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

Submission Title: The road map of THz wireless communications systems for Japan
Date Submitted: 21 July, 2011”
Source: Iwao Hosako Company: National Institute of Information and Communications Technology
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Re: N/A

Abstract: Results of investigative researches on THz tech (especially on wireless comm.) are described.

Purpose: To activate general discussions in P802.15 about THz-wireless-communication technology.

Road map of THz wireless communications systems for Japan

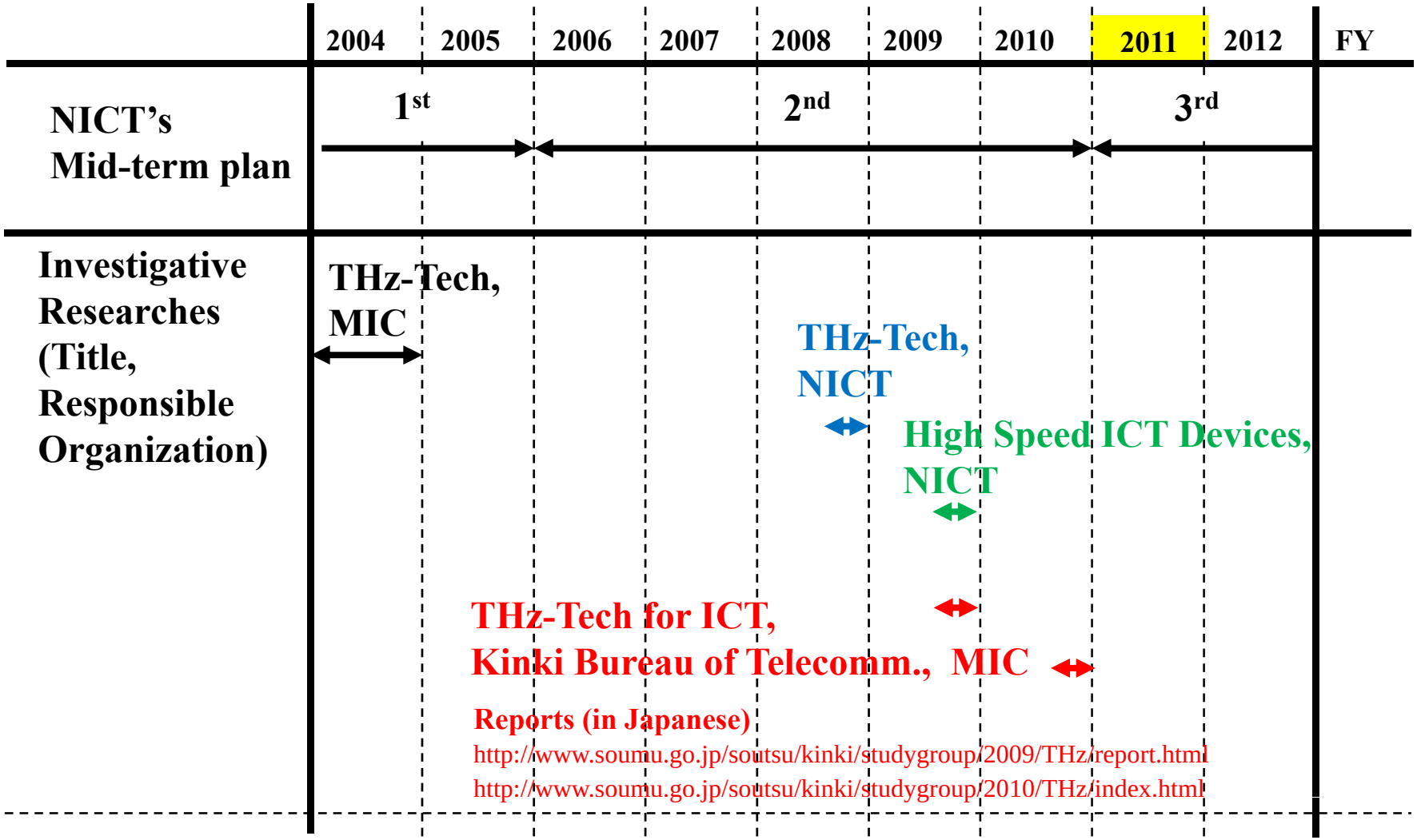
