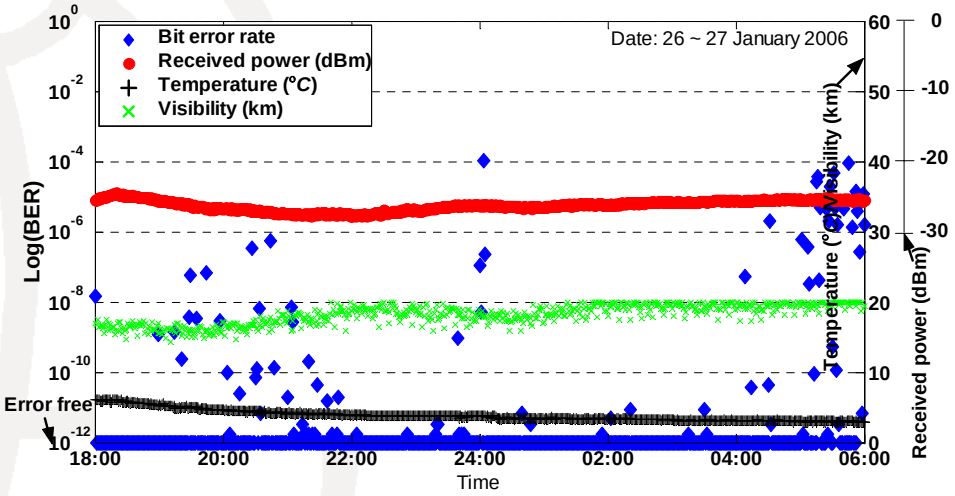
BER and receiver power characteristics

2.5 Gbps transmission



Single channel 1550 nm data link operating at 2.5 Gbps

10 Gbps transmission

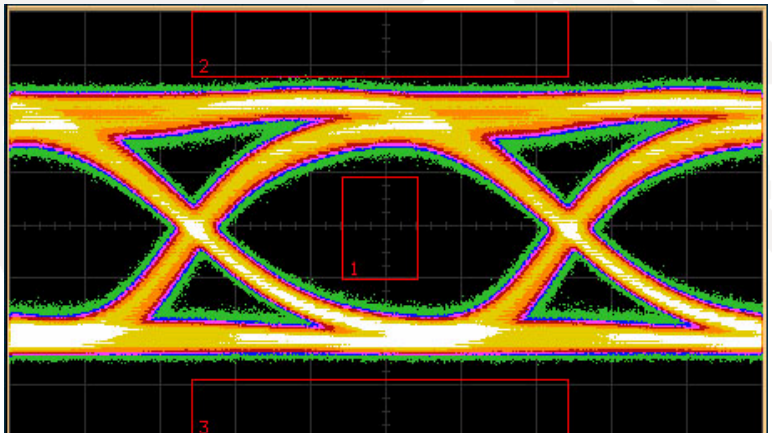


Single channel 1550 nm data link operating at 10 Gbps

Experimental results and analysis cont.

