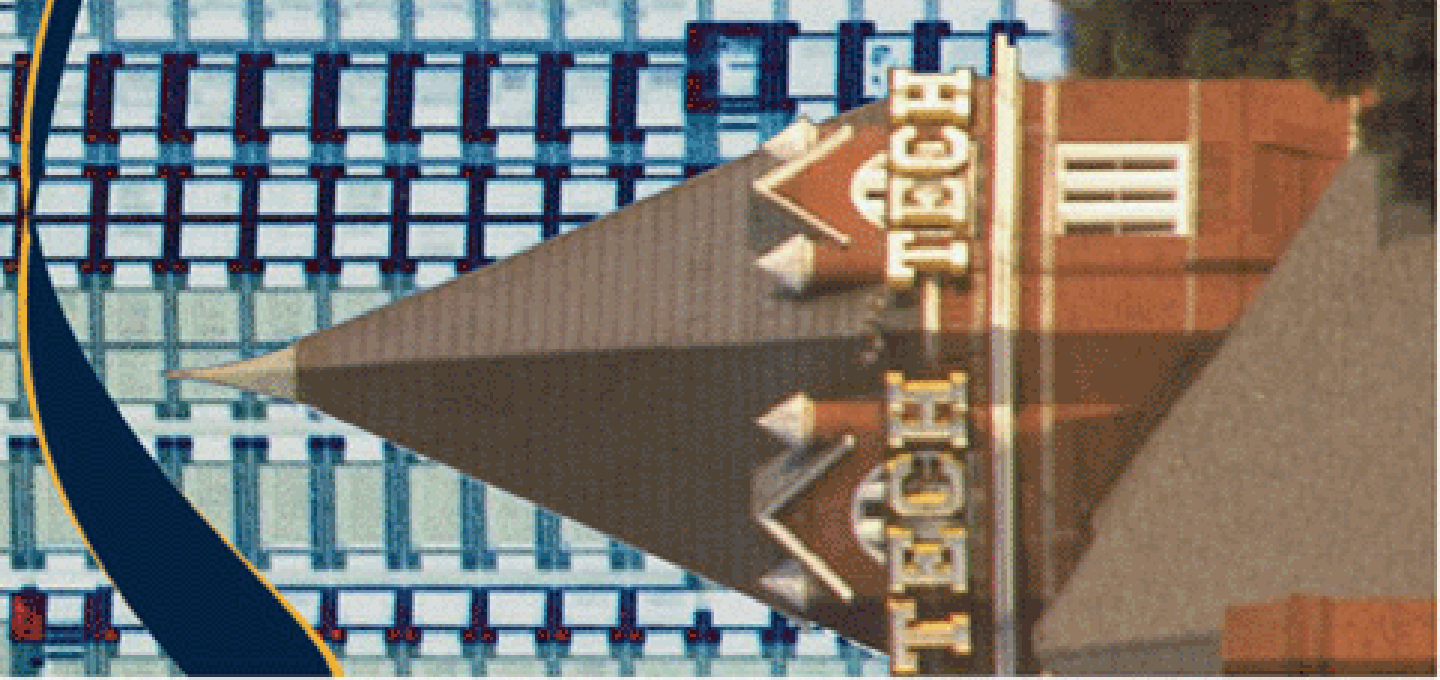


Convergence of Optical and Wireless Access Networks

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Optical Wireless Integration Workshop
OFC'08, February 25 2008
San Diego, California

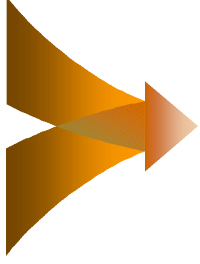


Outline

- **Convergence of Broadband Networking**
- **Integrated Optical Wireless Access Networks**
- **Optical Wireless Signal Generation**
 - Up-conversion of optical wireless signal
 - Multi-band wireless signals
- **Optical Wireless Network Architecture**
 - Dual Services: Wired and Wireless
 - Wavelength Reuse for Full-duplex Connection
- **Technology Challenges**
- **Conclusions**

Broadband Networking Trends

Meet the needs of future end-to-end, dynamic and flexible Internet services

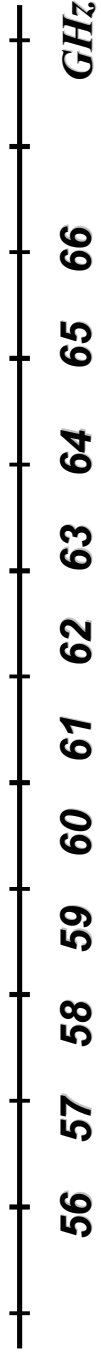
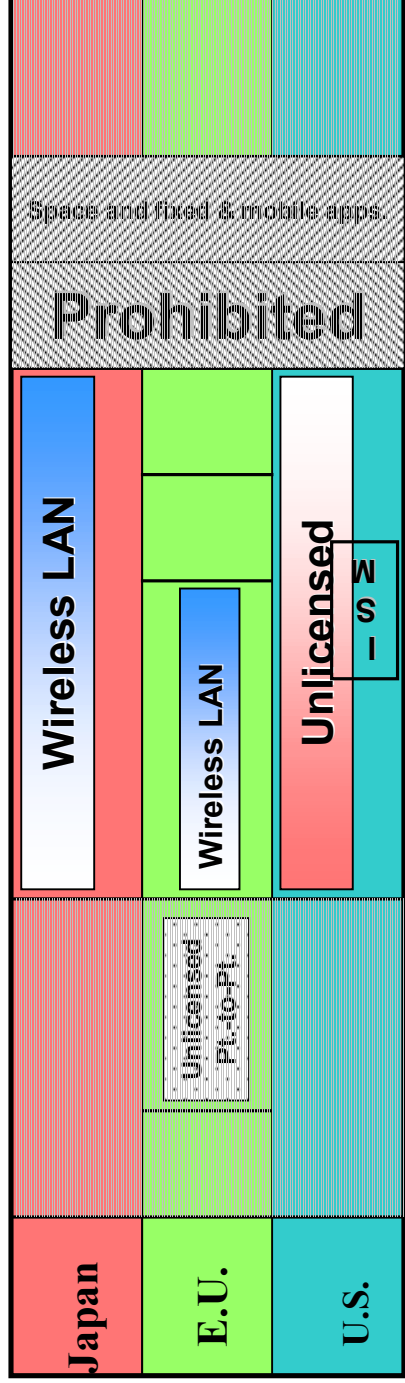


