Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Feasibility test of THz channel for high-speed wireless link
Date Submitted: 12 Nov 2013
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Abstract: For high speed wireless communication, a feasibility test of THz channel has been presented. Previously, we presented preliminary experiment results for 300 GHz wireless link (doc. IEEE 802.15-15-10-0845-00-0thz, Nov. 2010). In this contribution, we provide recent progress based on THz photonics and MMIC technologies for higher throughput.

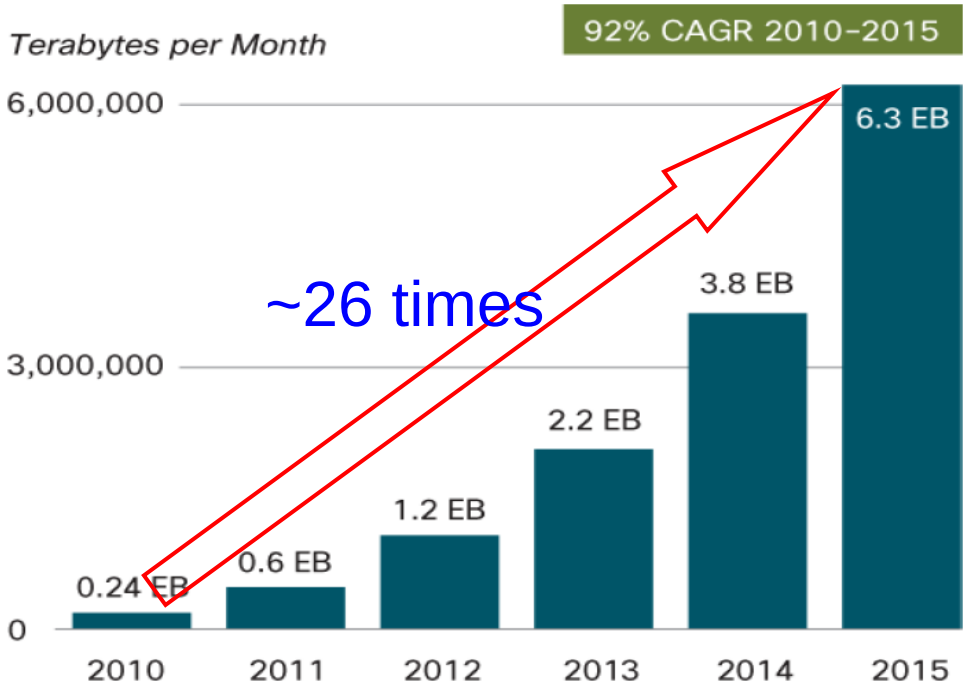
Purpose: for discussion

Feasibility test of THz channel for high-speed wireless link

Increasing Mobile Traffic

- Increasing of digital information and changing from Wire to Wireless

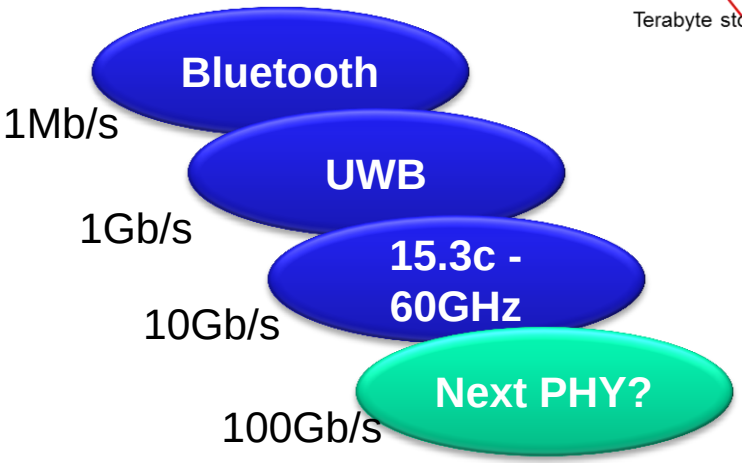
Figure 1. Cisco Forecasts 6.3 Exabytes per Month of Mobile Data Traffic by 2015

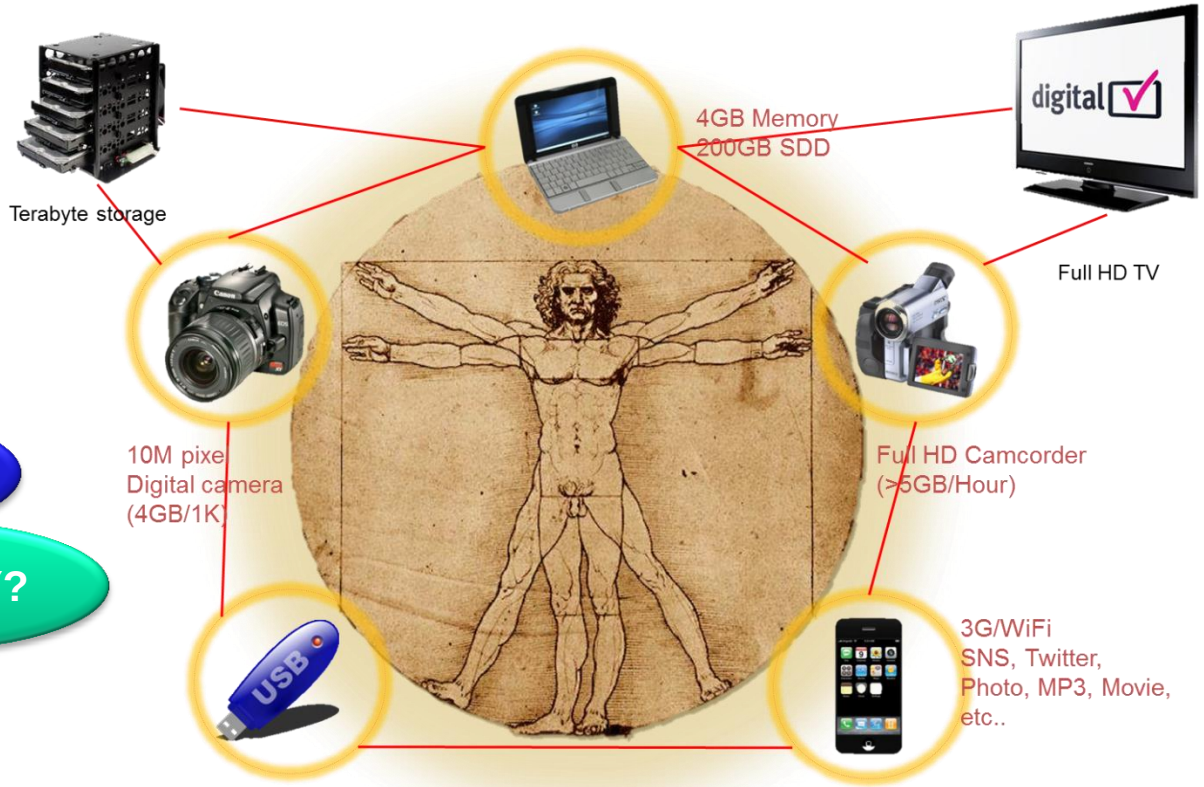


Source: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010–2015

WPAN in Future

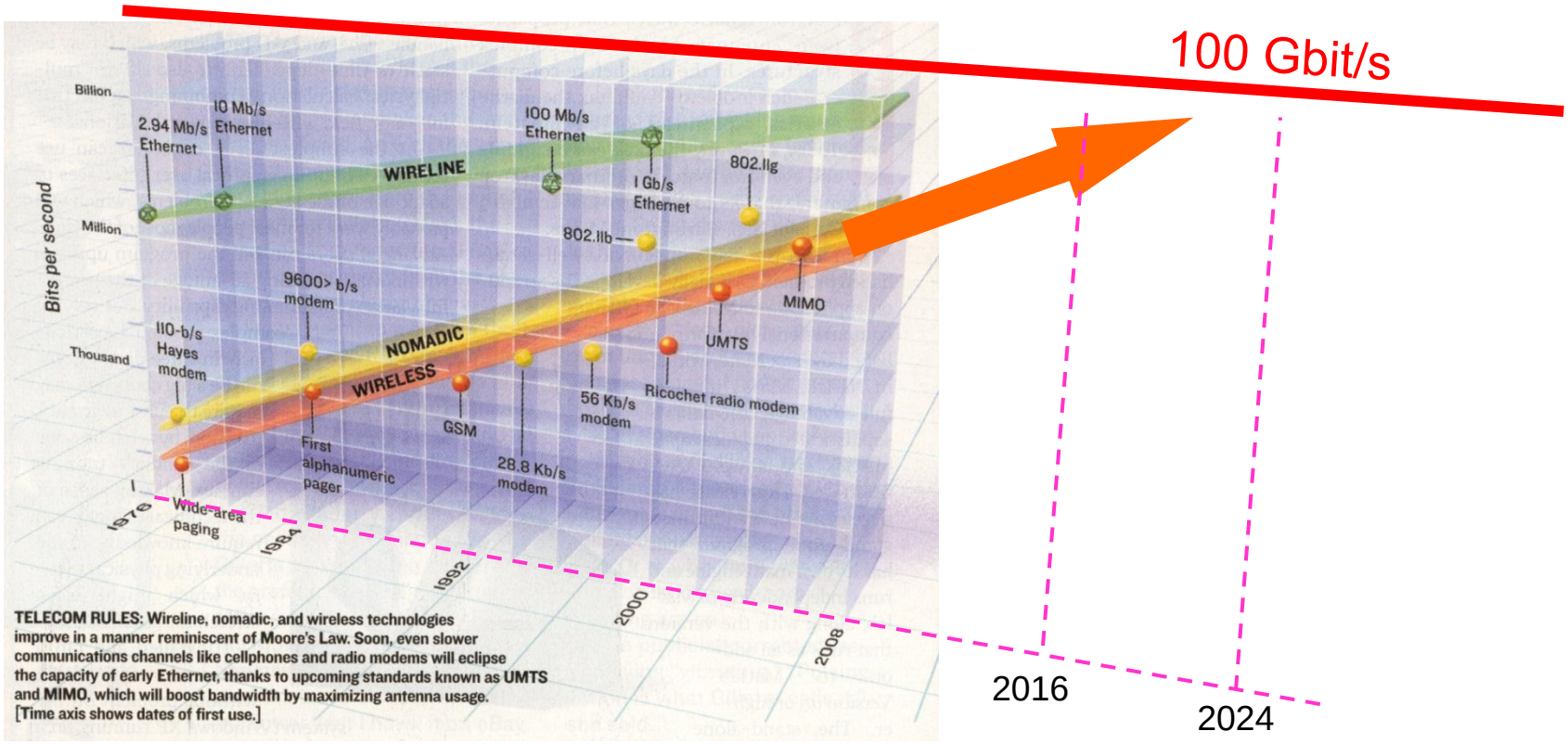
- WPAN exist for close wireless connections of electronics
- Advance of electronics requires faster connection