Iwao Hosako

National Institute of Information and Communications Technology (NICT), JAPAN

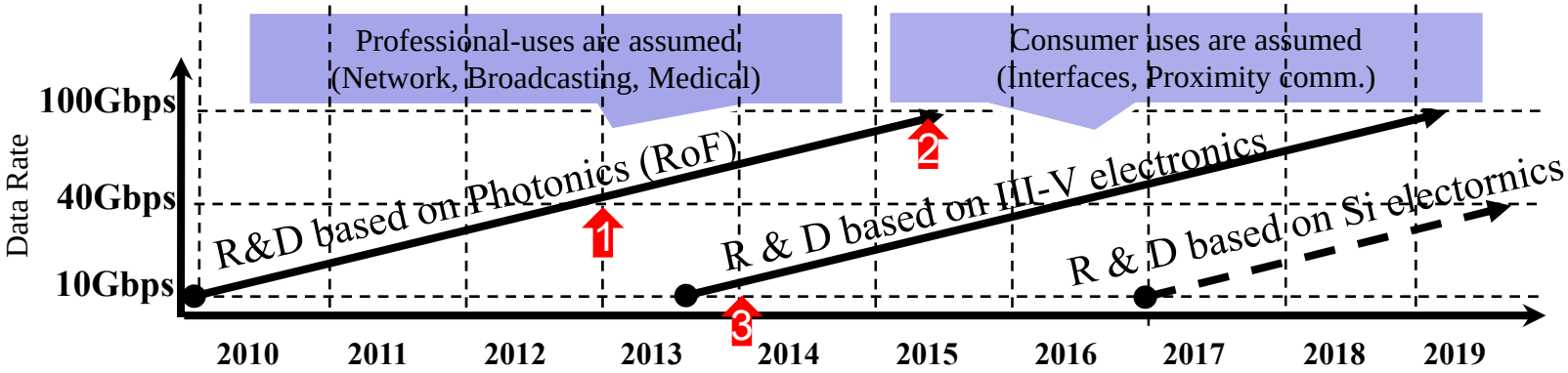
Acknowledgement

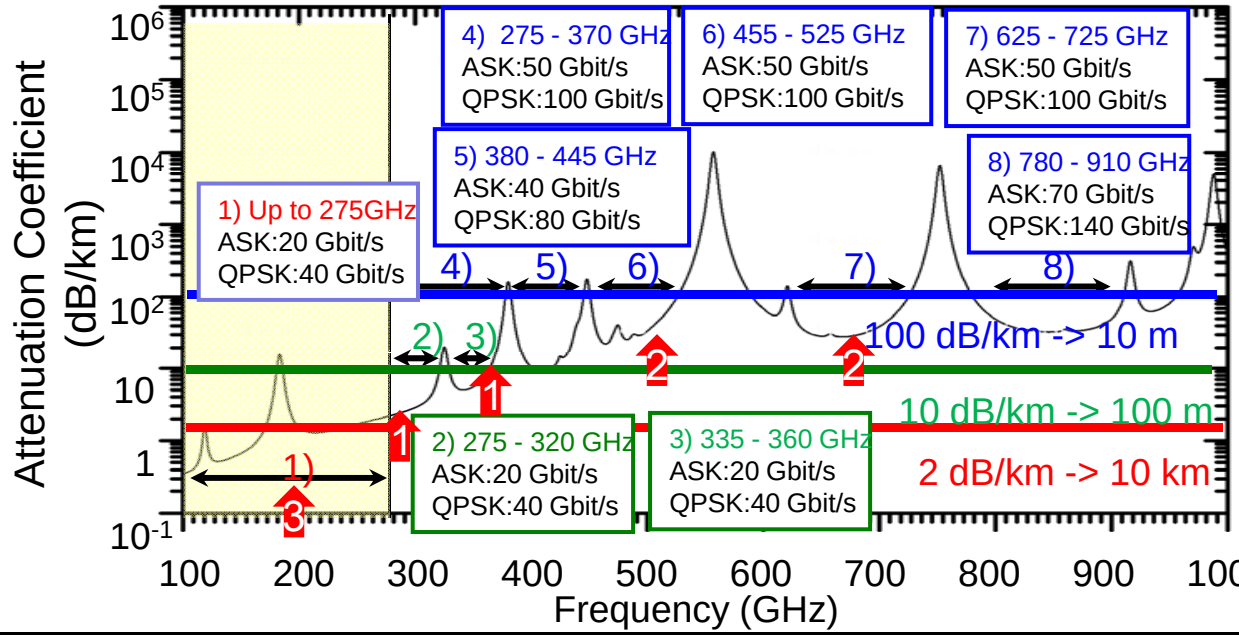
- Members of
  - Division of R&D, Bureau of International Strategy, Ministry of Internal Affairs and Communications (MIC)
  - Kinki Bureau of Telecommunications, MIC
  - Advanced ICT Device Group, NICT
- Committee members & lecturers of
  - Investigative research of Terahertz technology in FY2008
  - Investigative research of High Speed ICT Devices in FY2009
  - Investigative research of Terahertz technology for ICT in FY2009 & FY2010