Convergence of Voice, Data, Video and Interactive Multimedia Services

Convergence of DWDM Metro and Widearea Transport Networks

Convergence of Wireless and Wired Networks

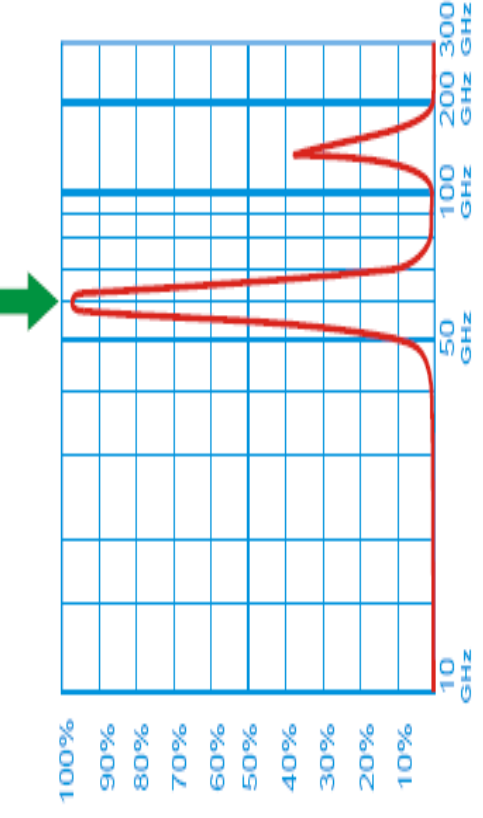
Opportunities: 60GHz mm-Wave for Wireless Services--- HD wireless is coming



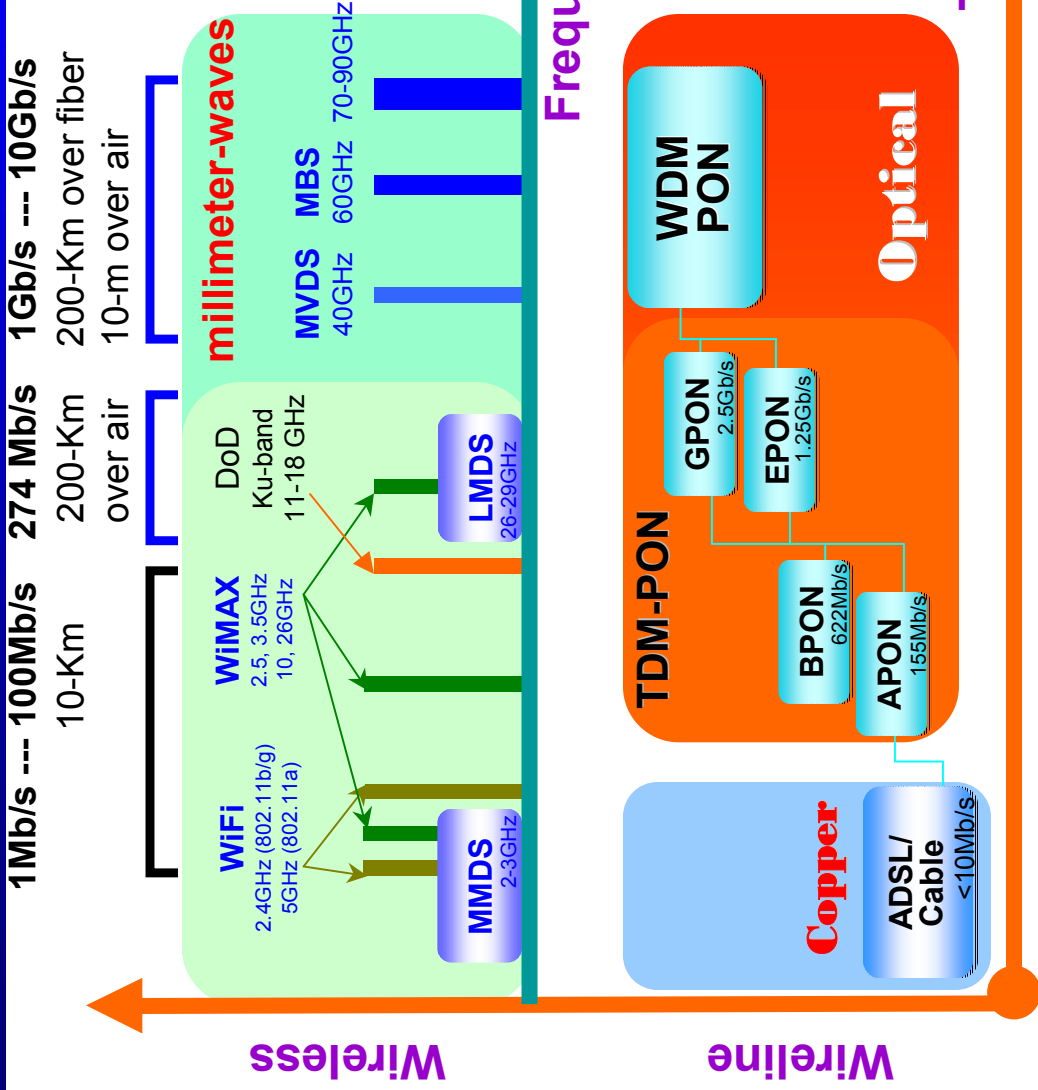
A license free band near 60GHz has up to 8 GHz antenna resonant bandwidth available for wireless communications.

It can provide super broadband wireless data and HD video links at > 1Gb/s.

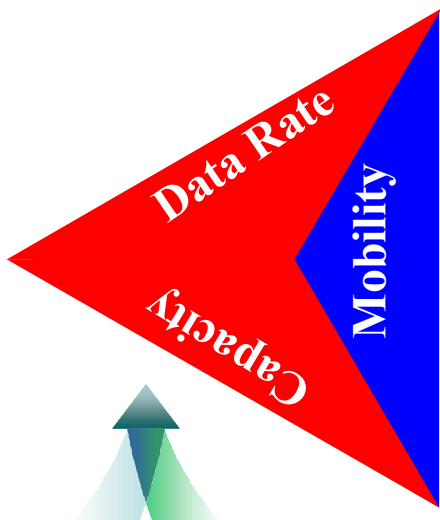
98% of Energy Absorbed by O₂ at 60GHz



Convergence of Broadband Access Networks



**Next Generation
Integrated
Optical Wireless
Systems**



MMDS: multichannel multipoint distribution service, LDMS: local multi-point distribution service
MVDS: microwave video distribution system, MBS: mobile broadband system

Impact of Radio over Fiber Systems

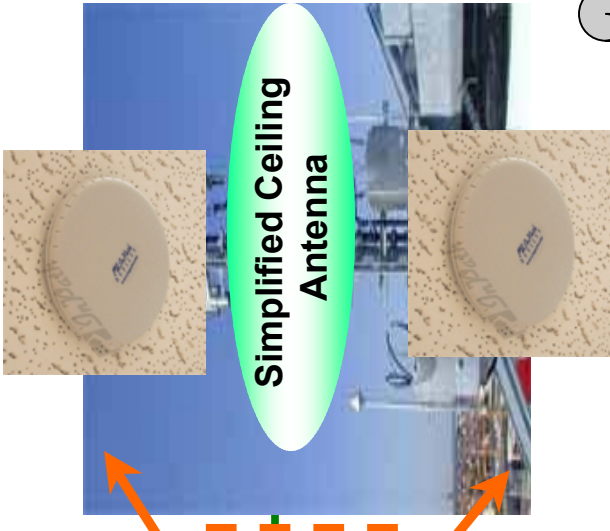
Current Radio Access

Huge Bandwidth, Low Attenuation
Immunity to RF Interference
Integration with WDM PON