Fast how much?

- Wireless throughput is rapidly increasing
- 100Gbit/s is a milestone for next generation wireless connection



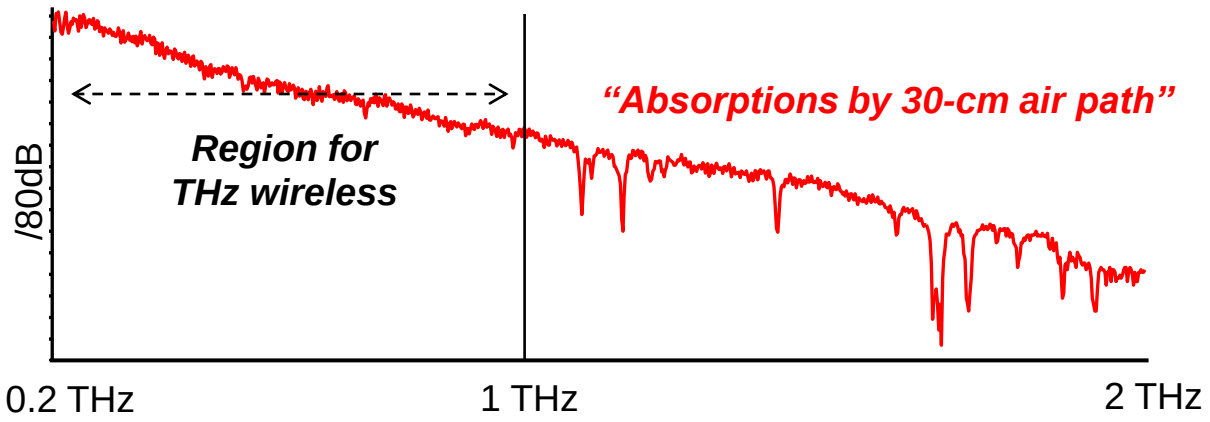
Channels for100Gbit/s (SG100G)

- Potential technologies in mmW, THz and IR for *100Gbit/s*

	mmW (60GHz)	THz (0.3-1THz)	Infrared
Channel BW	7 GHz	40-100GHz	∞
for 100Gbit/s	4ch 16QAM-OFDM	16QAM to QPSK	ASK
Issue	Channel BW	Device / IC tech.	Channel Obstacles

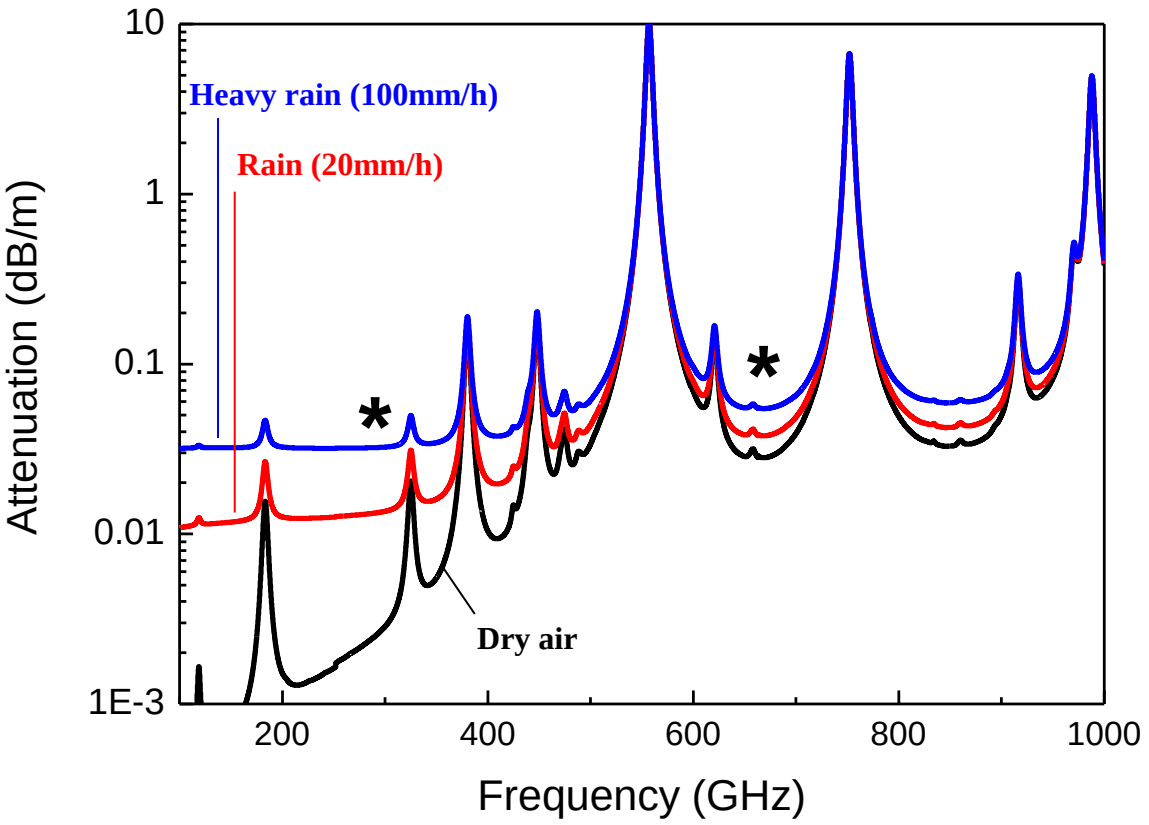
THz channel

: Technology limitation than channel availability



THz channels for wireless

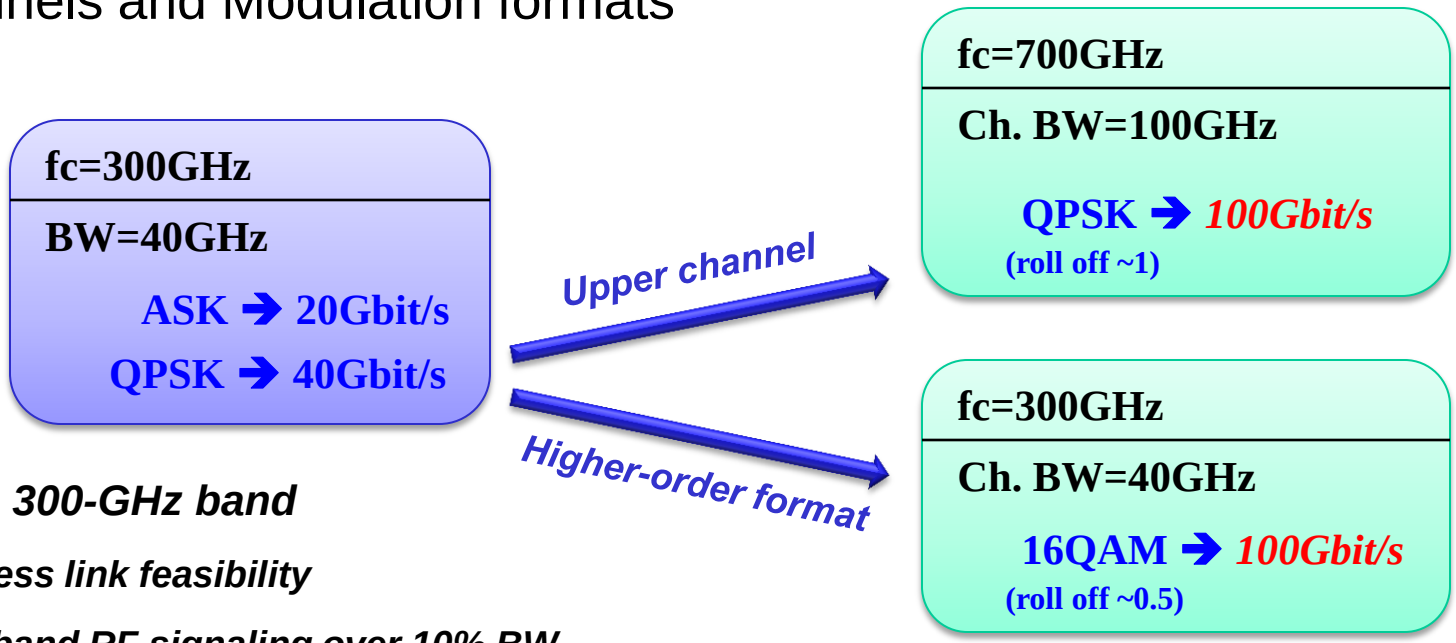
- Several frequency windows having attenuation less than 1 dB/m



Bands (GHz)	BW
185-315	130 GHz
275-315	40 GHz
330-365	35 GHz
390-435	45 GHz
450-515	65 GHz
625-725	100 GHz
790-900	110 GHz
925-950	25 GHz

Is it possible?