Investigative Researches of THz-Tech. in Japan



Summary of the report in 2008
Expecting time-lines of R & D



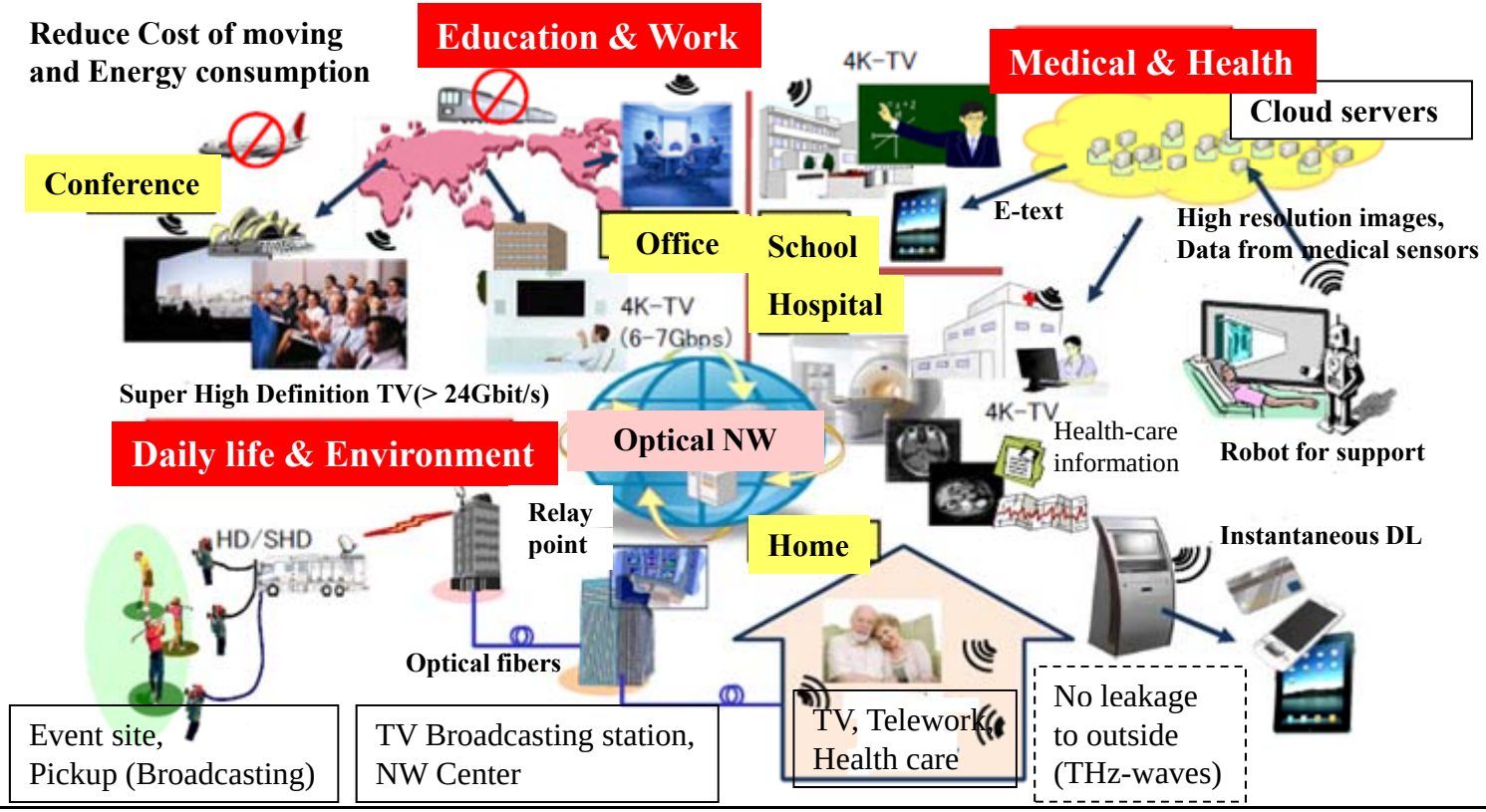


Summary of the report in 2009

THz-WL is useful for

+ Relieve bottlenecks of last-access
  (No speed difference between wired and wireless)
+ Realization of high speed wireless interface
  (Ultra-short range, instantaneous & intermittent, low energy consumption)