Data
Center

- Multiplexing, switching
- Optical wireless signal Generation

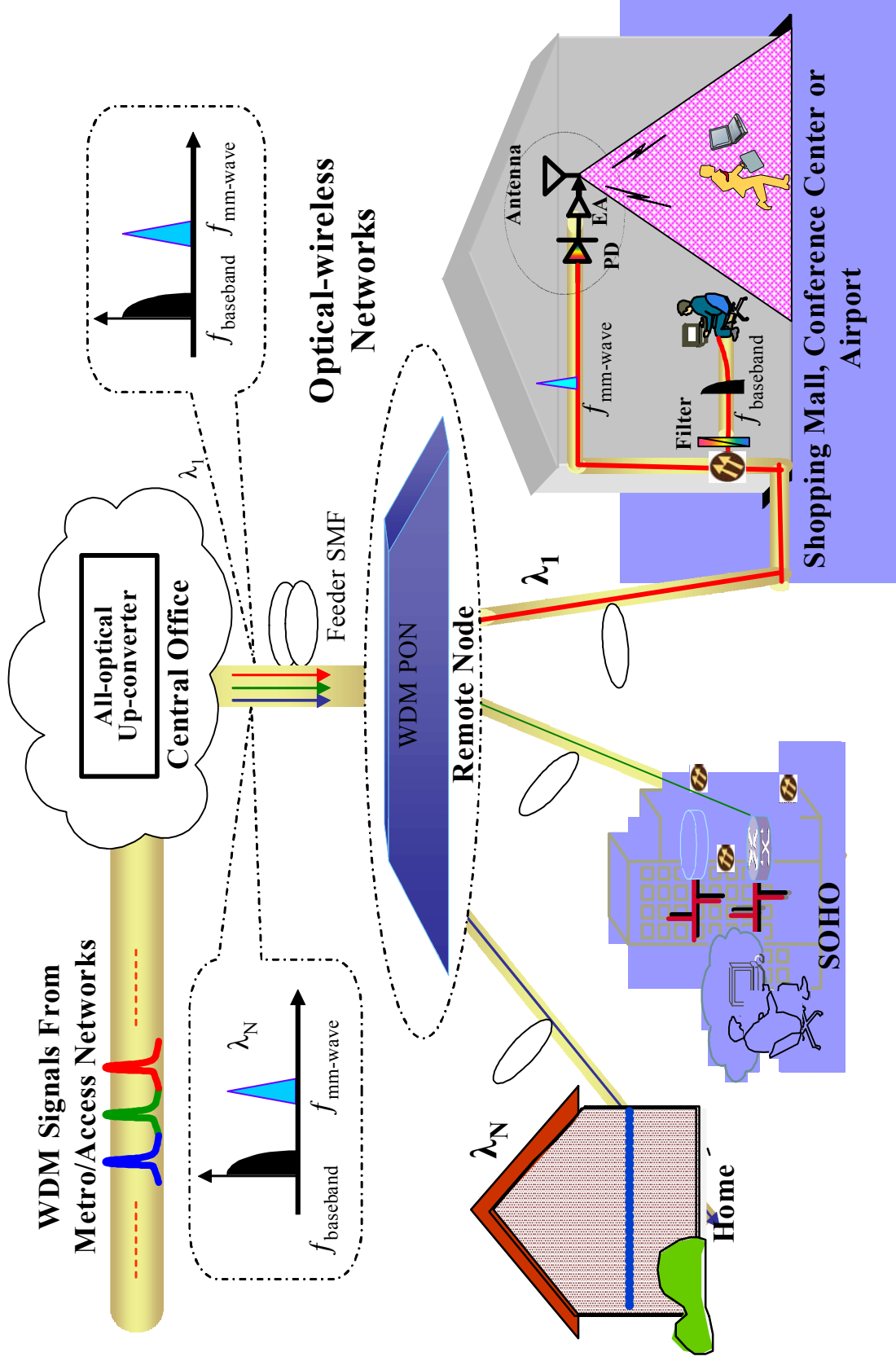


Simplified Ceiling
Antenna

Complex and expensive
equipment is kept at the
Shift the complex and expensive equipment to CS

- Up-conversion.
Modulation.
- Channelization.
Framing
- Amplification.

Optical Wireless Access Network Architecture

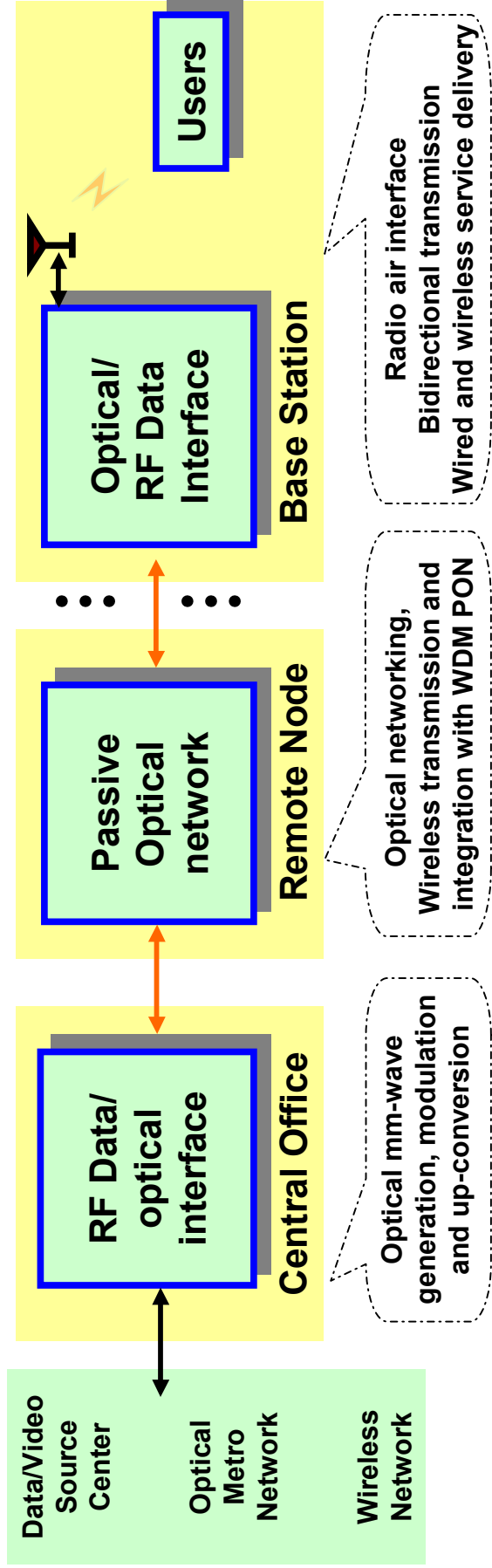


Optical Wireless Network Applications

Emerging applications requiring super broadband optical-wireless access:

- **HD wireless distribution**
- **Interactive multimedia games**
- **High-speed wireless (>1Gb/s) data access**
- **High mobility communications**
 - Base Station handoff
 - vehicle speed, bandwidth, and packet length