- Feasibility test of THz channel → Trial of IC availability
- Channels and Modulation formats



Tests @ 300-GHz band

Wireless link feasibility

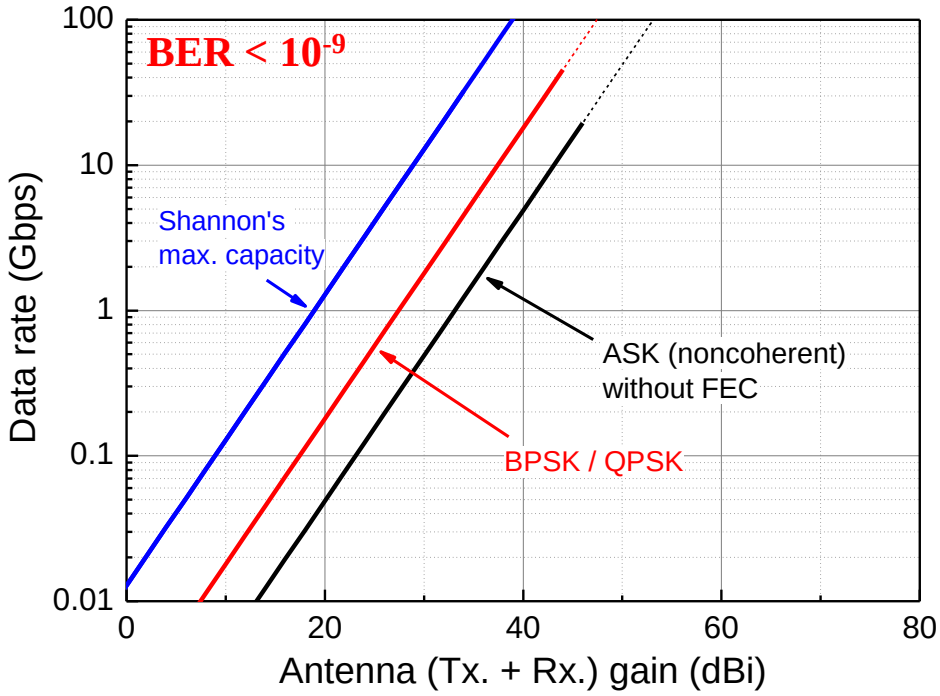
Wideband RF signaling over 10% BW

PSK modulation / demodulation

Wireless link budget @ 300 GHz

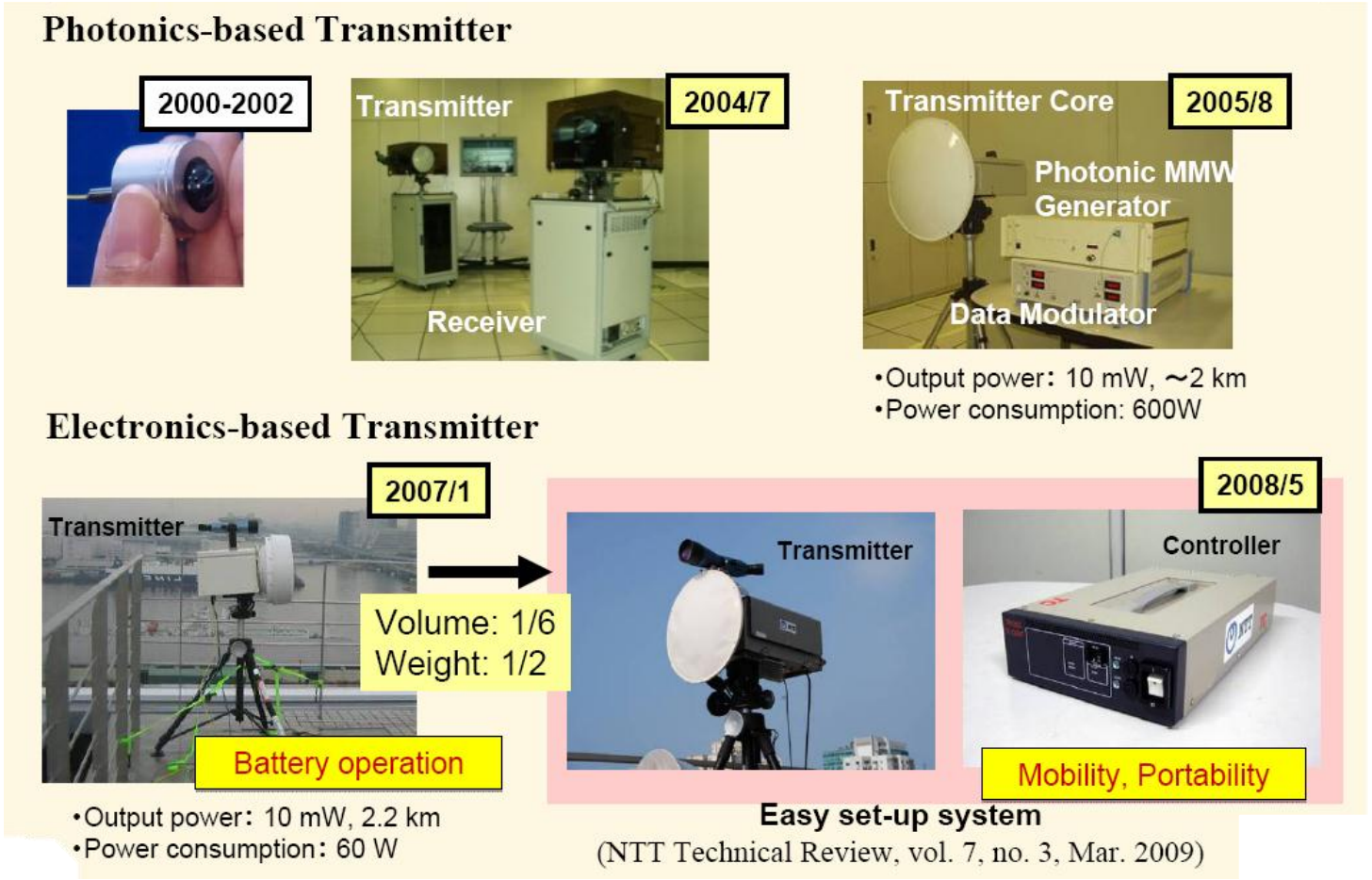
- ~45-dBi antenna gain enables 20Gb/s ASK or 40Gb/s PSK link

Quantity	Symbol	Value
Transmitting power	P_t	**10 dBm**
Carrier frequency	f_c	**300 GHz**
Wavelength	λ_c	1 mm
Distance	d	1 meter
Atmospheric attenuation	α_a	0.01 dB/m @ f_c
Excess loss	L_{ex}	0 dB
Noise spectral density	N_0	-178 dBm/Hz
Spectral efficiency		1 bps/Hz
Noise bandwidth	B	Data rate × spectral efficiency
Total noise figure	NF	**15 dB**
System margin	M	**10 dB**



Feasibility test

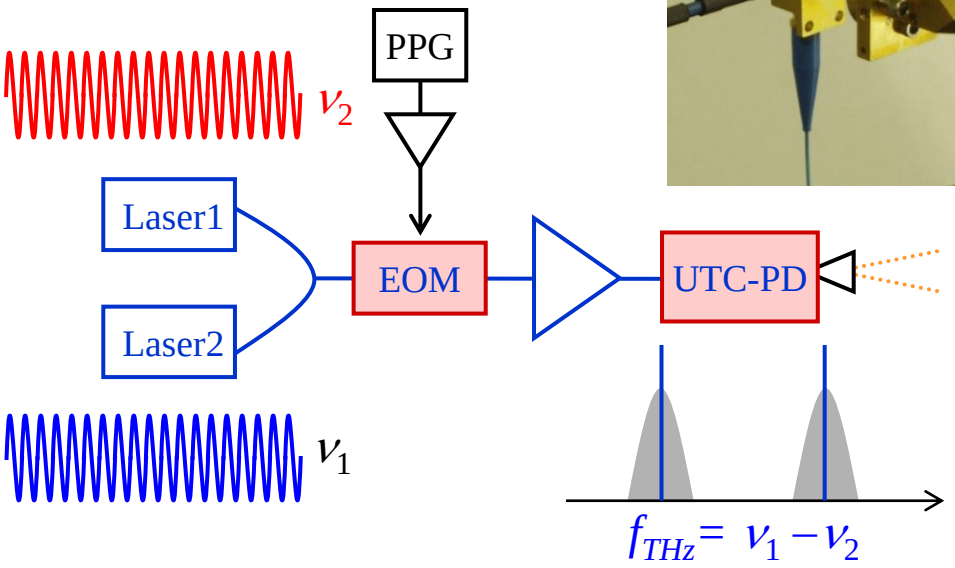
- Photonic technology : a good tool for feasibility test

