Tera Hz Communications

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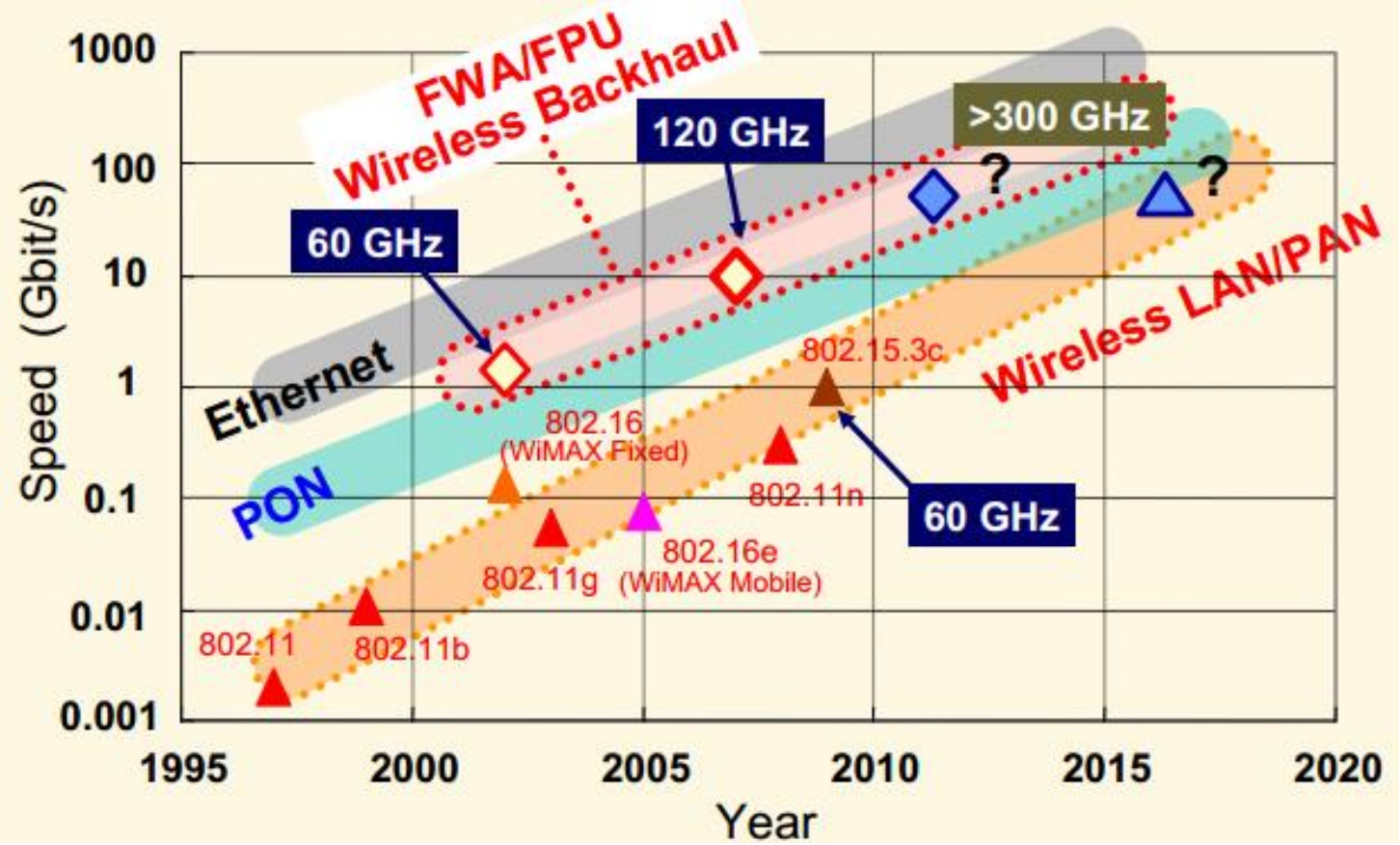
Outline

- Need for higher data rates.
- Introduction to THz.
- Challenges.
- Technology Overview.
- Sources/Detectors.
- Applications.
- Summary and Next Steps for THz Comm.