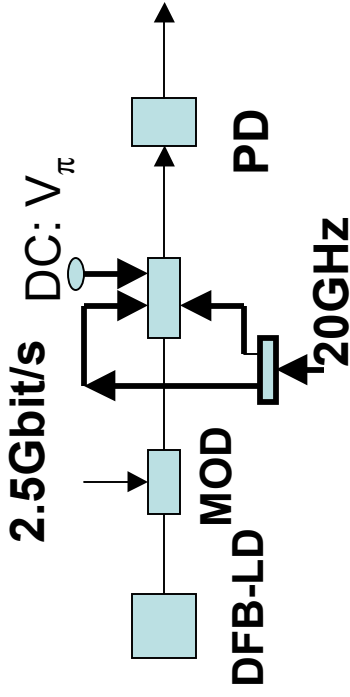
Wireless over Optical Access Network Technologies



- **Bandwidth**
 - >1 Gb/s for both directions
- **Mobility**
 - RF wireless for roaming connection

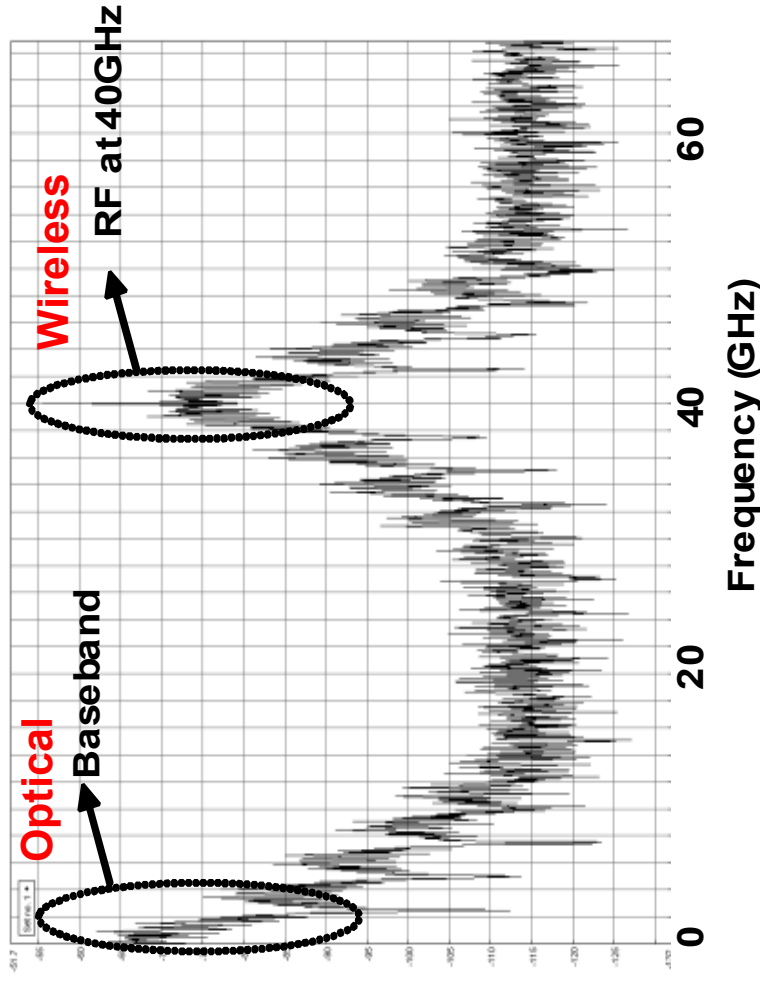
- **Coverage**
 - Optical fiber links for long distance
- **Multi-channel Capacity**
 - Seamless integration with WDM PON
 - All-optical methods for architecture design

Spectrum: Integrated Optical Wireless Signal

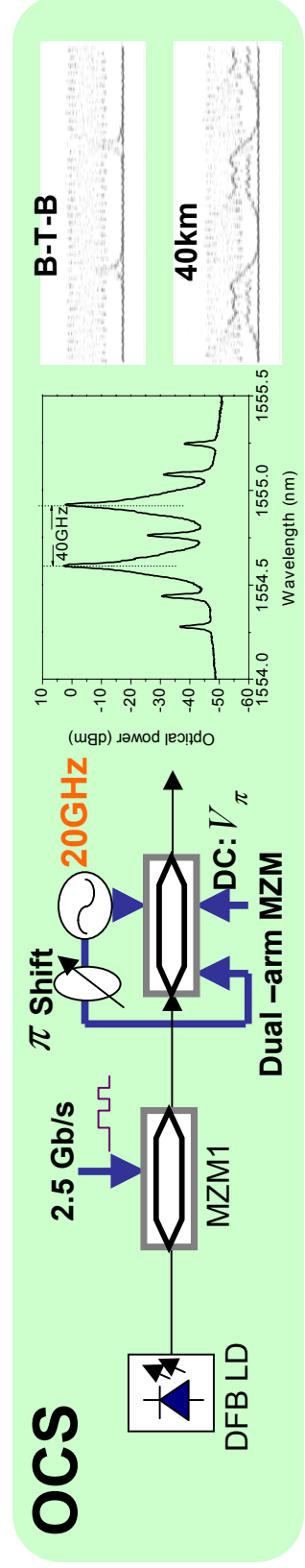
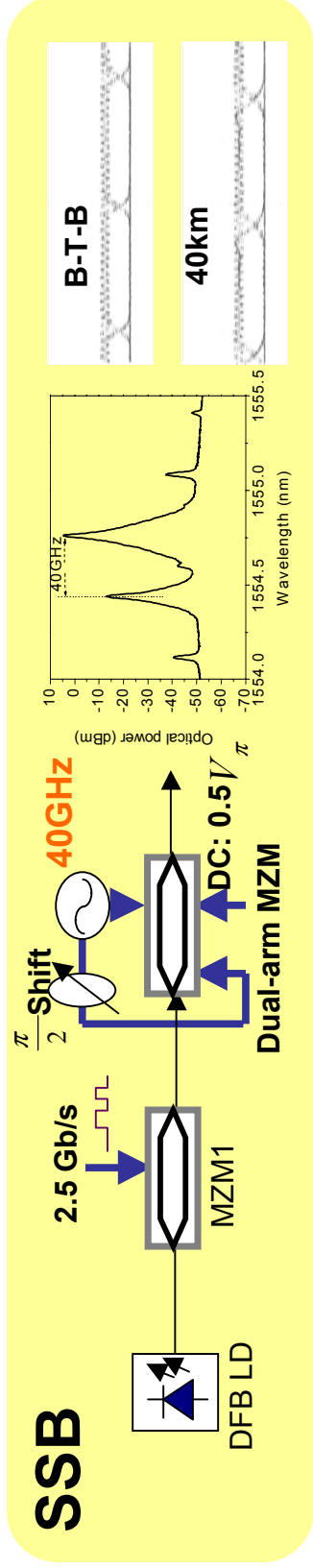
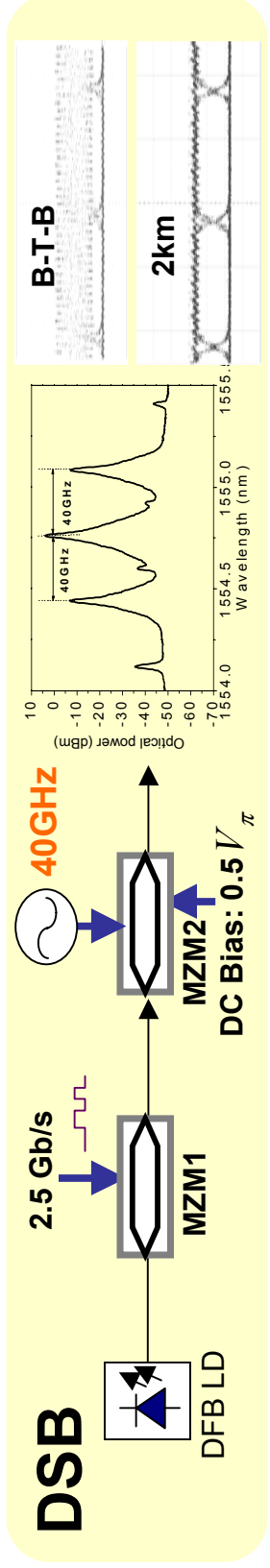