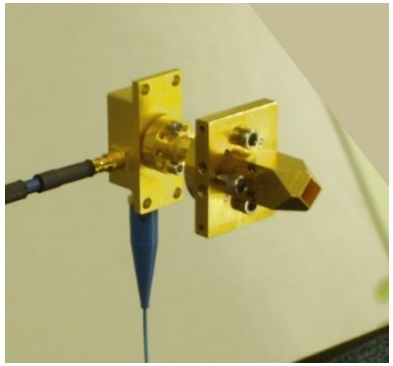


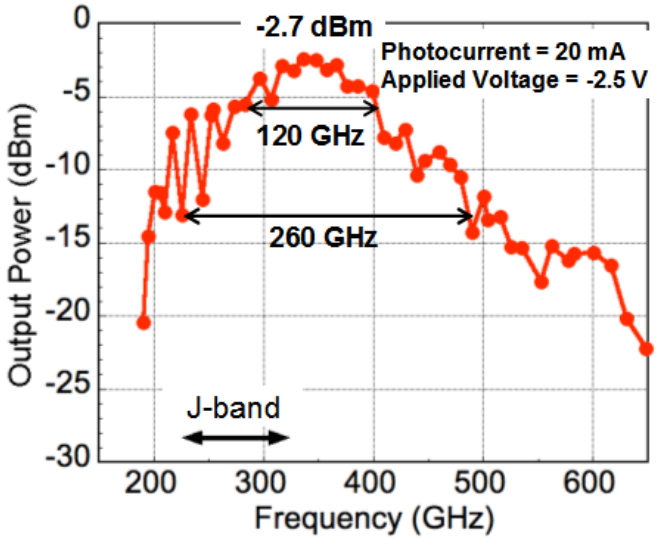
Photonic-THz transmitter

- Simple THz-wave generation and broadband modulation
- UTC-PD output of max. -3dBm @ 350 GHz and -20dBm @ 1 THz

"optical heterodyning"

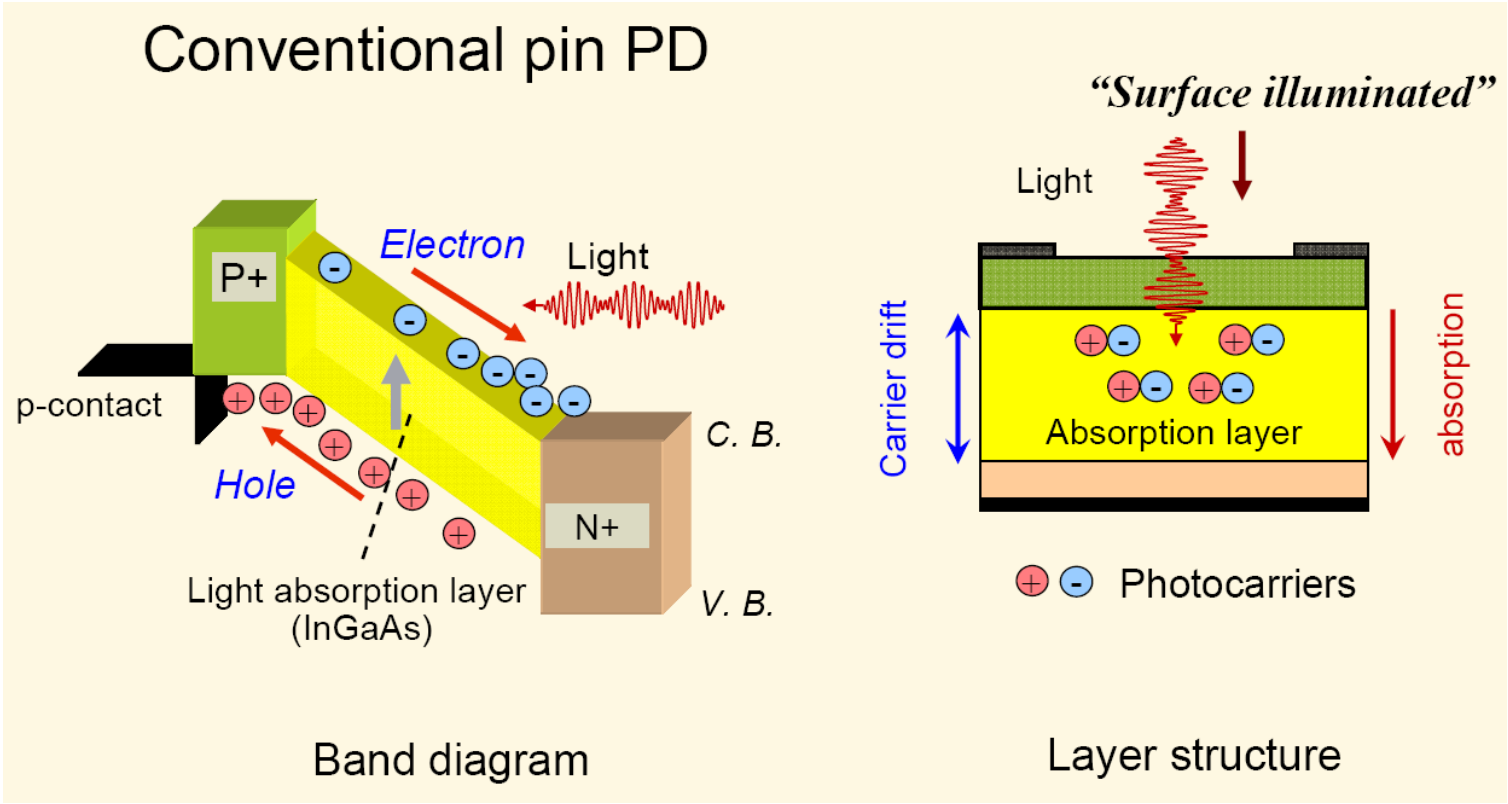






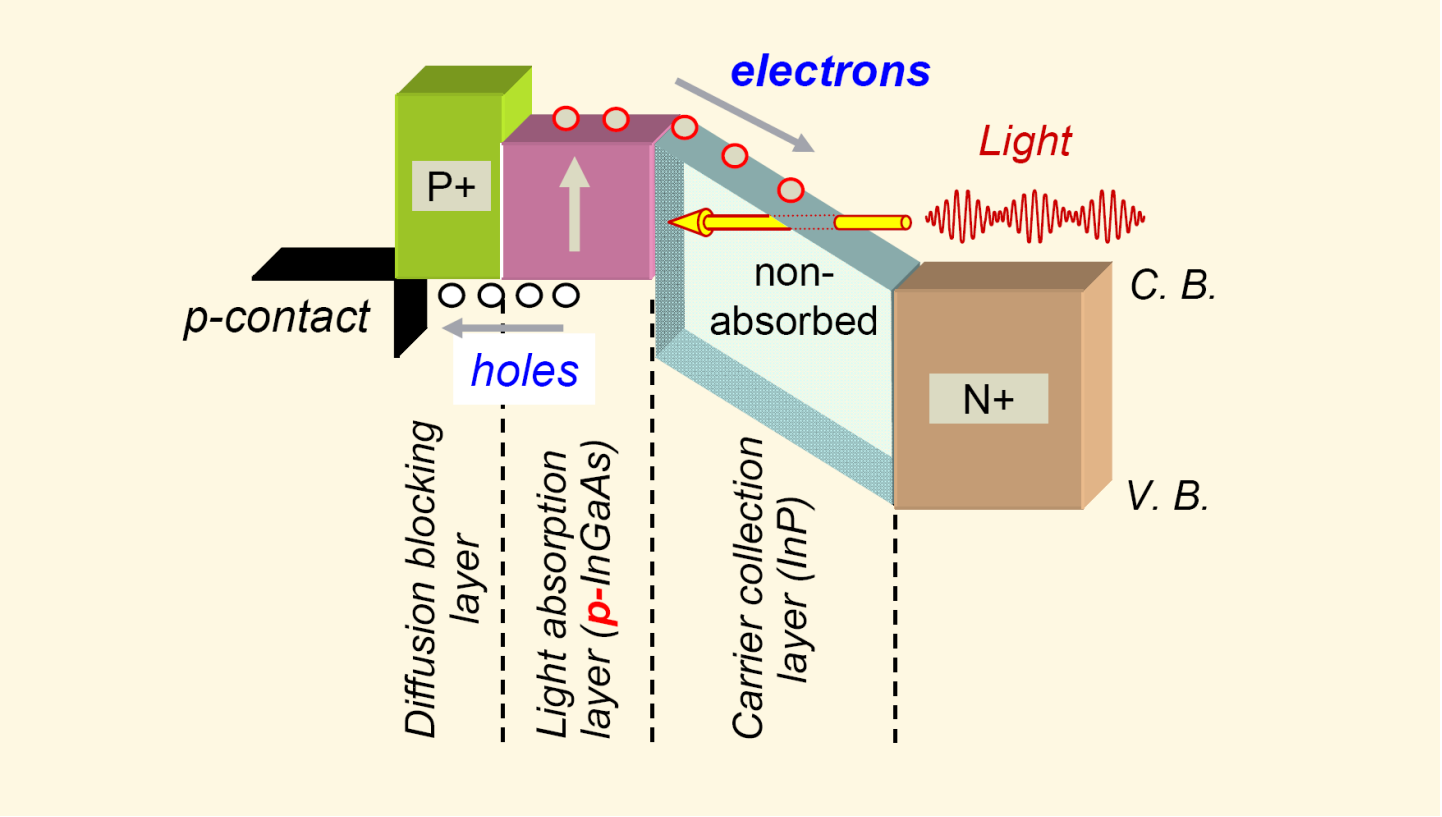
Limitation of conventional PD

- Holes limit carrier transit time in photodiode
- Thin absorption layer increases capacitance