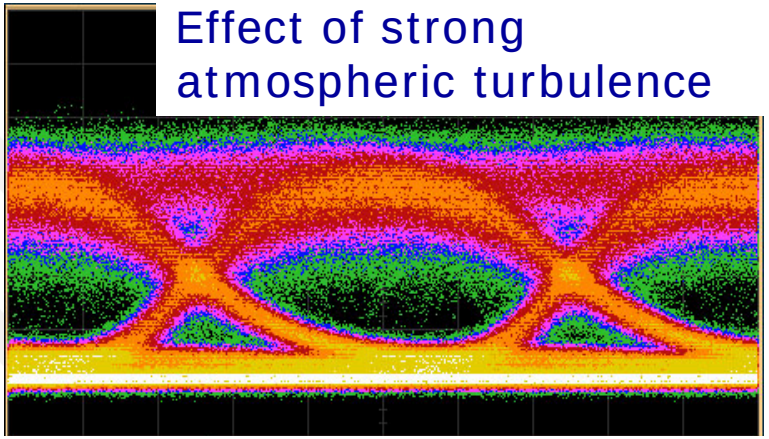
Eye pattern characteristics

2.5Gbps transmission



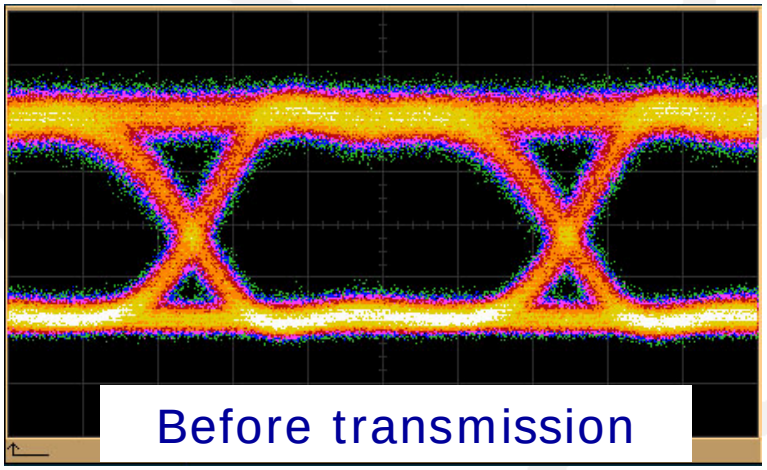
After transmission (typical case)

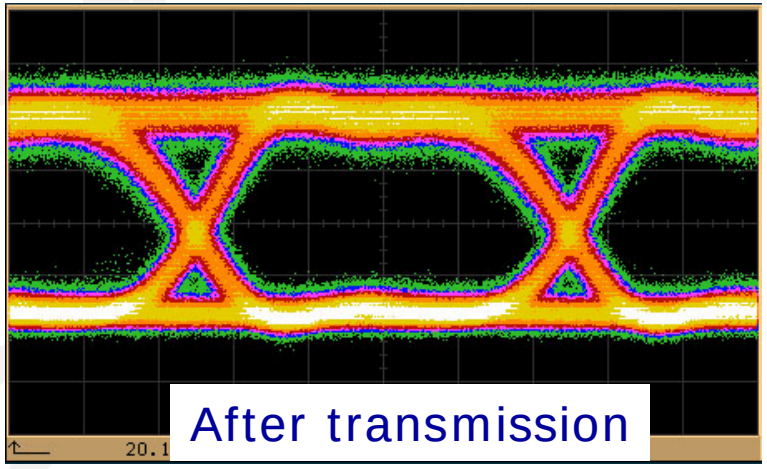
Effect of strong atmospheric turbulence



After transmission (worst case)

10 Gbps transmission





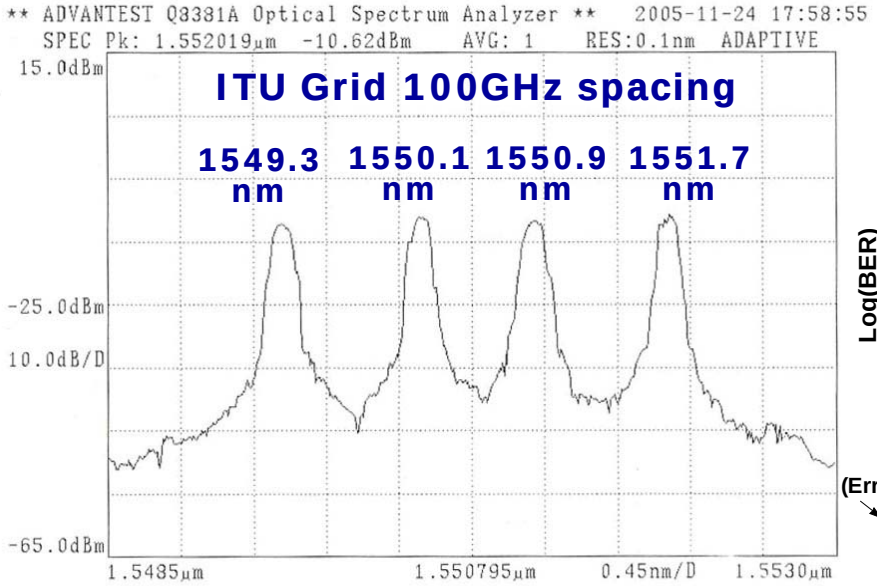
Most of the key wave shape parameters are within acceptable tolerance

Experimental results and analysis cont.