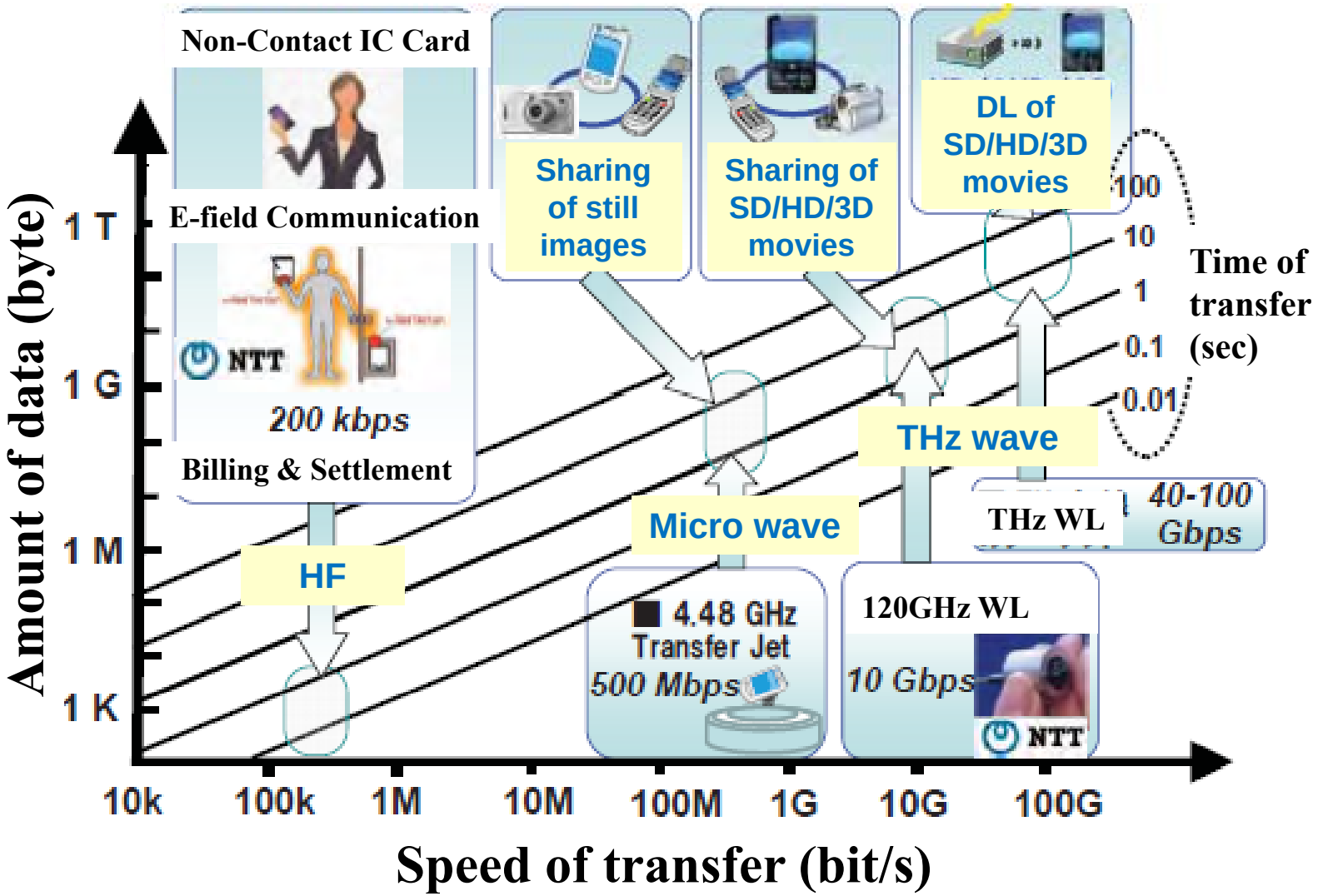
and for following usage scenes.



Contents of investigative research in FY2010

- Needs
  - Instantaneous data transfer
  - From professional-use to mass-use
- Possible Contributions of THz-WL for
  - Energy Saving
  - Human Life
- Follow-up: Technological trends for THz-WL