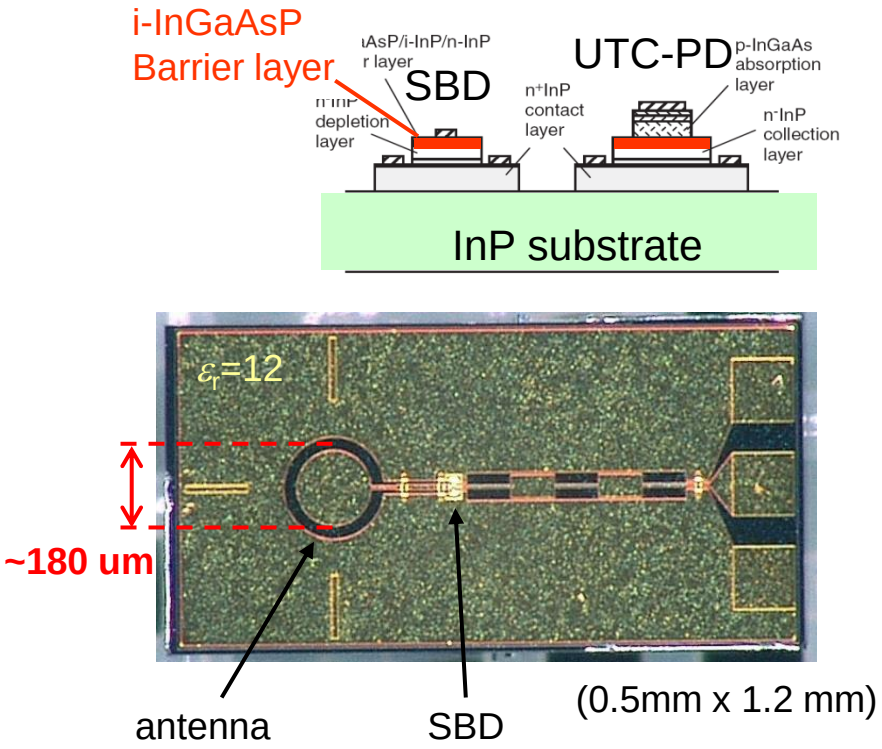
Uni-traveling carrier photodiode

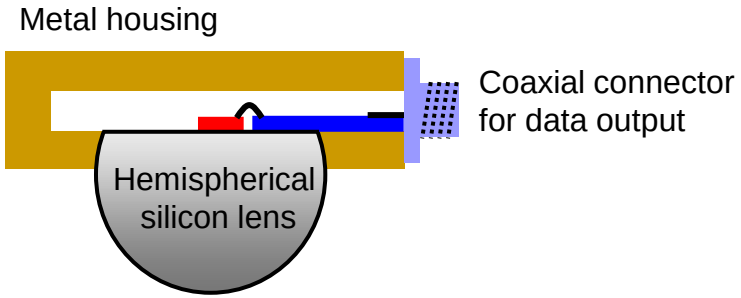
- Separation of hole and electron traveling
- Free from the transit time and capacitance trade-off