Dual Stage Modulation using
Optical carrier suppression

There are two components of electrical signals after all-optical up-conversion:
one part occupies the baseband,
the other occupies high-frequency band near 40 to 60GHz.

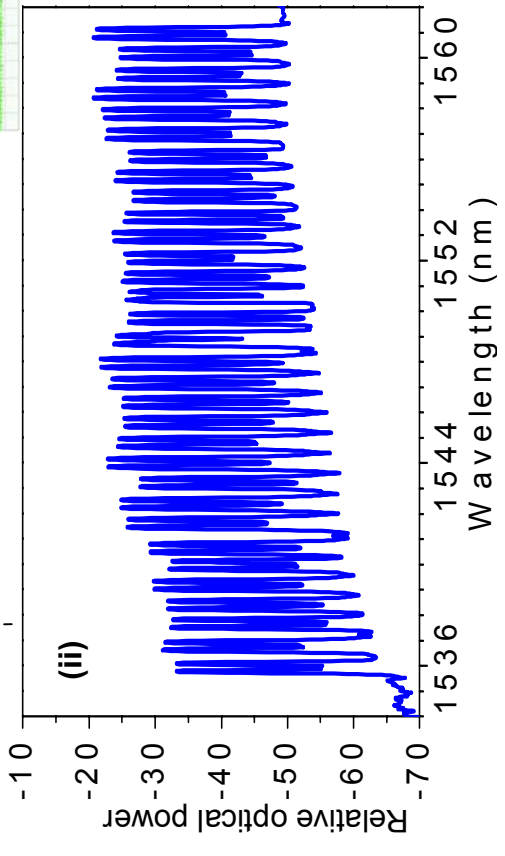
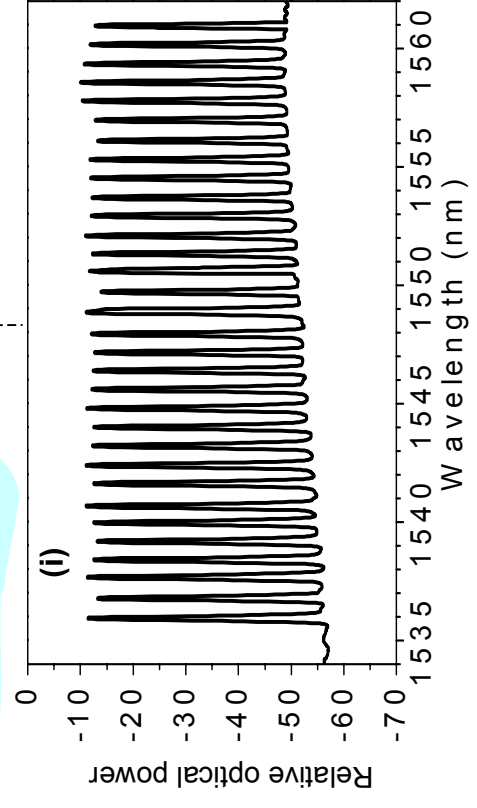
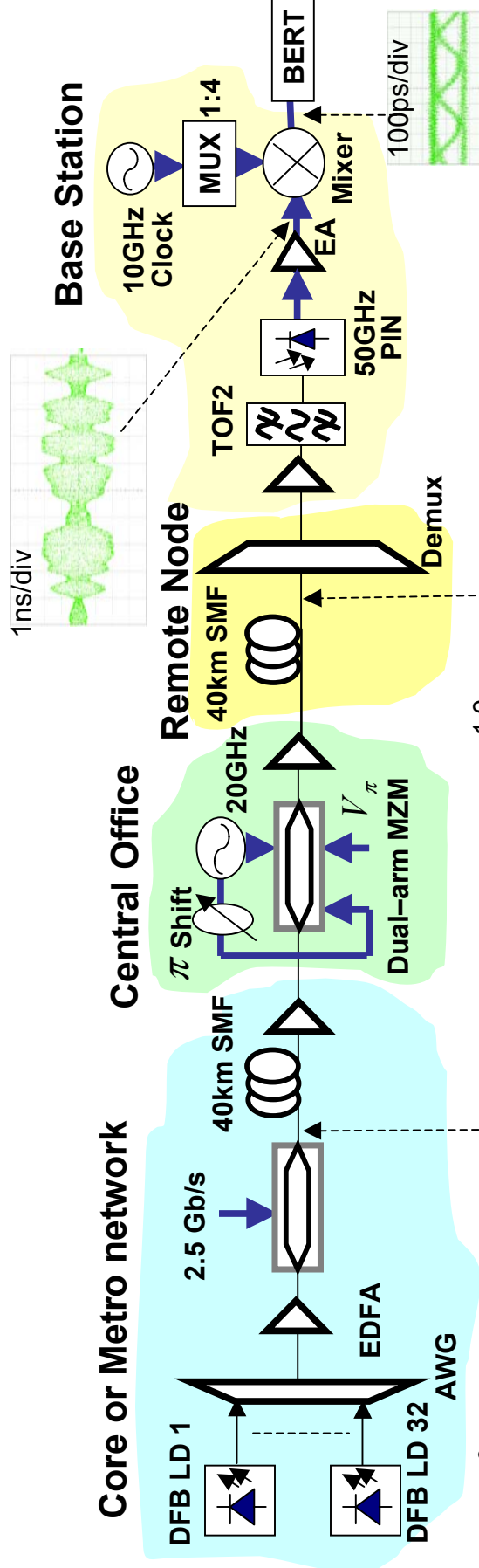