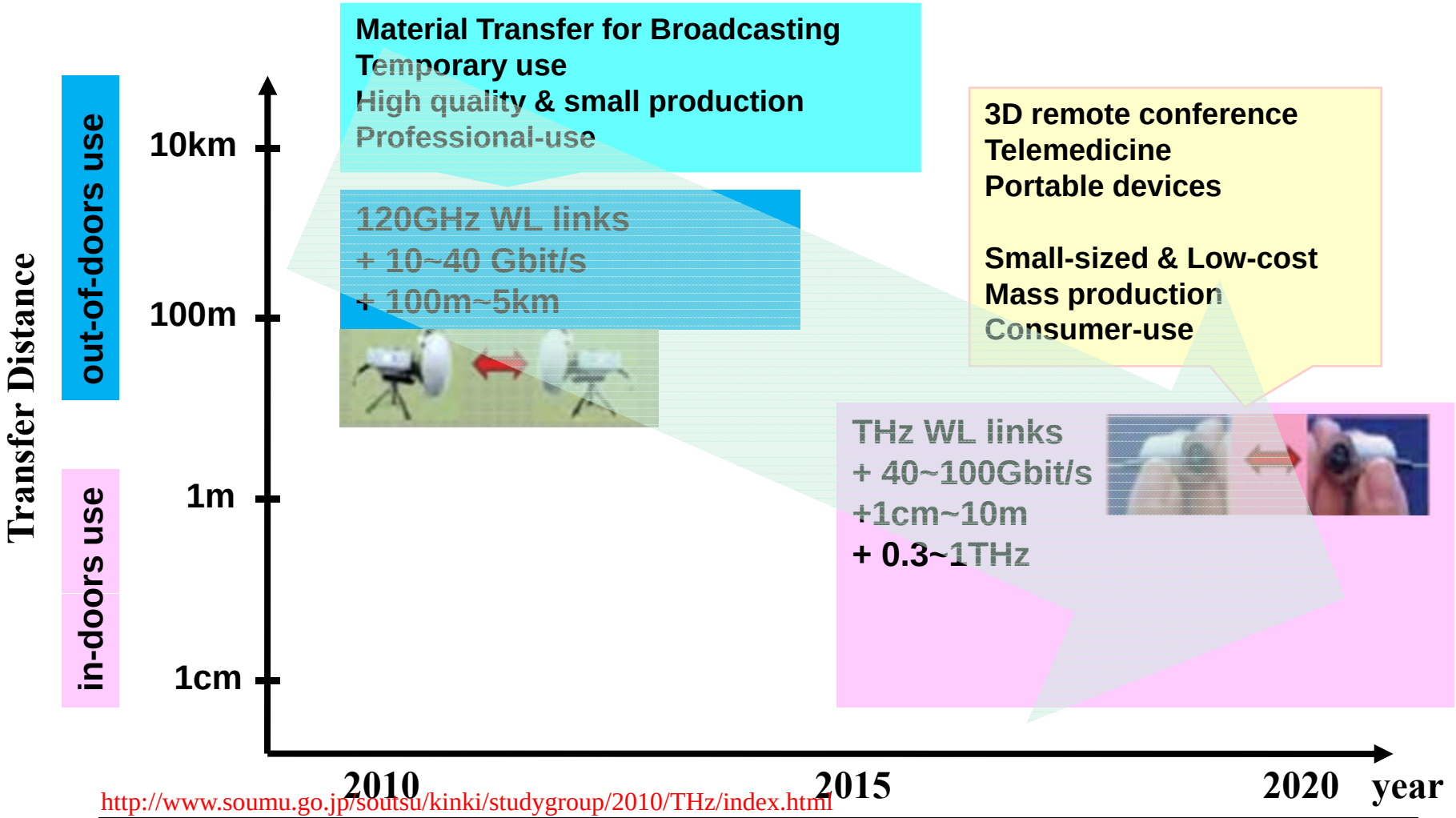
Needs of instantaneous data transfer



http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

Transition of needs

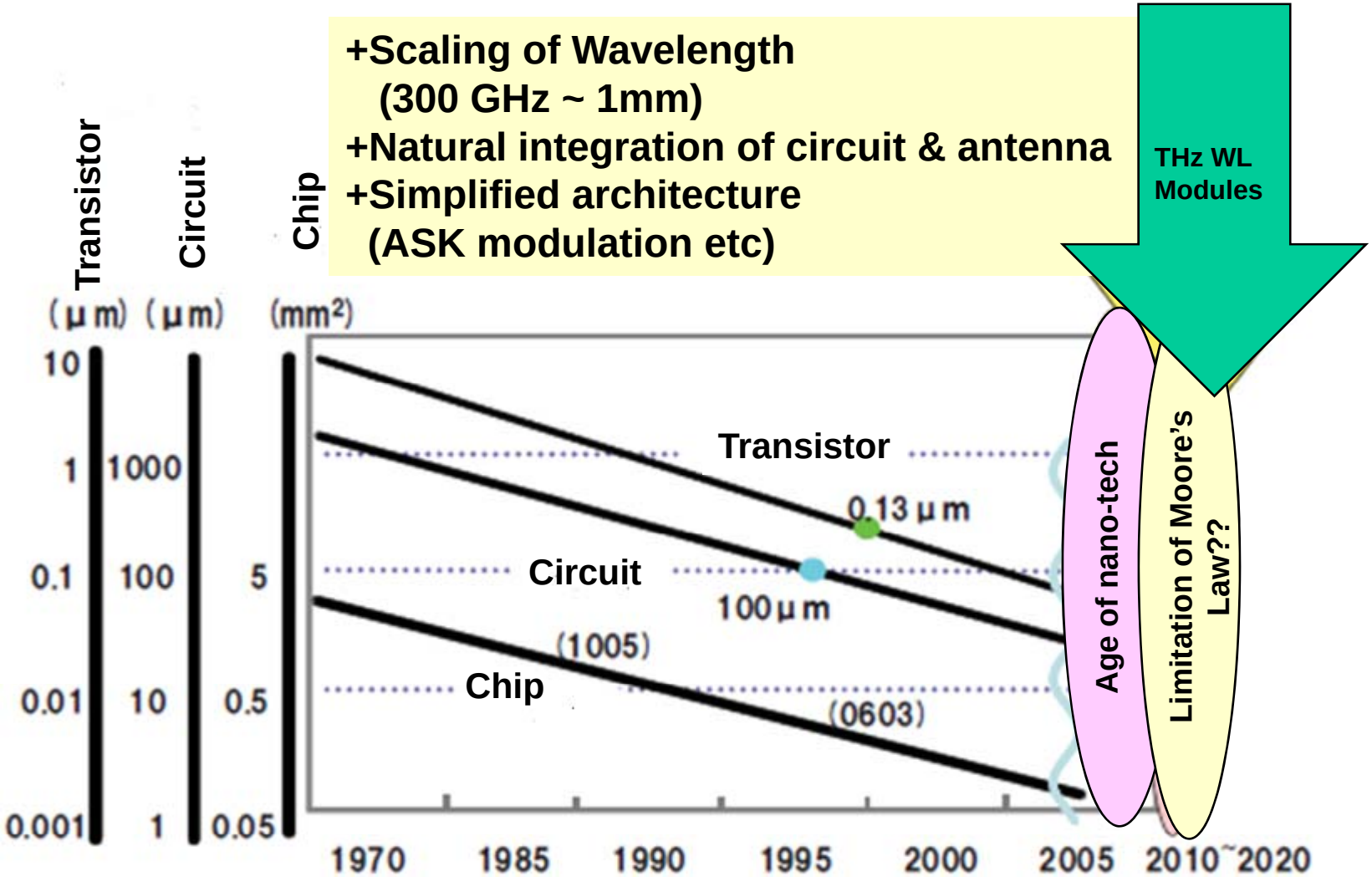
from professional-use to mass-use



http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

Trend of miniaturization & THz modules

+Scaling of Wavelength
(300 GHz ~ 1mm)
+Natural integration of circuit & antenna
+Simplified architecture
(ASK modulation etc)