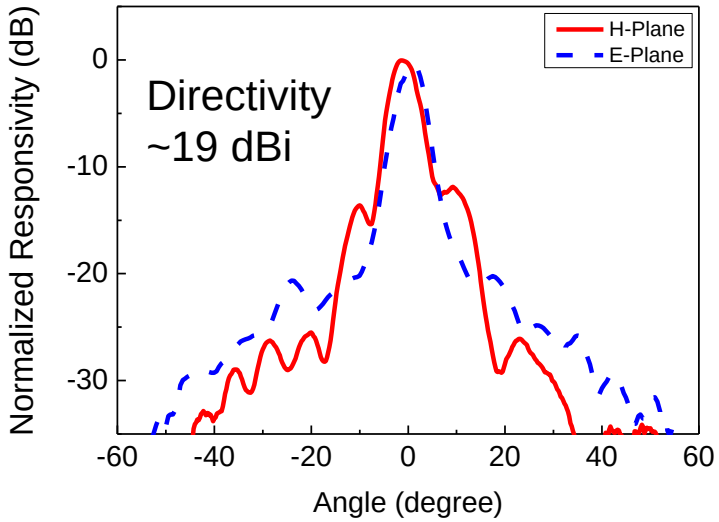


SBD detector

- Antenna integrated SBD (on same epilayer with UTC-PD) and Si lens

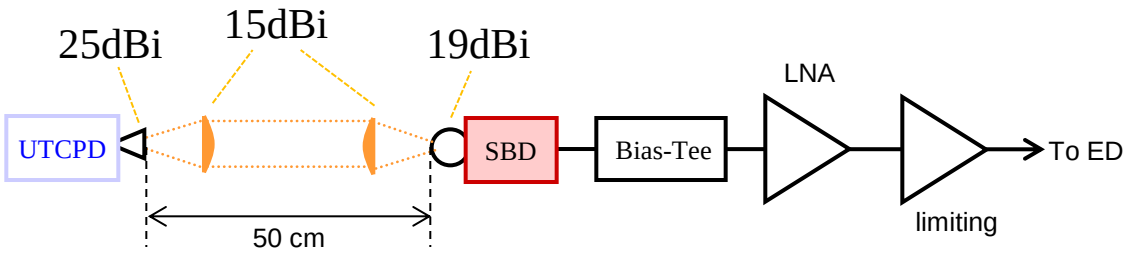


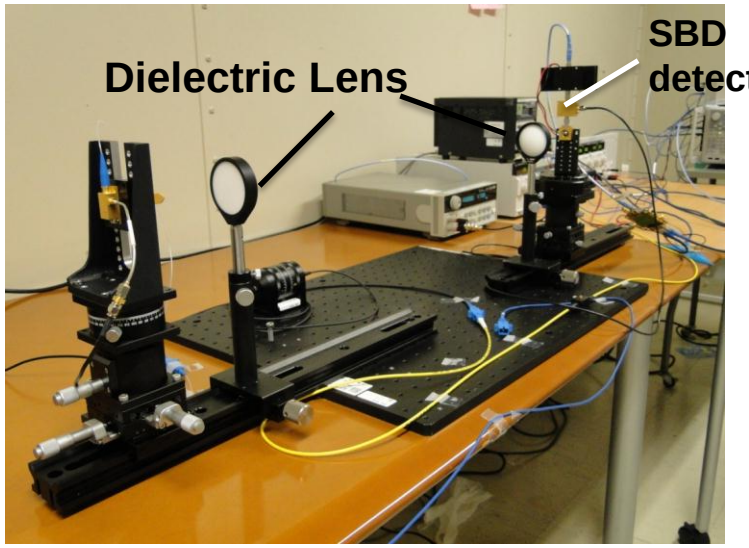


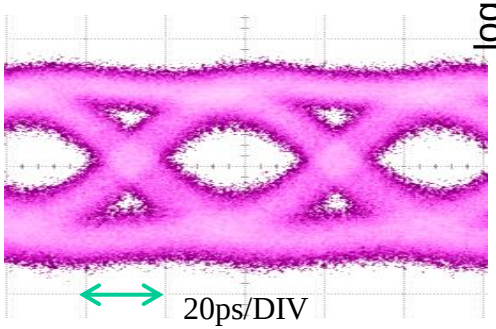


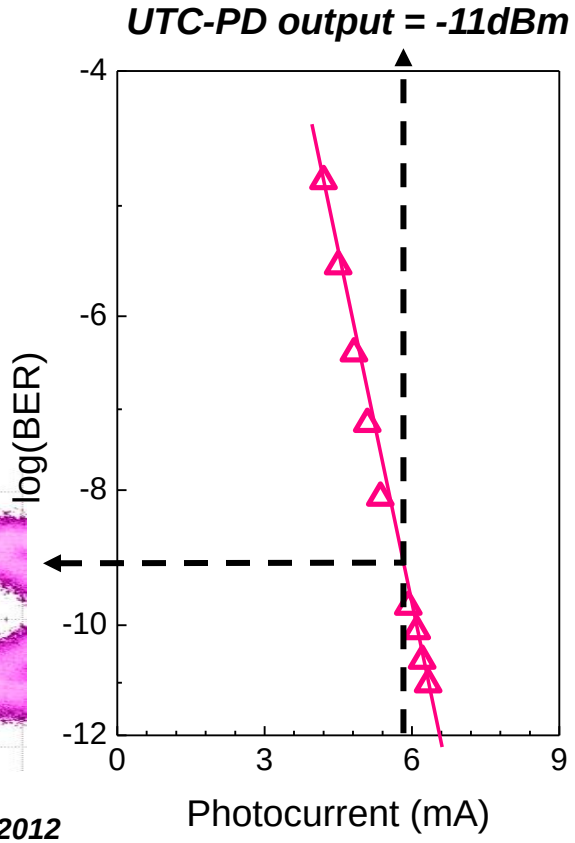
ASK transmission for SBD detector

- 20Gbps (BER=10^{-9}) transmission over 0.5m with 74dBi antenna gain





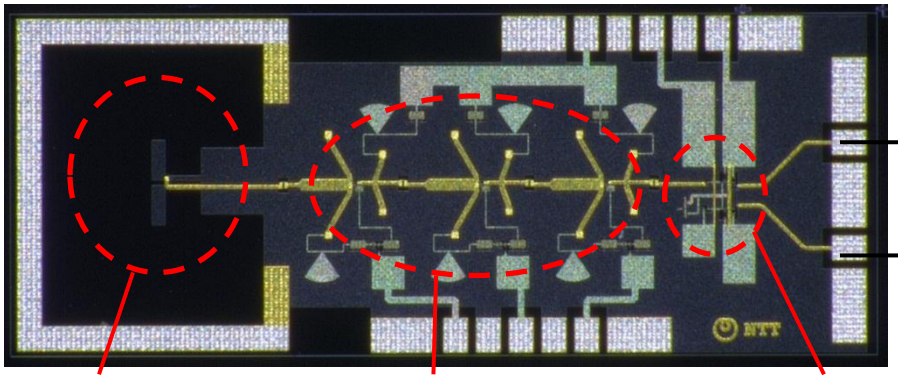


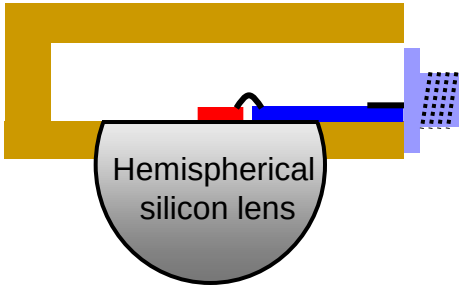


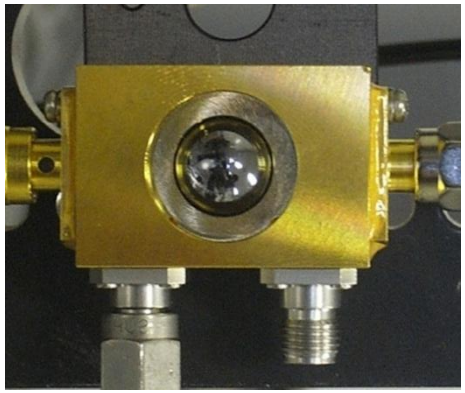
- H.-J. Song et al, Electron, Lett. 2012

Integrated ASK receiver

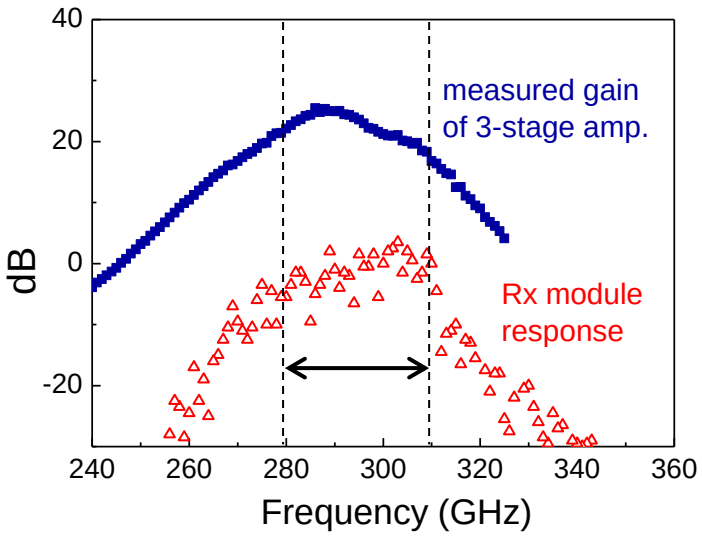
- Integrated antenna, amplifier (24-dB gain) and HBT detector





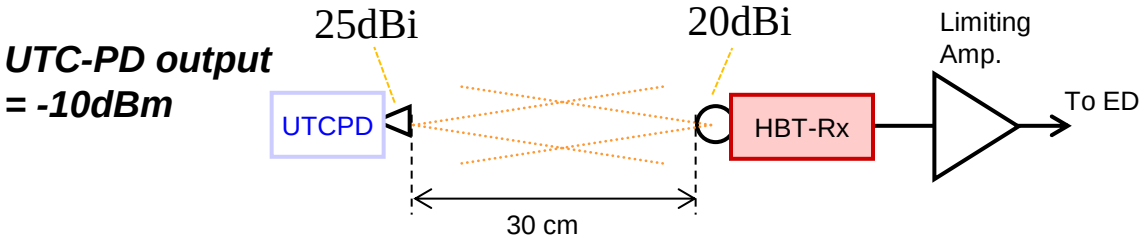


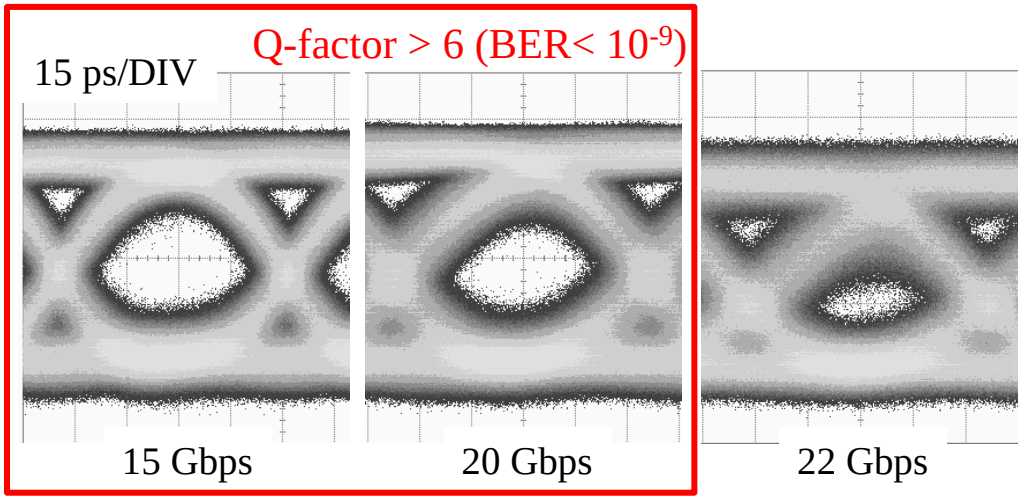
RF bandwidth > 30GHz

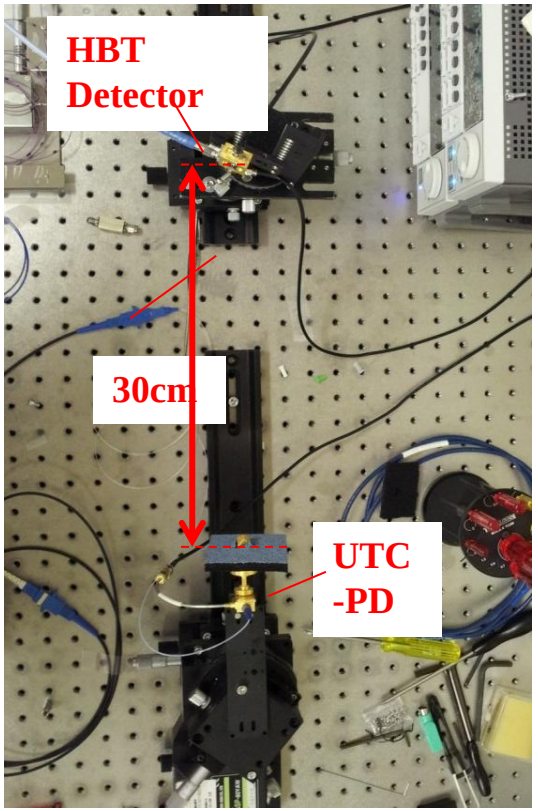


ASK transmission for integrated receiver

- 20Gbps (BER=10^{-9}) transmission over 0.3m with 45dBi antenna gain



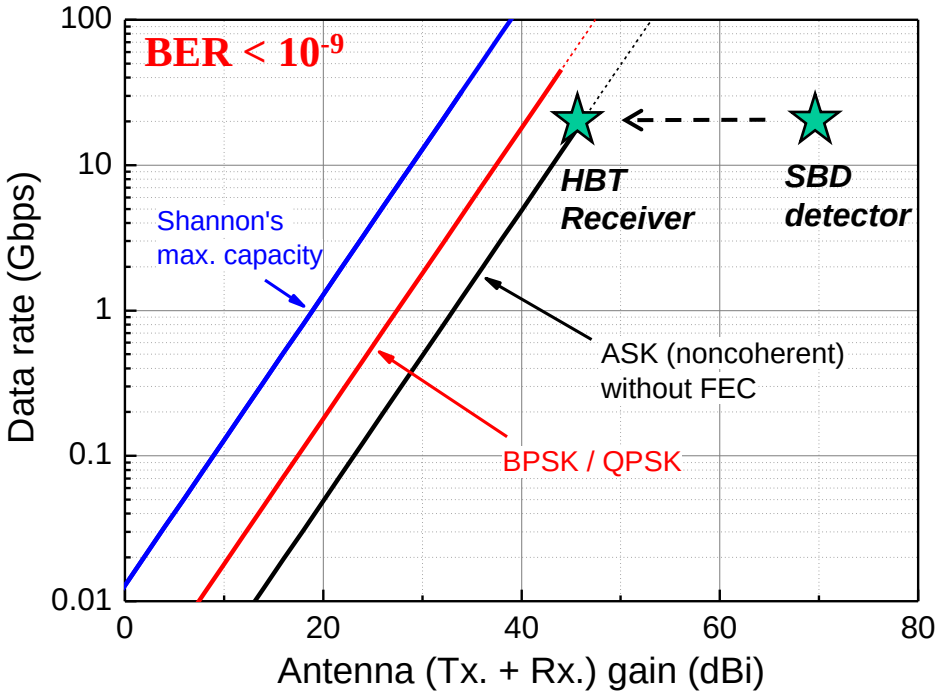




- H.-J. Song et al, IEEE trans. THz sci. tech. 2013

Budget vs Demo.