Signal Up-Conversion Based on External Modulation

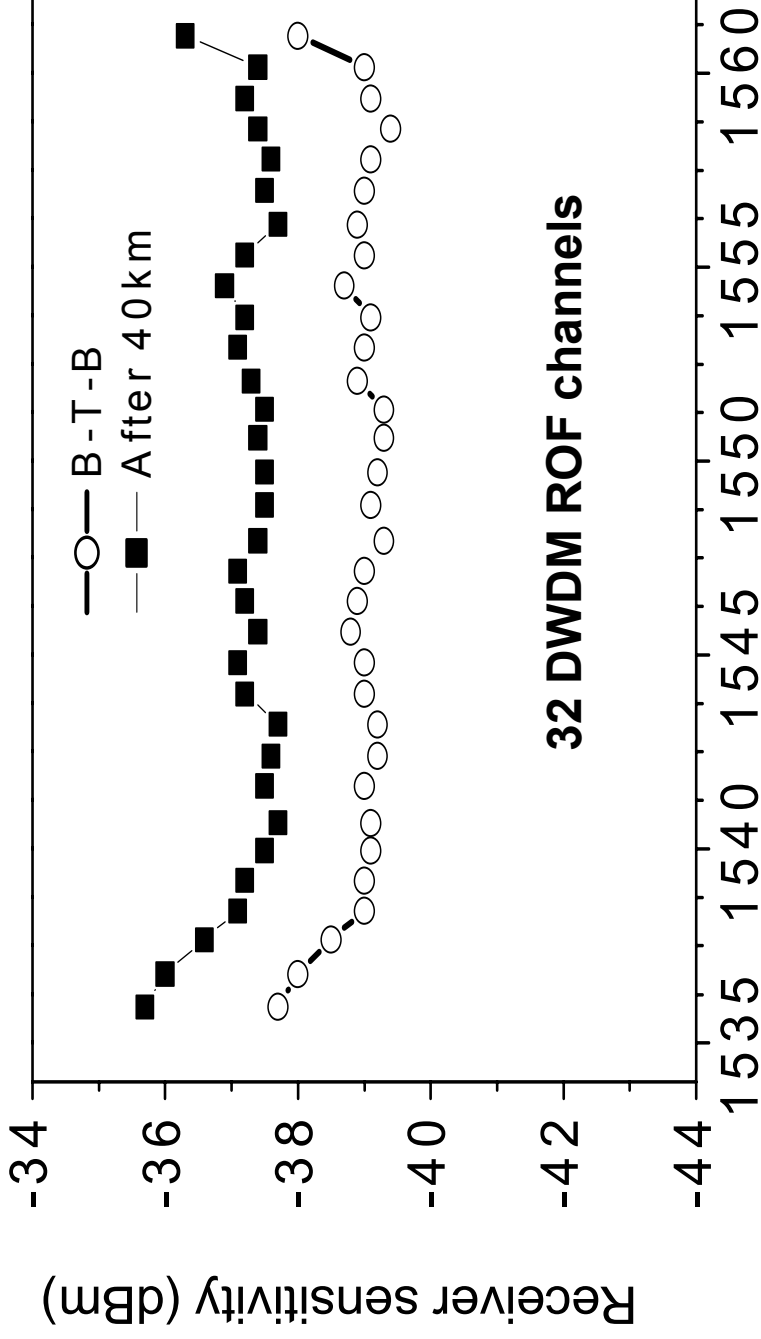


DSB: Double sideband; SSB: Single sideband; OCS: Optical carrier suppression

32-Channel DWDM ROF Transmission based on OCS external modulation



Transmission of 32-Channel ROF Signals



Wavelength (nm)

**Power penalty is less 2dB
for all channels.**

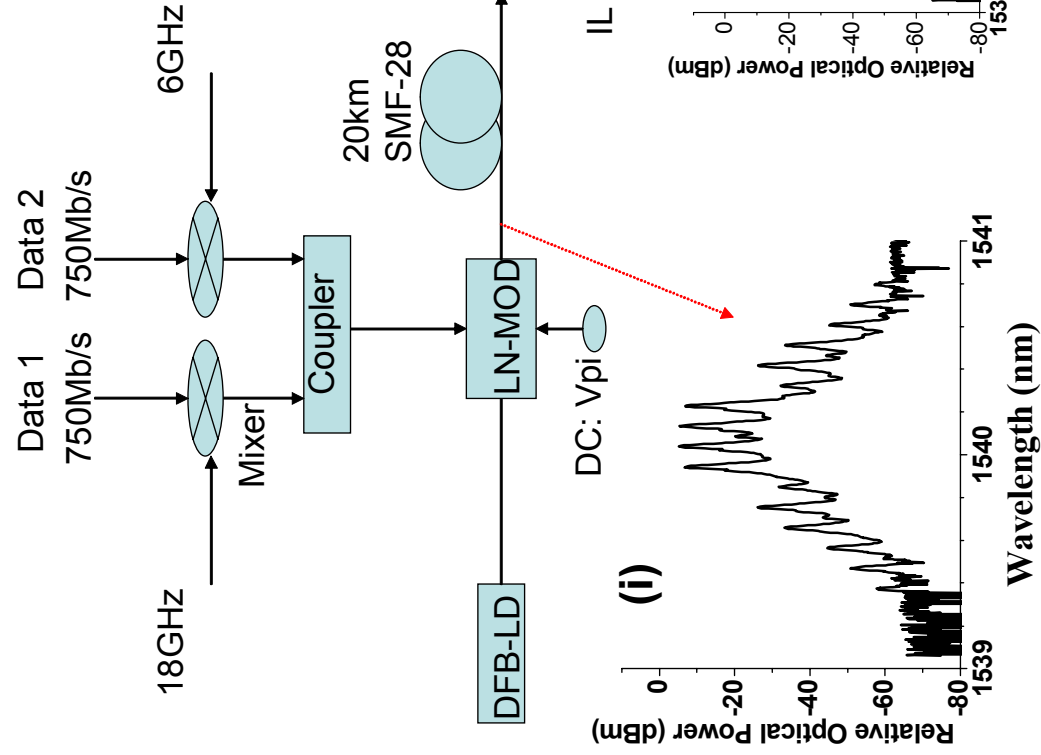
J. Yu, Z. Jia and G. K. Chang, ECOC 2005, Post Deadline, 2005, Th 4.5.4.