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Possible Contributions for “Energy Saving”

Green of ICT

- Energy saving (ES) in wireless applications
  - Energy saving by speeding up of wireless applications
  - Merits of THz wireless
    - ES by instant huge-data-transfer
    - ES by intermittent operation
    - ES by simple modulation format (use wider band)

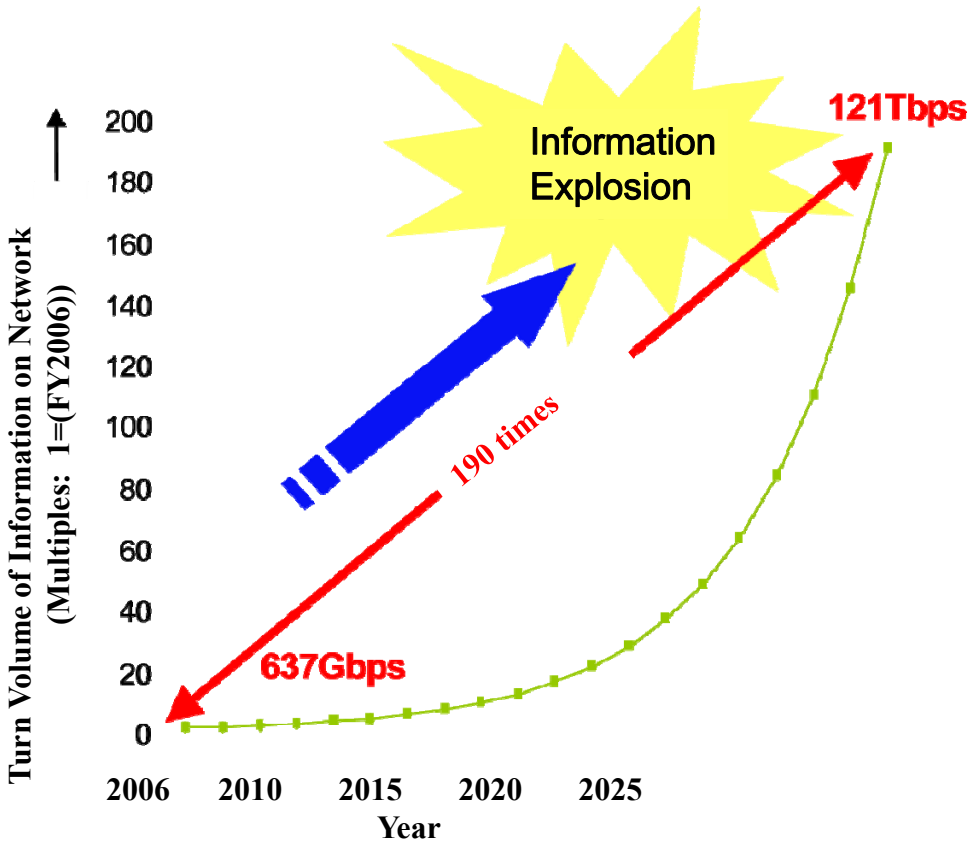
Green by ICT

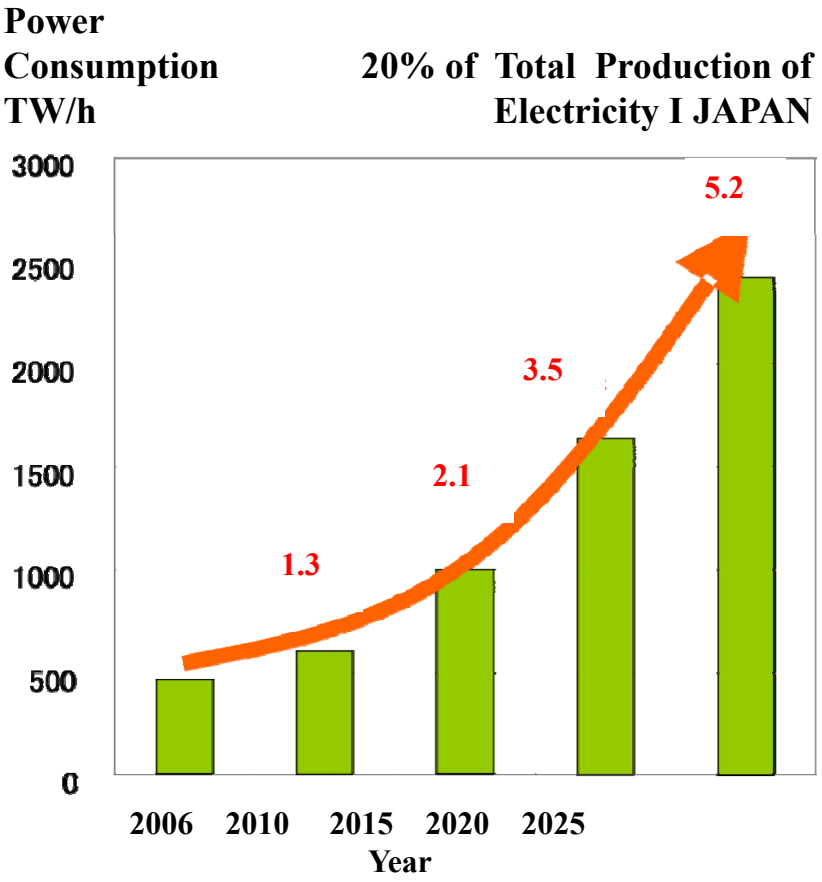
- Energy saving by application of ICT
  - Spread use of teleworking
  - Reduction of moving (goods, human)
  - Efficiency gain of production & consumption