Evolution of data rates



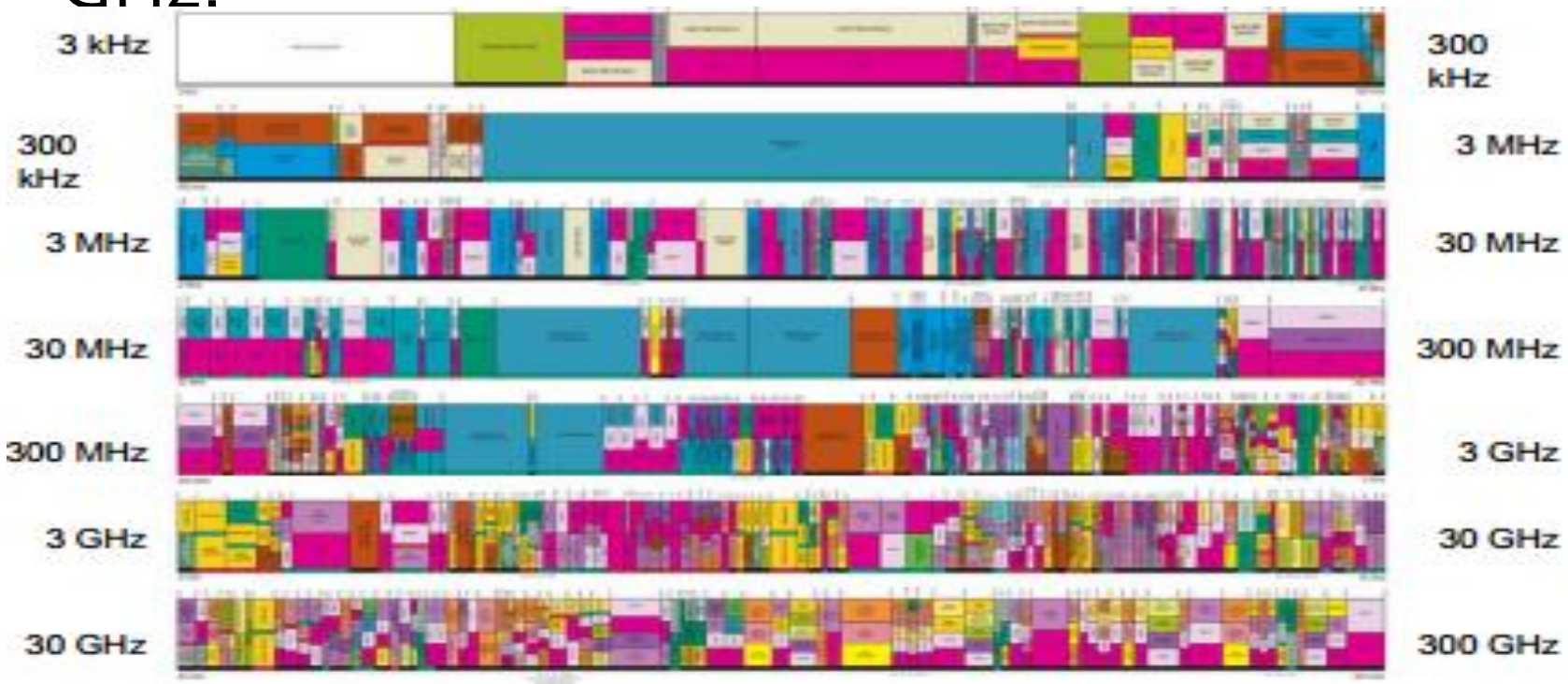
Source: Towards 100-Gb/s wireless using THz waves. March 2011

Need for higher data rates

- 60 GHz standards currently available offer data rates of 6 -7 Gbit/s.
- Assuming development observed in future we need wireless 100 Gbit/s around 2020.
- Higher channel bandwidths (25-100 GHz) needed to achieve this high data rates.