Key Technologies for RoF Signal Generation



Multiple Bands RF Signal Generation: Microwave and Millimeter-Wave

Multiband RF Signal Generation



Microwave

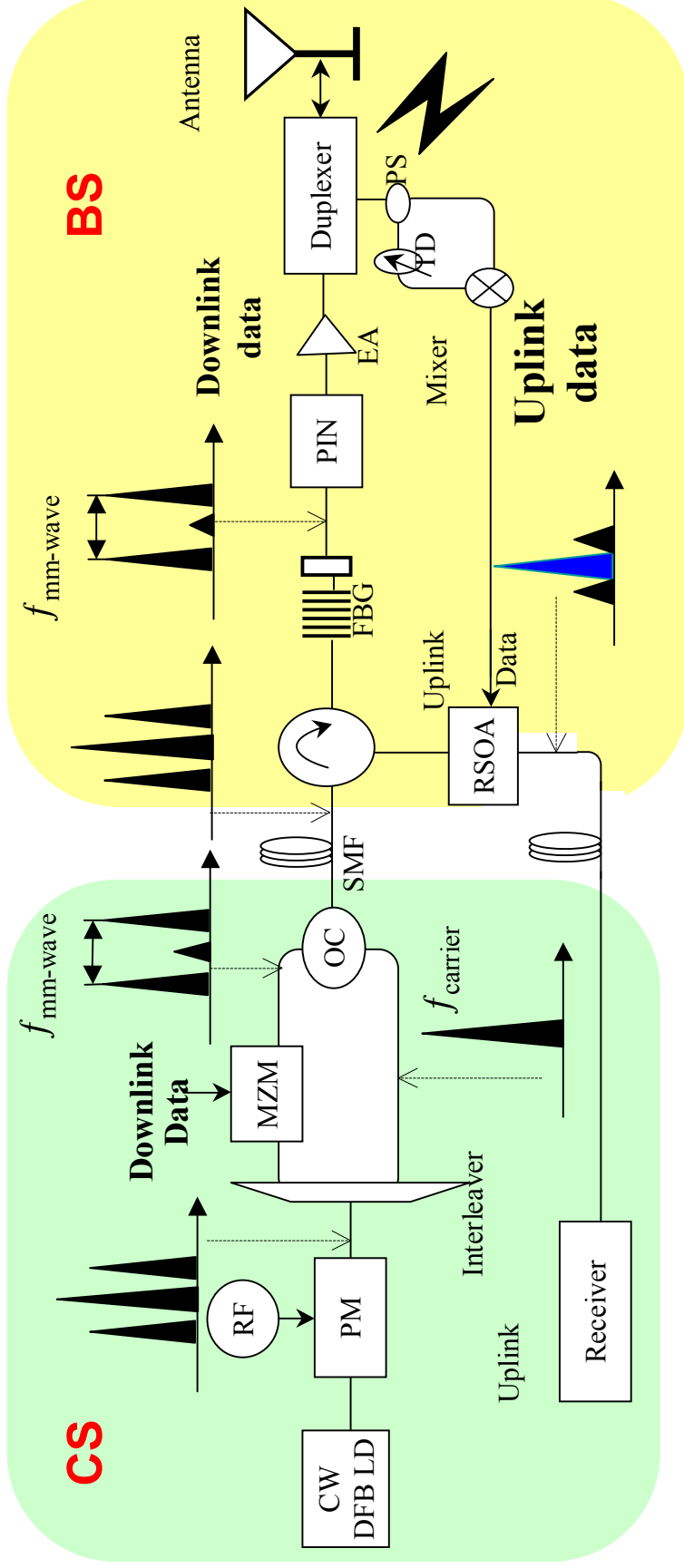
mm-wave

Optical Wireless Access Network Architecture Design



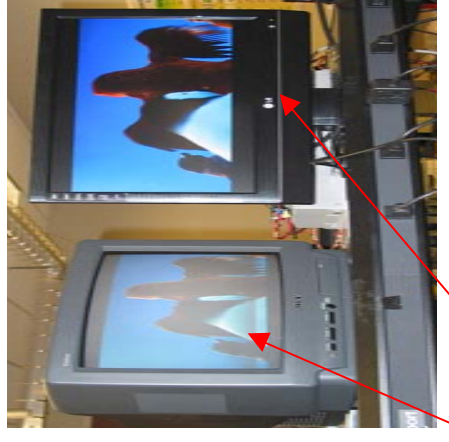
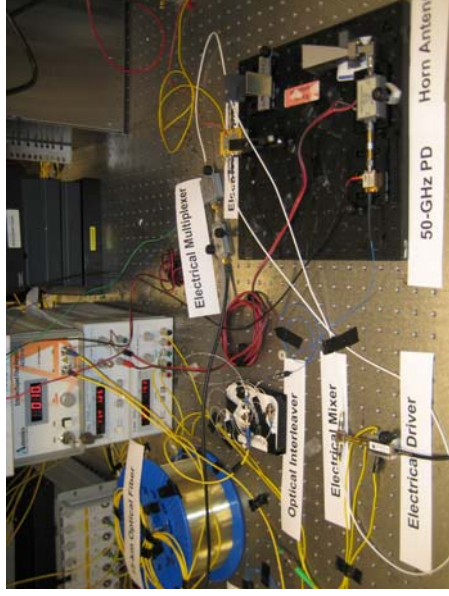
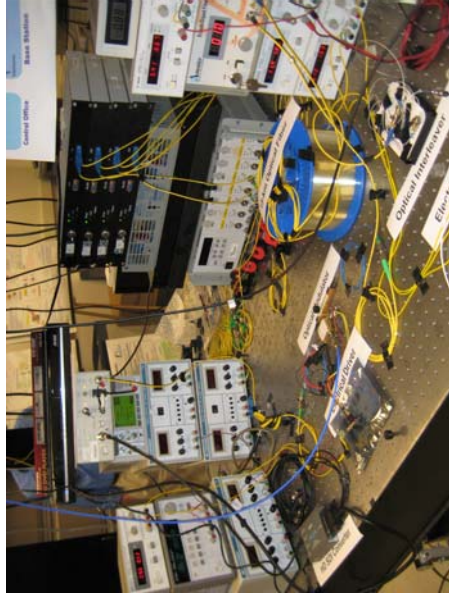
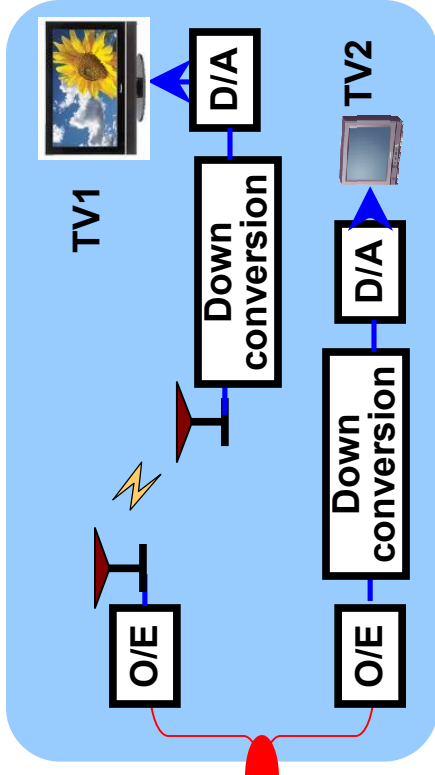
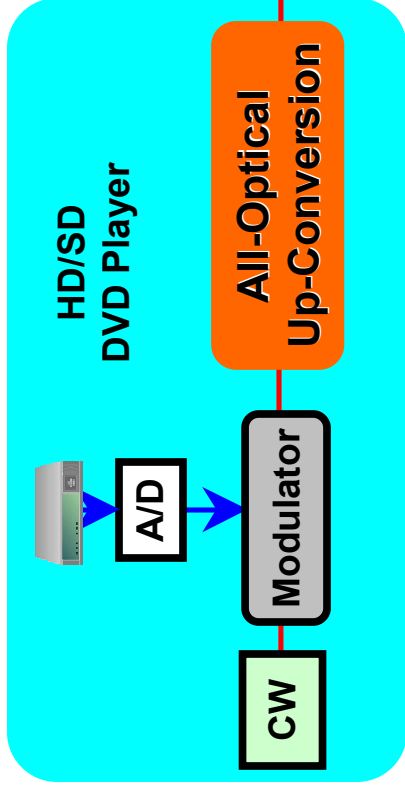
Full-Duplex Operation with Wavelength Reuse for Upstream Link