http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

Trends of Information Explosion & Power Consumption in ICT

(METI, JAPAN, Oct. 2008)





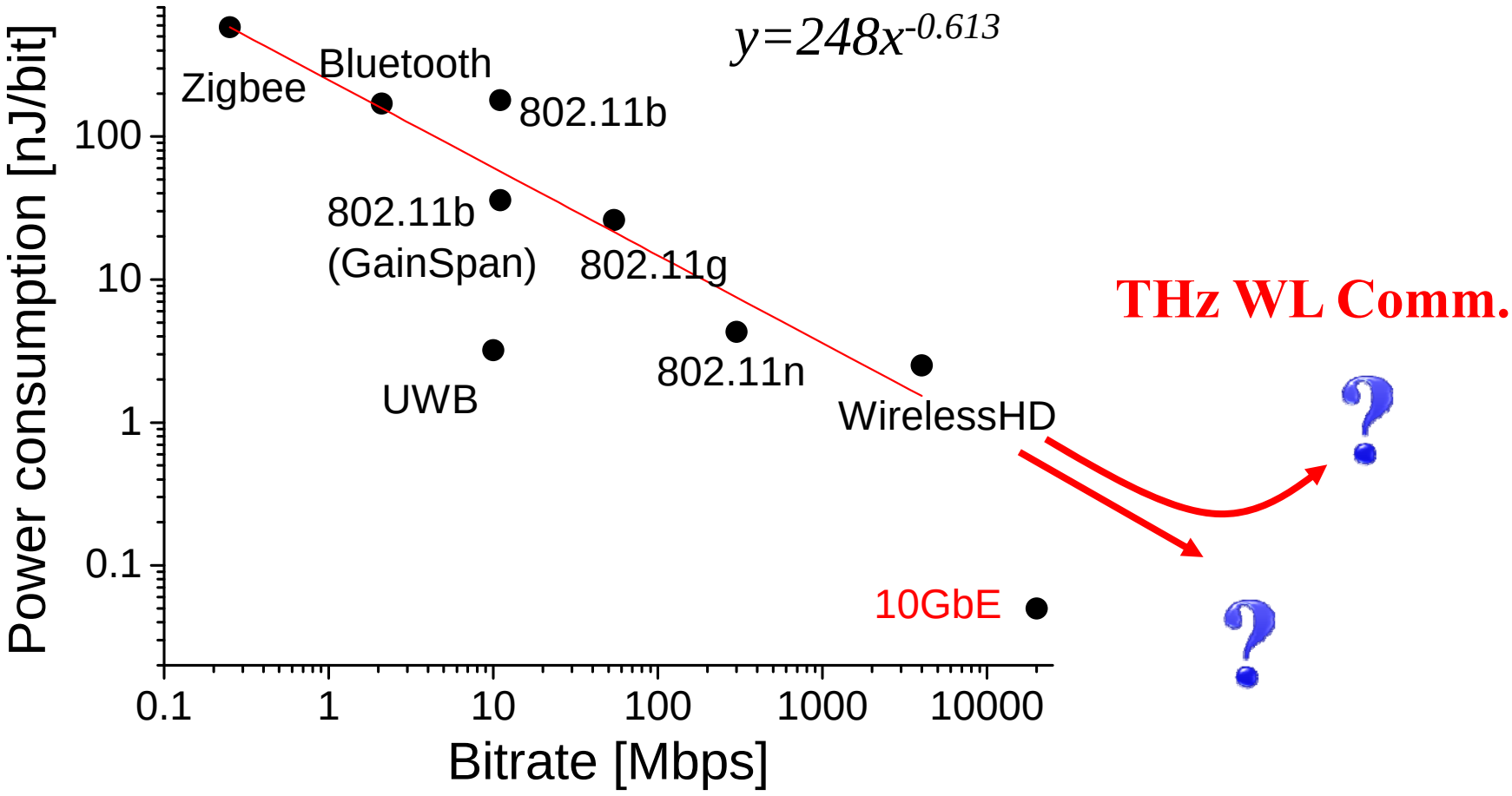
Power Consumption/bit v.s. Bit rate

	MBit/s	nJ/Bit		
Zigbee (TYP)	**0.25**	**580**		
Bluetooth3.0+EDR (Planex)	**2.1**	**170**	Production	BT-Micro3E2X
802.11b (TYP)	**11**	**180**		
802.11b/g (iodata)	**54**	**26**	Production	WN-G54/CB3L
UWBDice	**10**	**3.2**	R & D	
802.11b/g/n (iodata)	**300**	**4.3**	Production	WN-G300U
802.11b GainSpan (Alps)	**11**	**36**	Evaluation kit	UGFZ1