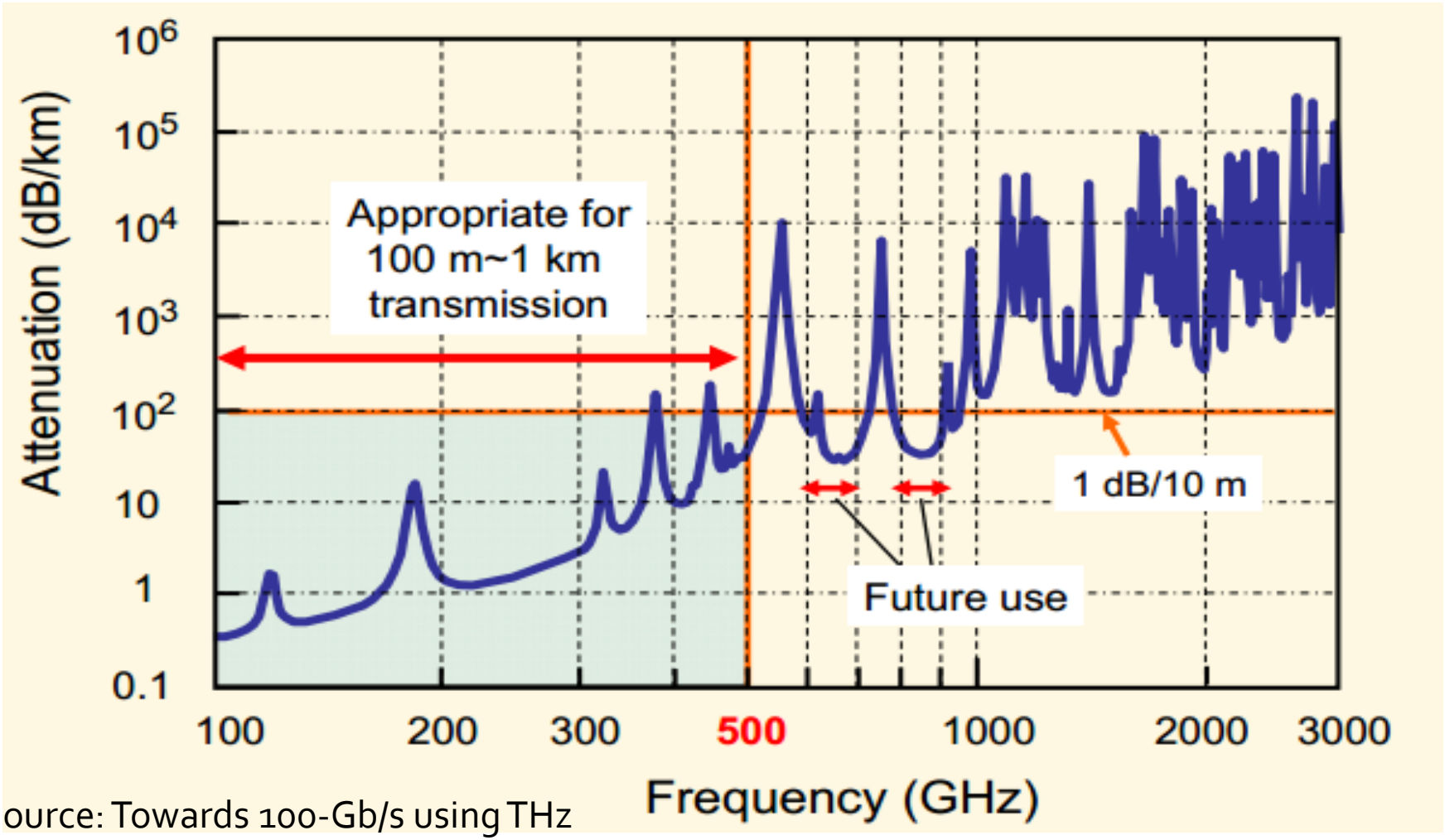
Why choosing THz frequencies ?

- Spectrum allocations by the ITU below 300 GHz:



- No free spectrum available below 300 GHz to achieve such high data rates.

Atmospheric Attenuation



Source: Towards 100-Gb/s using THz waves. March 2011

Channel Modeling

- Propagation attenuation

  Total path loss = free space loss + atmospheric attenuation.
- Challenge: Very high attenuation.
- Solutions

  1. Transmission in atmospheric windows.
  2. LOS connection with AWGN conditions.

Challenges in THz channel

- High free space loss and atmospheric attenuation.
- LOS or directed NLOS required.
- Shadowing by objects or persons.
- High reflection loss.
- THz waves are transparent for smoke and fog.

Challenges for prototype

- Propagation
  - High gain antennas to overcome high path loss.
- Technology
  - Optical or electro-optical generation/detection of THz signals.
  - Electronic devices with transit frequencies beyond 1THz.
- Transmission and Networking
  - Appropriate solutions for PHY and MAC layer need to be defined.