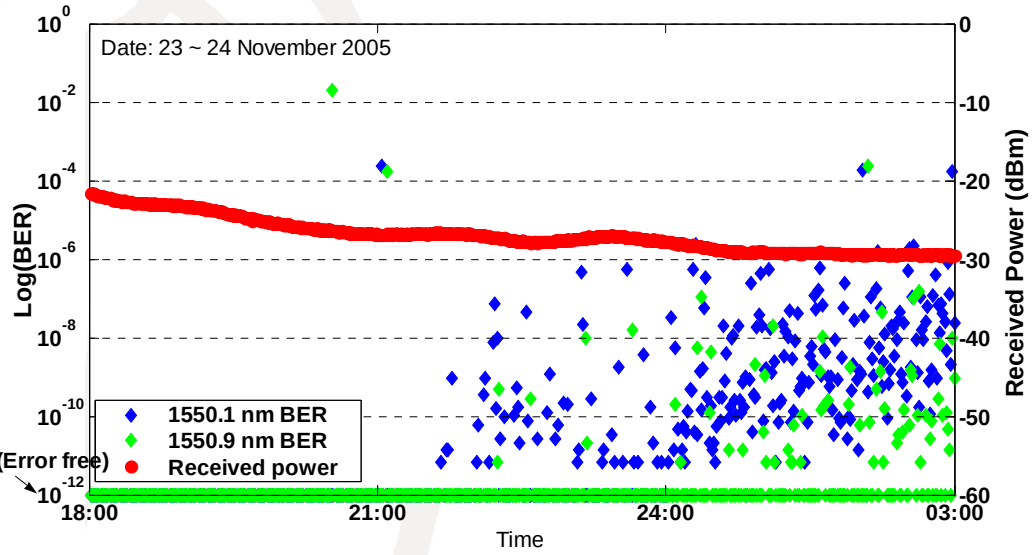
WDM experiment

Four channel 1550 nm data link operating at 2.5 Gbps WDM

WDM received signal spectrum



BER and received power characteristics



- 2.5 Gbps X 4 channels with output power 100mW/wavelength
- Stable communication was achieved with no fluctuation or interference between wavelengths

Conclusion

- Developed a **transparent optical wireless communication system** which is readily compatible with existing widely deployed PON access technology.
- Demonstrated that the systems offers **stable and reliable transmission** at single channel 2.5 and 10 Gbps as well as WDM transmission.
- Confirmed the technology can be used as **alternative broadband access technology in the emerging NGN**.
- **Standardization activities** with respect to transceivers and devices for ease in adaptability with existing broadband access technologies both wire-line and wireless based.
- Further work in **research and development of advanced DWDM RoF-OWC** system for heterogeneous wireless communication signals transmission.

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Supported by

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Thank you for your attention

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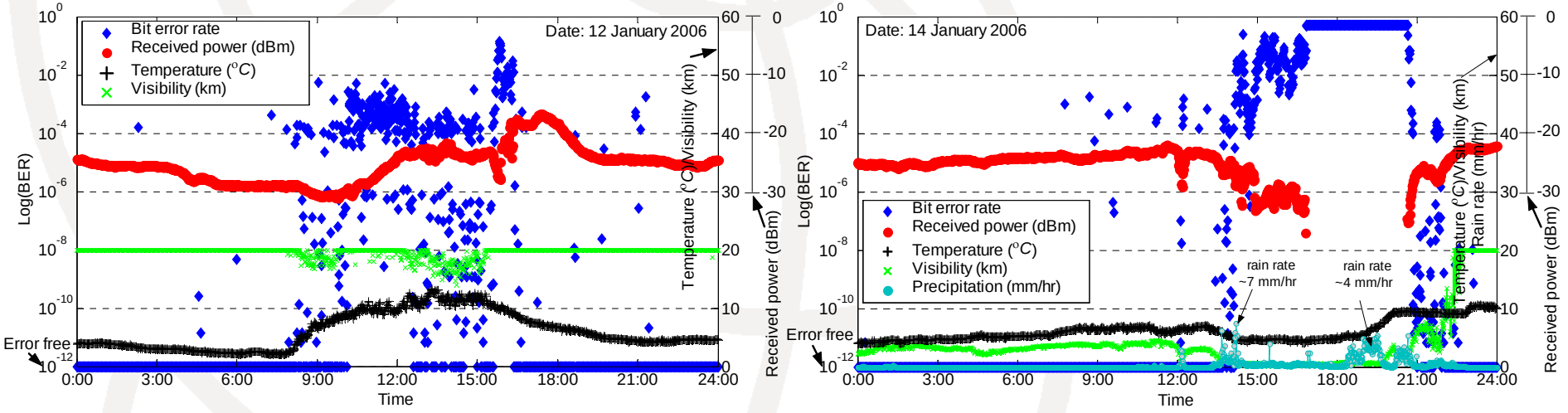
Backup slides

Experimental results and analysis cont.