Full-Duplex Colorless Transport for Uplink



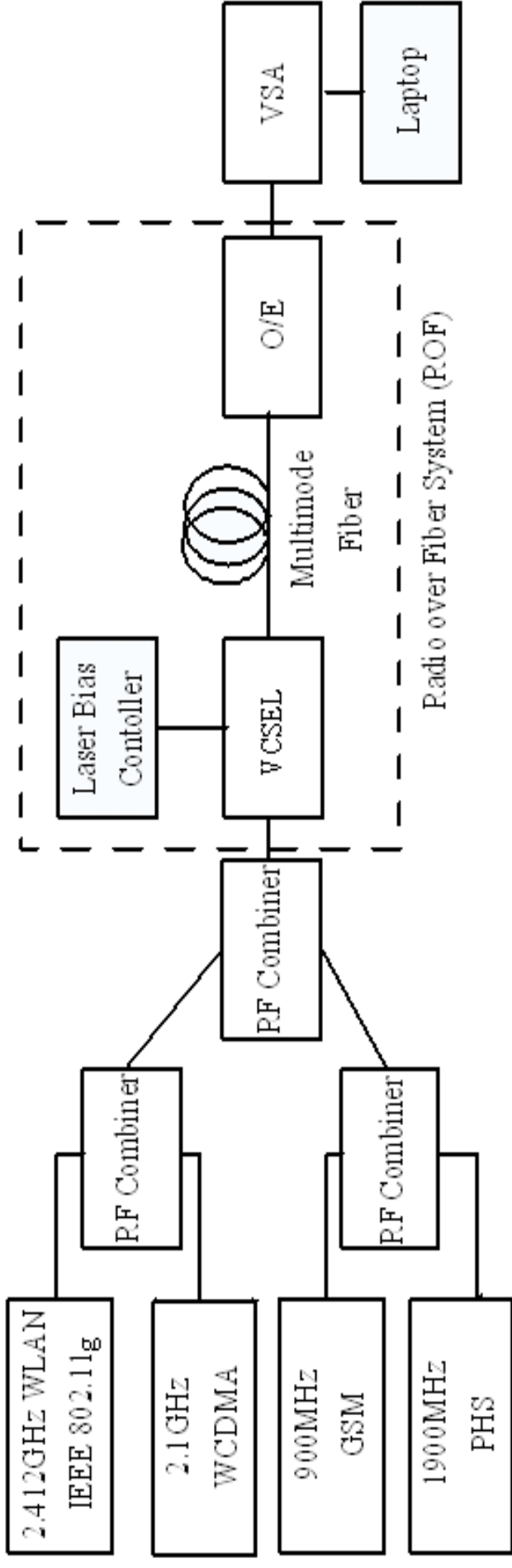
- At CS, Phase modulation and the subsequent interleaver for optical mm-wave generation.
- At BS, FBG is used to reflect the optical carrier while pass the downlink mm-wave signal.
- At BS, RSOA performs the function of both amplification and modulation.

Demonstration of Uncompressed SD/HDTV by Integrated Optical Wireless Systems



Uncompressed SDTV Signals (SMPTE 259M): 270 Mb/s
 Uncompressed HDTV Signals (SMPTE 292M): 1.485 Gb/s

Multi-Standards Wireless Transmission

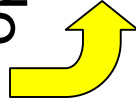


- Various wireless services can share common fiber infrastructure.
- A testbed setup at ASTAR-I²R consisting of four wireless standards were simultaneously transmitted to stress the ROF distribution network.
- 802.11g, WCDMA, GSM and PHS were combined electrically and distributed via 300m of MMF ROF system.

What's Coming Next?

Wireless over fiber systems using ROF technologies

operating in the 0.8-2.5GHz band have been demonstrated



- Moving from RF and microwave to mm-wave carriers for higher bandwidth services
- Moving from point-to-point links to point-to-multiple points access network architectures
- Moving from low mobility wireless over fiber systems to high speed moving trains and planes using FSO and fiber
- Facilitating new system integration and applications

Future Considerations and Challenges (1)

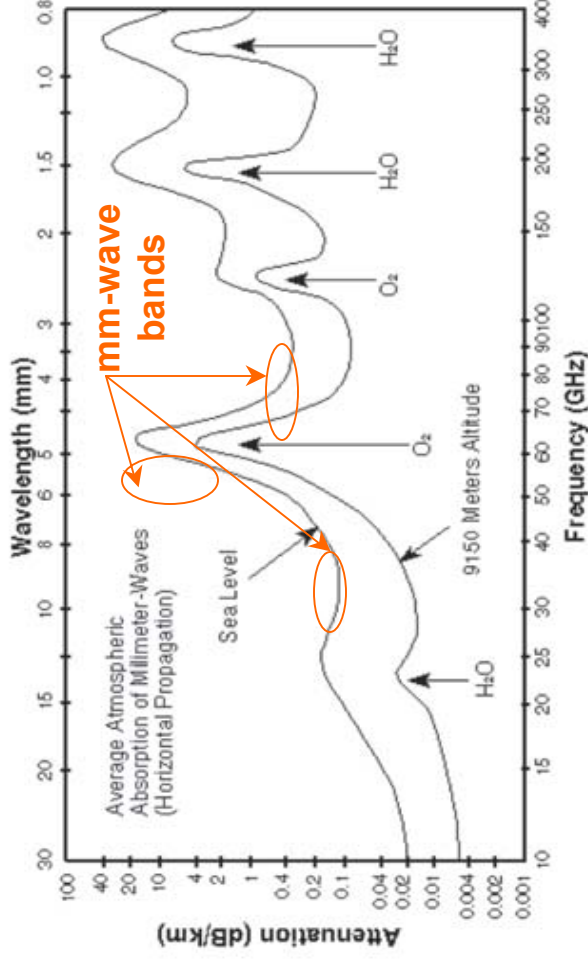


- **Optical technology**
 - **Improve efficiency, simplicity and stability of signal generation and up-conversion for the optical wireless systems;**
 - **Increase the wavelength utilization efficiency in full-duplex operation when integration with WDM PON;**
 - **Mitigating the optical mm-wave signals transmission impairment, particularly for the dispersion tolerance.**

Future Considerations and Challenges (2)

- **Electrical components and integration**
 - Low profile, high gain, high frequency antenna and mixer design;
 - 40GHz, 60GHz, 70 GHz and beyond optical millimeter carrier wave characteristics;
 - Improvement for wireless signals synchronization, interference and stability.

- **O/E and E/O Interfaces**
 - Requirement for power, noise, bandwidth and coding methods;
 - Media Access Control and Standardization issues.



Conclusions

- **Optical wireless signal generation and up-conversion techniques play key roles in realizing integrated optical wireless network.**
- **A novel architecture is developed for bidirectional optical wireless access network integrated with WDM-PON with wavelength reuse in base stations.**
 - **Demo of uncompressed SD/HDTV over both wireline and wireless links**
- **Technology challenges are ahead of us:**
 - **low-cost optical and RF components,**
 - **optical wireless system interface,**
 - **optical wireless protocols and standardization.**