Antenna needed

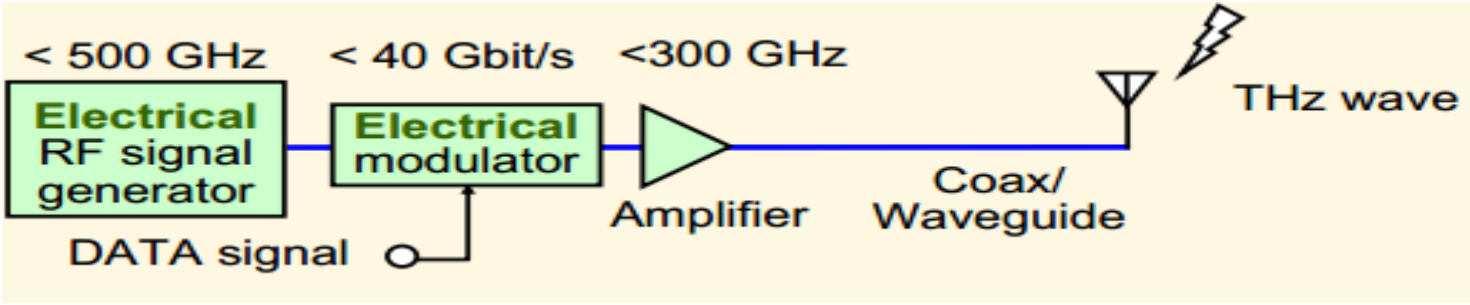
- Quarter wave antenna problem: At 300 GHz (1 mm wavelength) maximum Omni-directional antenna size is 250 microns.
- Antenna array for beam forming and beam switching.
- Wave shaping/steering capabilities of programmable Metamaterials.

Sources

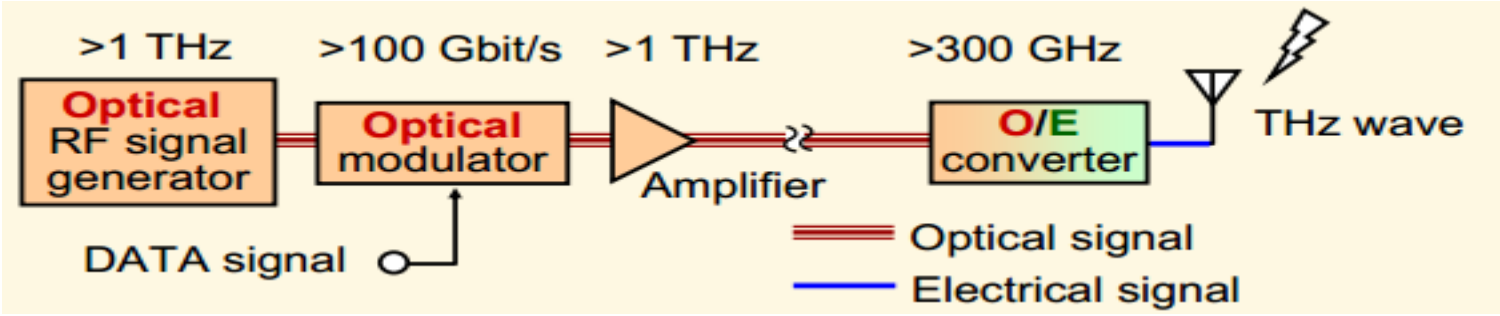
- Two main approaches for THz implementation
  - Optical approach
    - Challenge: lowering the operation frequency.
    - CO_2 Pumped laser, Terahertz pulse methods.
  - Electrical approach
    - Challenge: raising the operation frequency.
    - Gunn Diodes/Mixers.