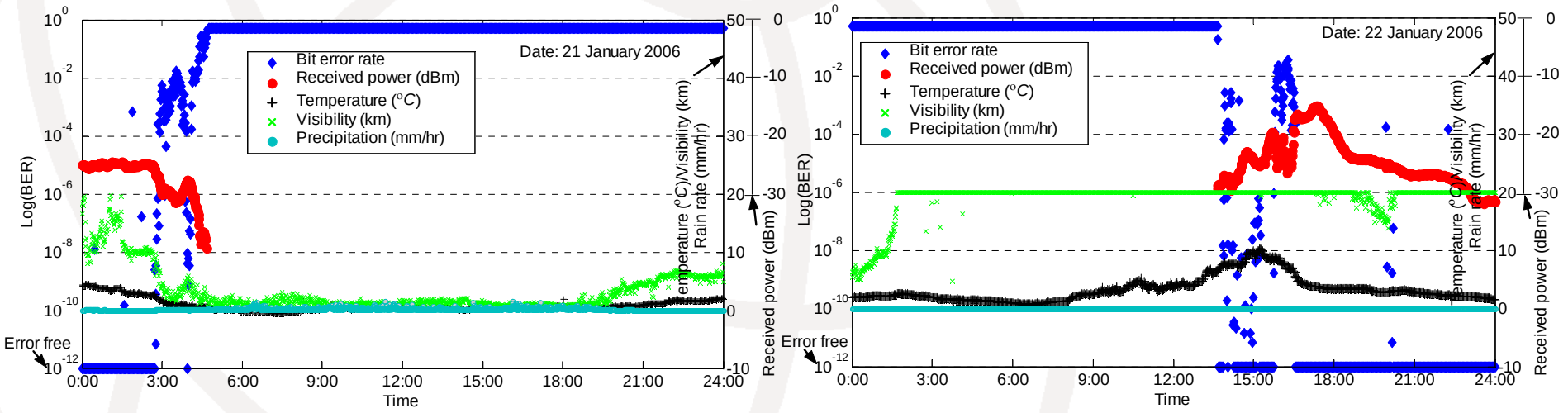
BER and receiver power characteristics



Single channel 1550 nm data link operating at 2.5 Gbps BER and received power characteristics under the influence of strong atmospheric turbulence and rain

Experimental results and analysis cont.

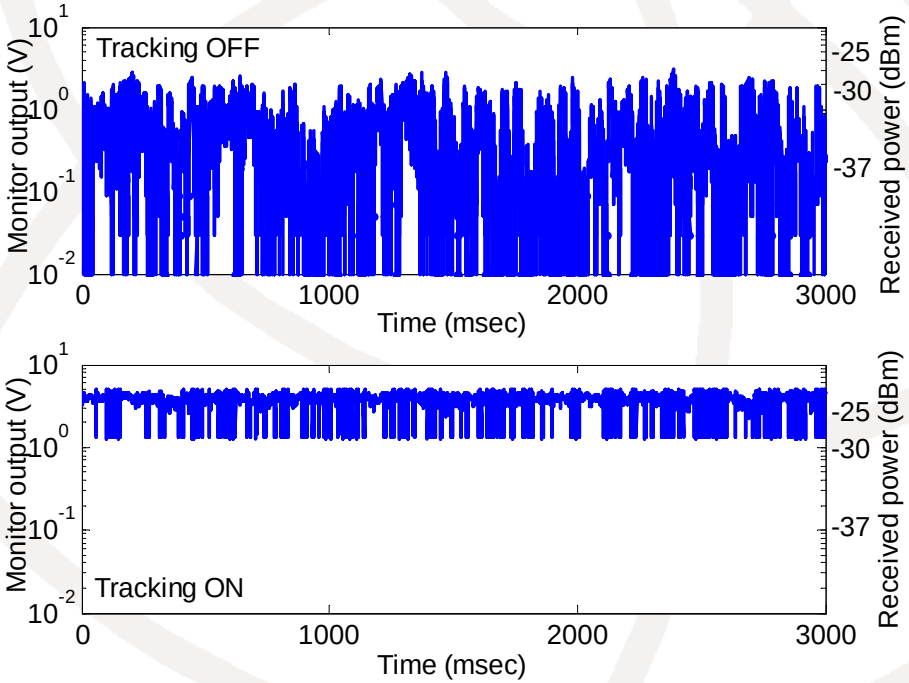
BER and receiver power characteristics



Single channel 1550 nm data link operating at 2.5 Gbps BER and received power characteristics under snow event