- Demonstrated 20Gb/s ASK transmission with 45-dBi antenna gain using ASK receiver of ~15dB noise figure

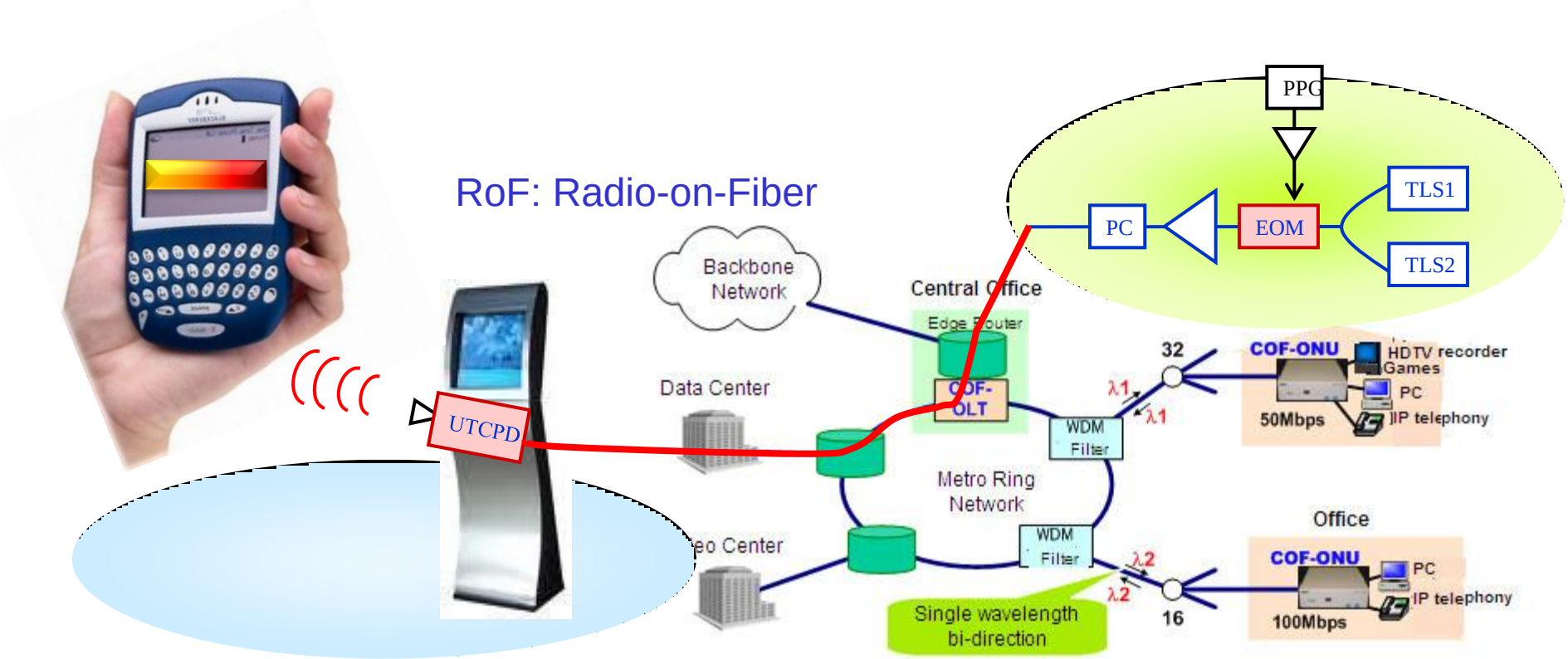


Quantity	Symbol	Budget calculation	Link Demo. With HBT receiver
Transmitting power	P_t	**10 dBm**	**-10 dBm**
Distance	d	**1 meter**	**0.3 meter**
Total noise figure	NF	**15 dB**	**~15 dB**
System margin	M	**(10 dB)**	**-**

Equivalent link parameters

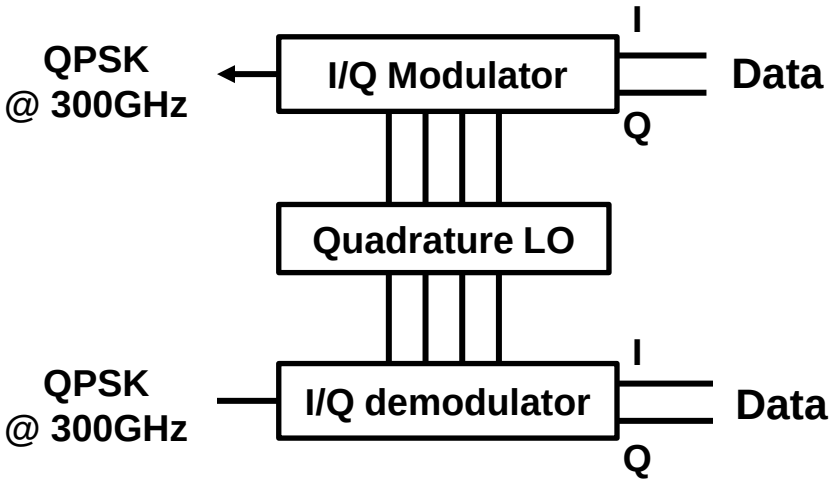
RoF + THz wireless

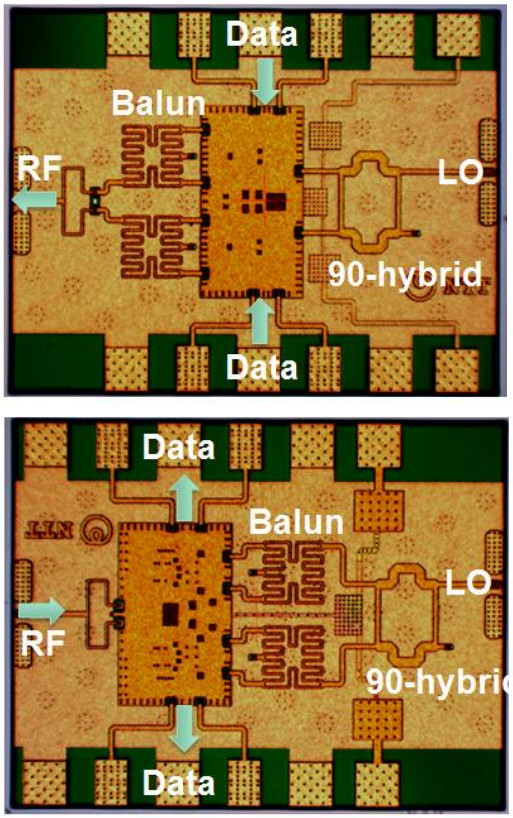
- Photonic-based THz transmitter with UTC-PD for THz RoF (Radio-on-Fiber) system

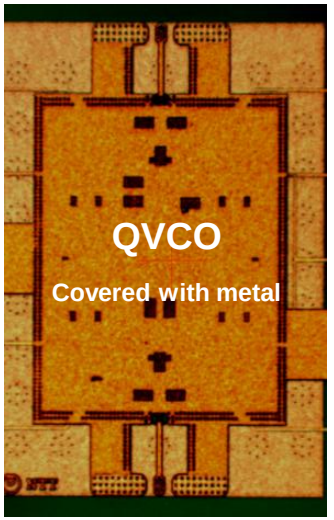


Quadrature Signaling

- QPSK modulation and demodulation, for >40Gbps data throughput @ 300-GHz band using MMICs





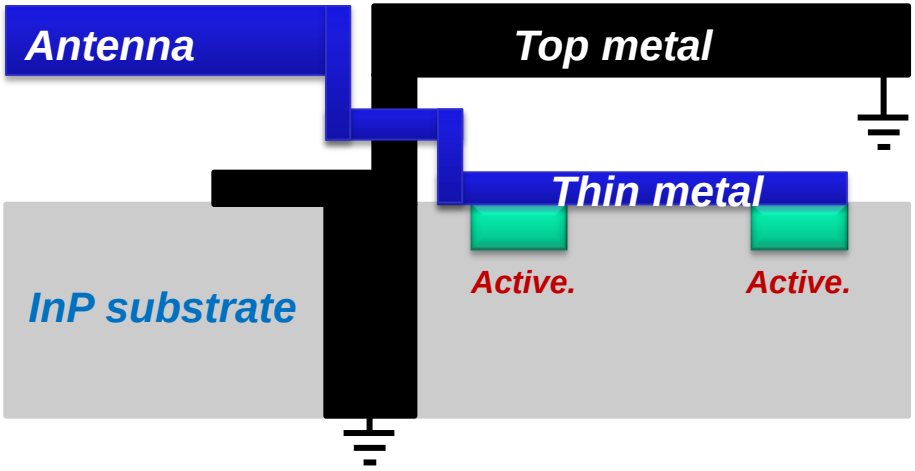


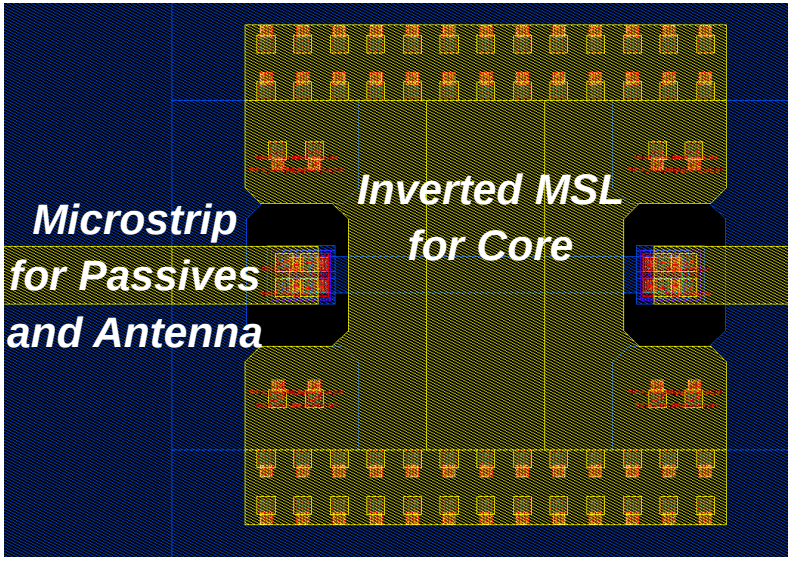
250-nm InP HBT
f_T/f_{max} > 350/650 GHz