Approaches: Electronics vs photonics

- Electronics based Tx

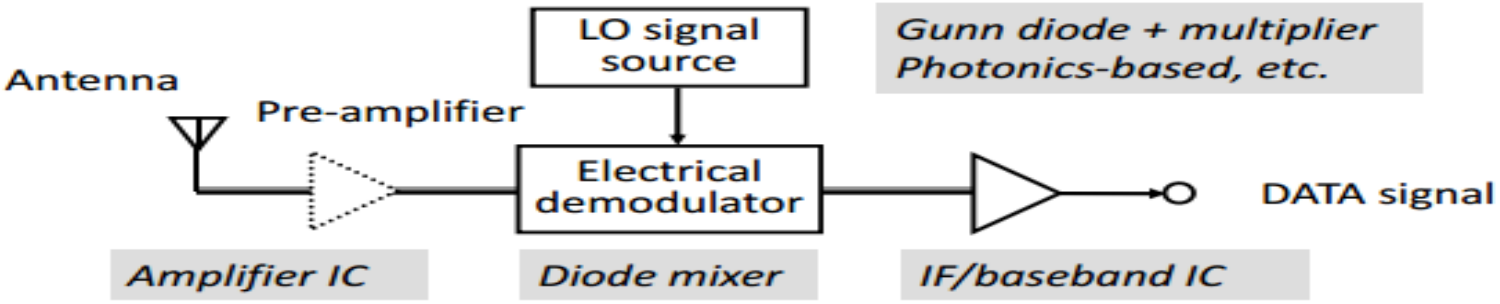


- Photonics based Tx

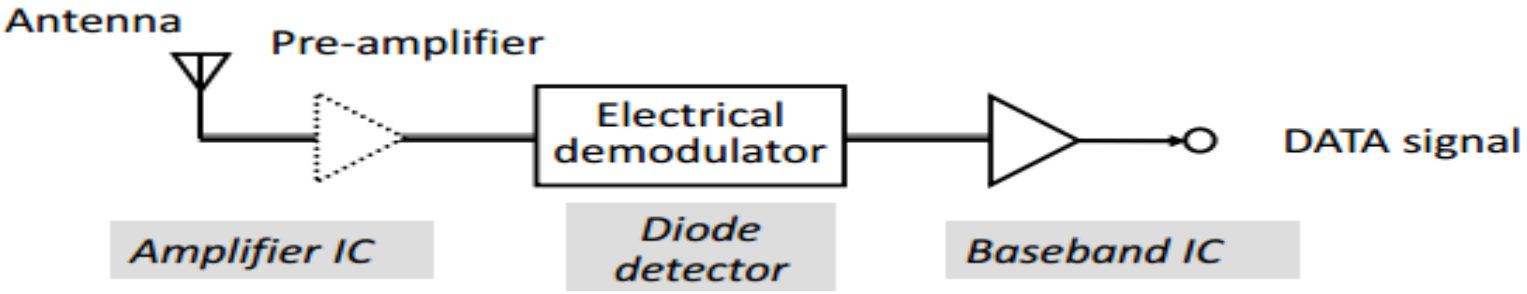


Rx: Technologies

- Heterodyne detection



- Direct detection



Source: Towards 100-Gbit/s Wireless Using Terahertz Waves, March 2010.