Fluctuation suppression

Fiber received power after setting the antenna FPM tracking speed to 1 kHz



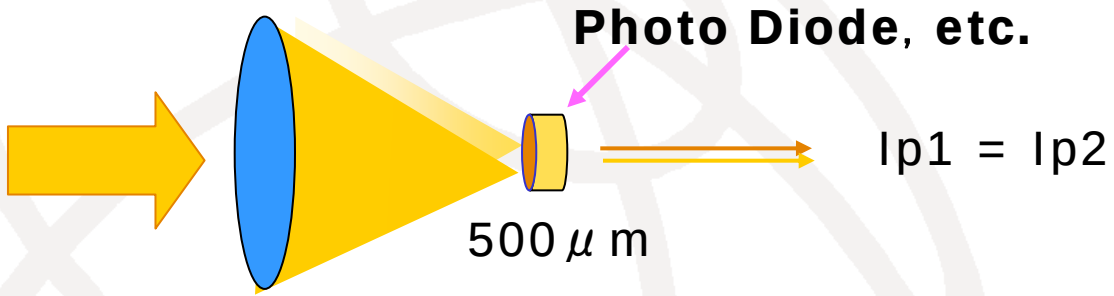
Fiber coupled signal power without FPM tracking

Fiber coupled signal with FPM tracking

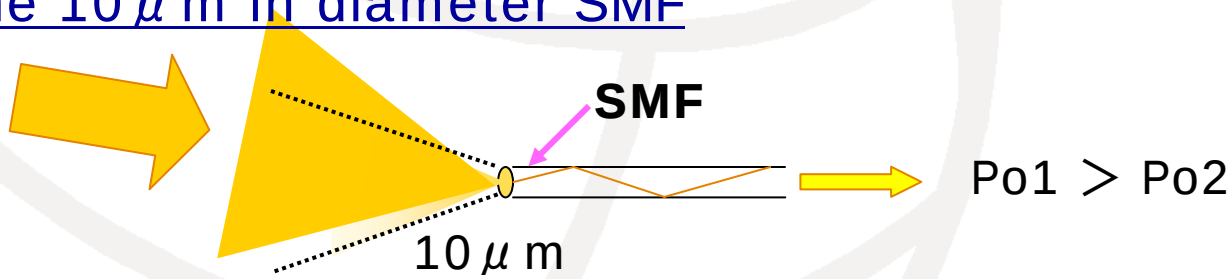
Tracking system reduces the pointing errors which suppresses the atmospheric induced scintillation effects.