for THz MMICs

- Inverted microstripline (InvMSL) for low-loss core interconnections
- Isolation of antenna and core parts by thru-substrate-Via

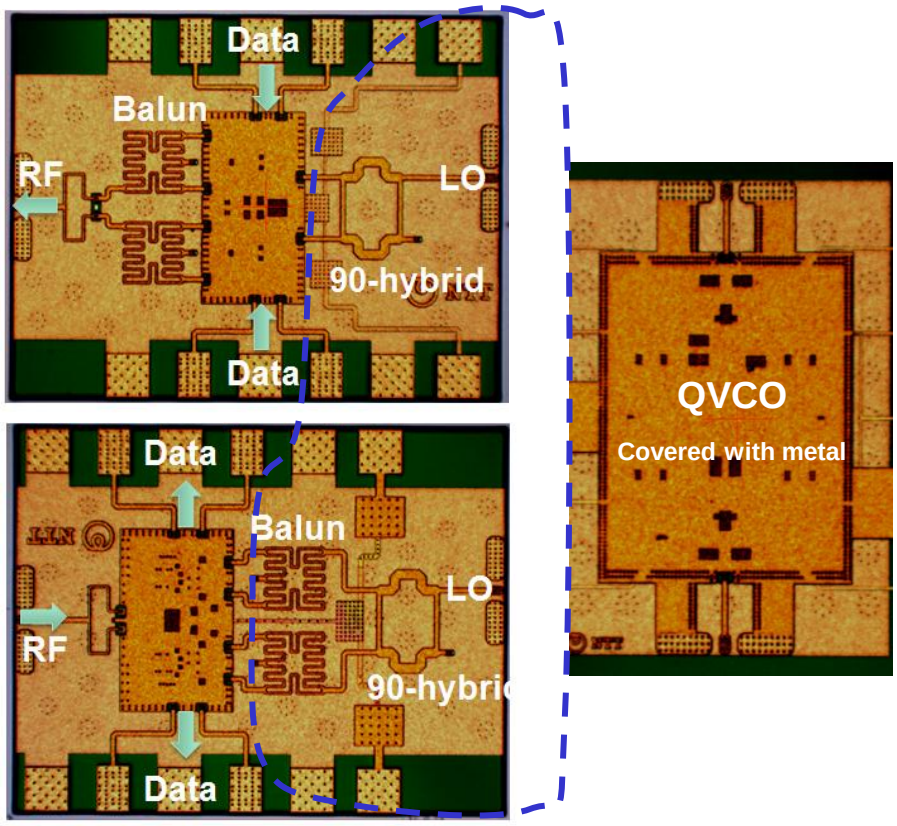
Isolated core from antenna

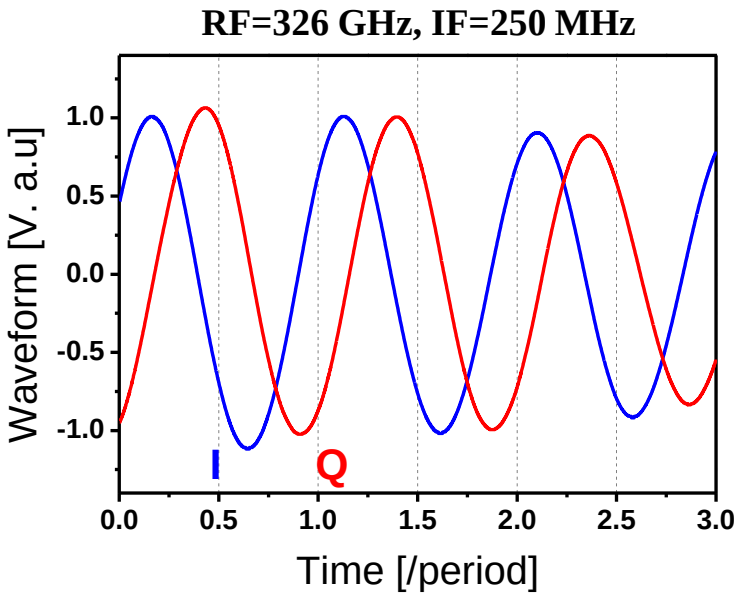




Quadrature LO source

- QVCO to replace quadrature LO supply chains with lossy passives of baluns and hybrids



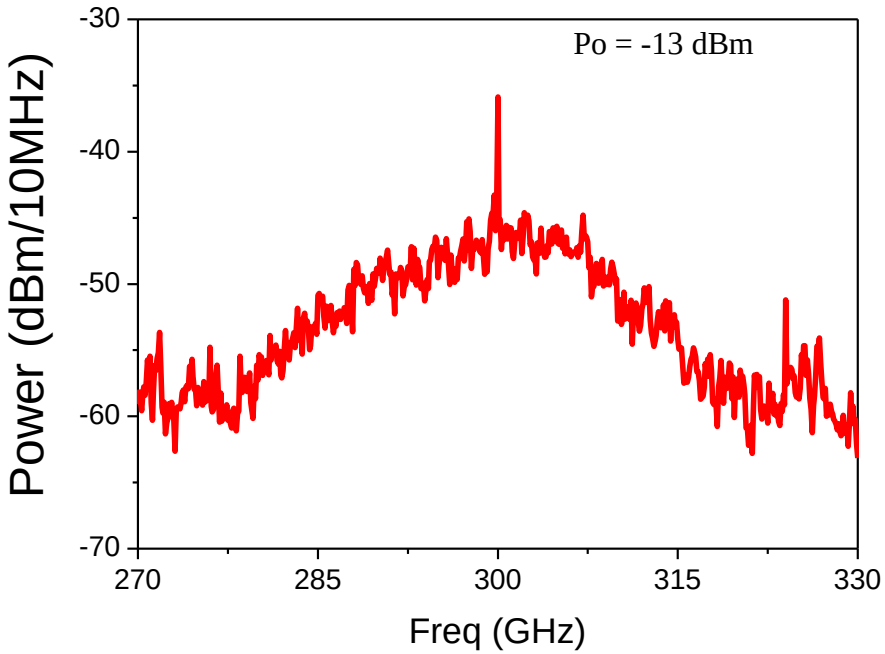


- J.-Y. Kim et al, IEEE Microw. comp. letts. 2013

QPSK modem @ 300-GHz

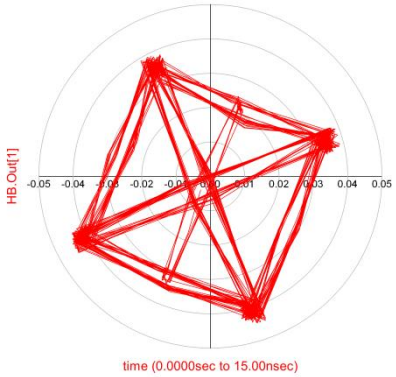
- I/Q modulator and demodulator BW is >40GHz
- Recently, >50Gbit/s back-to-back error transmission demonstrated.

Measured spectrum of 40Gbps QPSK

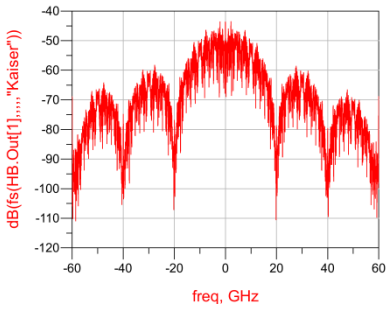


- H.-J. Song et al, EuMIC 2013

Simulation results



IQ constellation of 40Gbps



Spectrum 40Gbps IQ @ 300GHz

Toward 100 Gbit/s

- More spectral efficiency to double the throughput

Feasibility checked for

- 300-GHz wireless channel capacity

- MMIC availability for QPSK

Issues

- Phase noise of LO source

- Amplifier nonlinearity, ADC and DSP

Summary

- THz-wave: potential candidate for PHY of broadband WPAN over 100 Gbit/s
- Feasibility test of THz-wave with photonic and MMIC technologies @ 300-GHz band
  - 20Gbit/s ASK transmission has been demonstrated
  - QPSK up to 50Gbit/s has been achieved