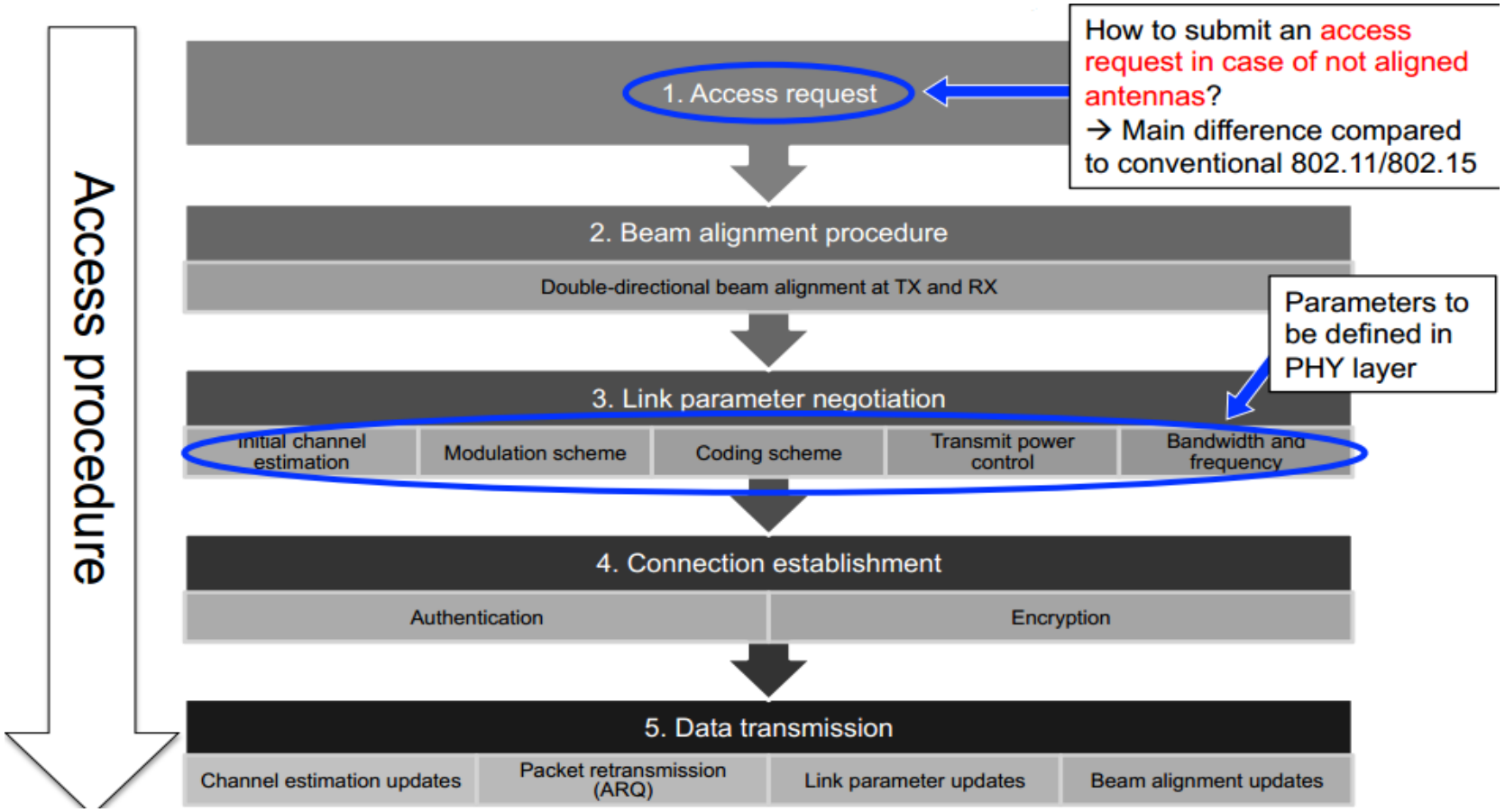
Gunn & Tunnett diodes

- High power but limited frequencies available.
- Multipliers need to be used for extending band.
- Handling heat and power is a problem.
- Semiconductor, electrical devices attractive but not very developed for practical use.

Photonics Sources

- Quantum Cascade Laser
  - High output power
  - Require sophisticated fabrication process.
  - Low temperature operation
- p-Germanium laser
  - 10-100 μW power.
  - 1.0 – 5 THz tuning range.
  - A cryogenic installation requiring super conducting magnet.

MAC layer functions



Source: MAC layer concepts in THz, EPFL, FEB 11-13, 2013

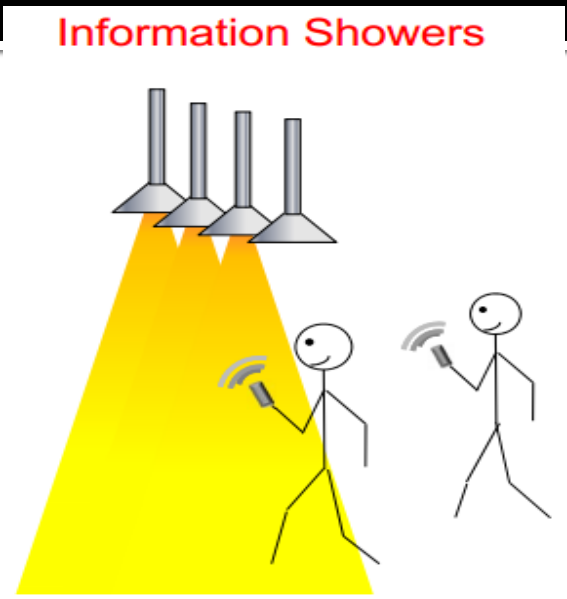
Latest Results

Carrier Frequency	Technology		Max. Bit rate (Error free)	Affiliation
	Tx	Rx		
120 GHz	Photonics-based	MMIC(InP) (direct det.)	10 Gbit/s	NTT
120 GHz	MMIC(InP)	MMIC(InP) (direct det.)	20 Gbit/s (with pol.MUX)	NTT
300~400GHz	Photonics-based	Disc. comp. (direct det.)	24 Gbit/s	Osaka-U NTT

- 100 Gb/s reported, but not error free (FEC was used with other signal processing).
- MAC layer concepts for THz communication are being studied.

Source: Tera Hertz: New opportunities for industry, EPFL , FEB 11-13, 2013

Applications



- Kiosk Downloading.
- Next Gen WLAN/WPAN.
- THz nano cells for mobile NW.
- THz imaging for explosives detection.
- Fixed Wireless access using highly directive antennas.

Summary and Next Steps

- Recent advancements in technology show wireless communications @ carrier frequencies beyond 300GhZ possible.
- Development of better sources, modulators and detectors needed.
- Communications standard initiatives begun (802.15 IG THz).

THANK YOU