Receiving Structure

1. Almost no effect AoA to PD in Existing system

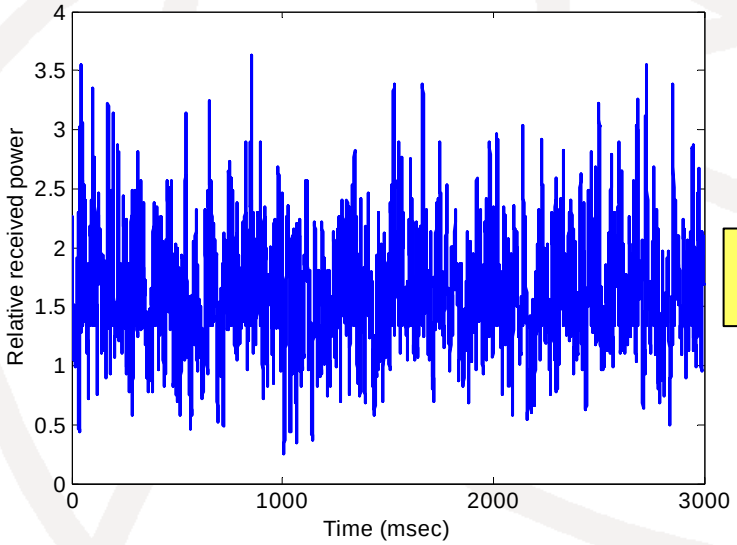


2. Necessity to input the Receiving Opt. beam to the core of the 10 μm in diameter SMF



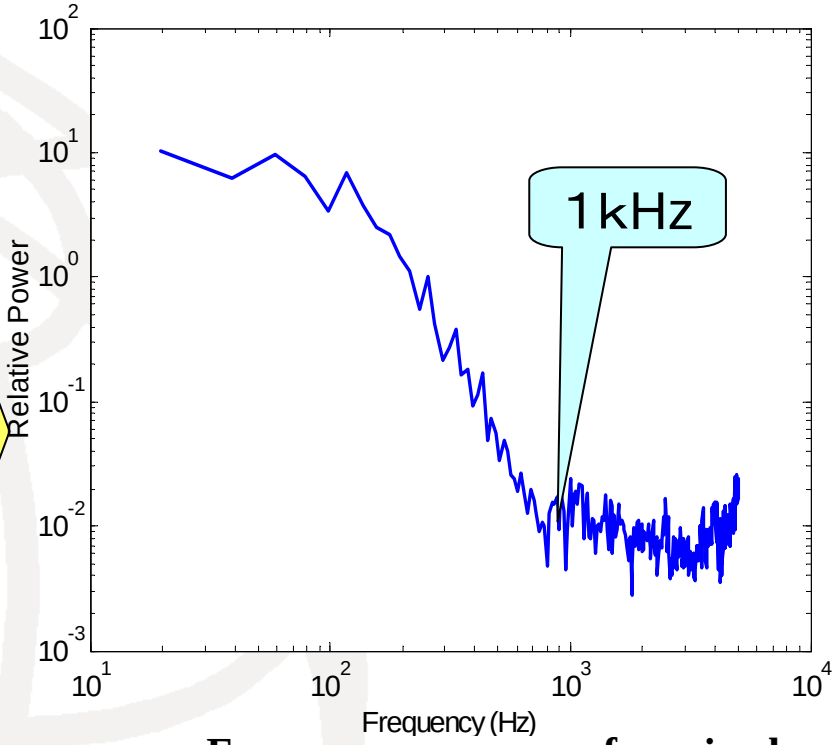
Susceptible to atmospheric effects (atmospheric fluctuations)

Scintillation (intensity fluctuations)



Optical beam intensity fluctuation

FFT

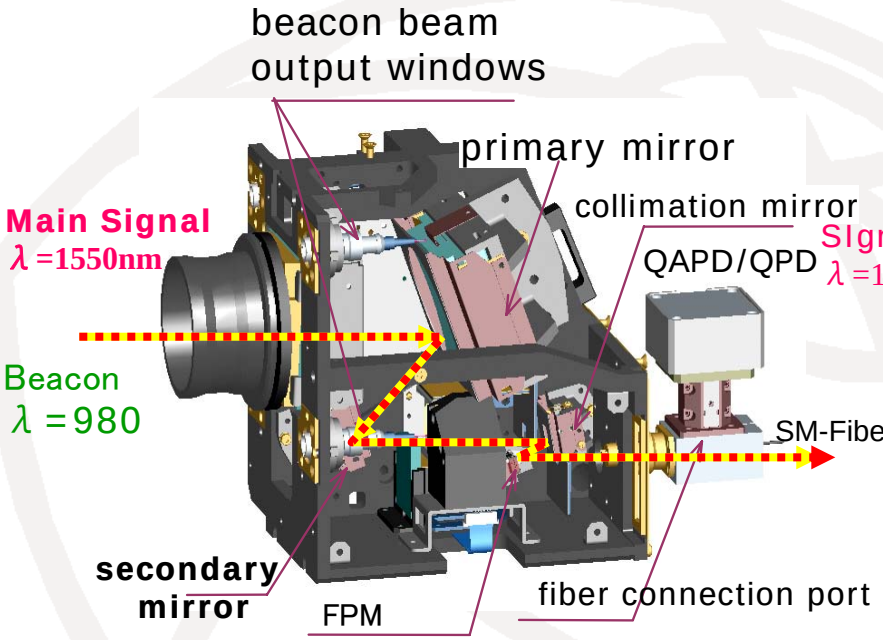


Frequency response of received power variations

A general fluctuation rate of variability is distributed within the range from several to 1kHz.

An quick change of 100Hz or more of received power decreases dramatically. However, the fiber direct coupling cannot be done without repairing of the fluctuation

Optical outline



Optical antenna internal structure