WirelessHD SiBeam (Panasonic)	**4000**	**2.5**	Production	TU-WH1
Optical transceiver 10GbE(SEI)	**20000**	**0.05**	Production	SPP5000

By Dr. Tetsuya Kawanishi of NICT
http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

Power Consumption/bit v.s. Bit rate

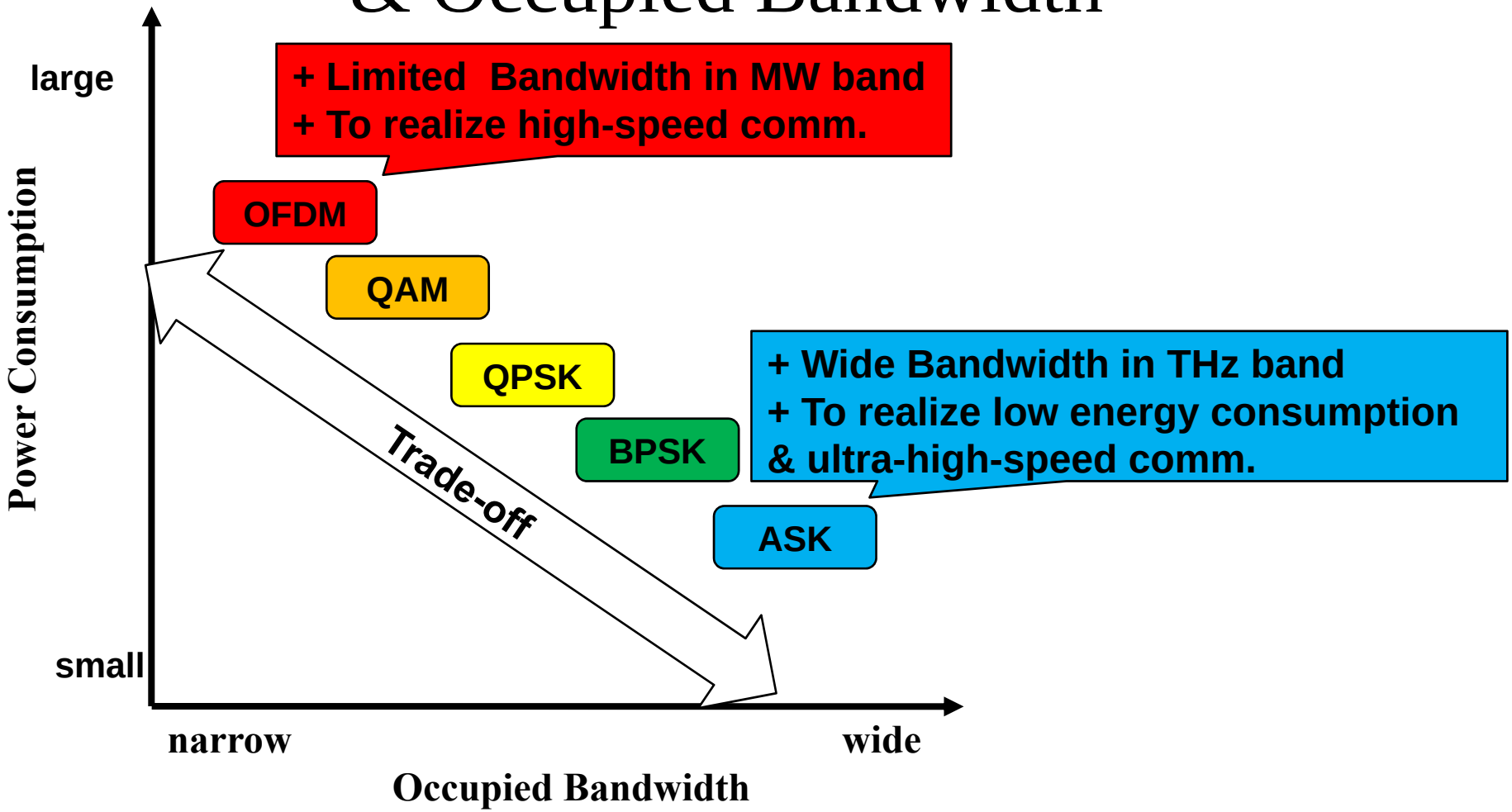
Fitted by Zigbee, Bluetooth, 802.11b(GainSpan), 802.11g, 802.11n, WirelessHD



By Dr. Tetsuya Kawanishi of NICT

http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

Trade-off between Power Consumption & Occupied Bandwidth



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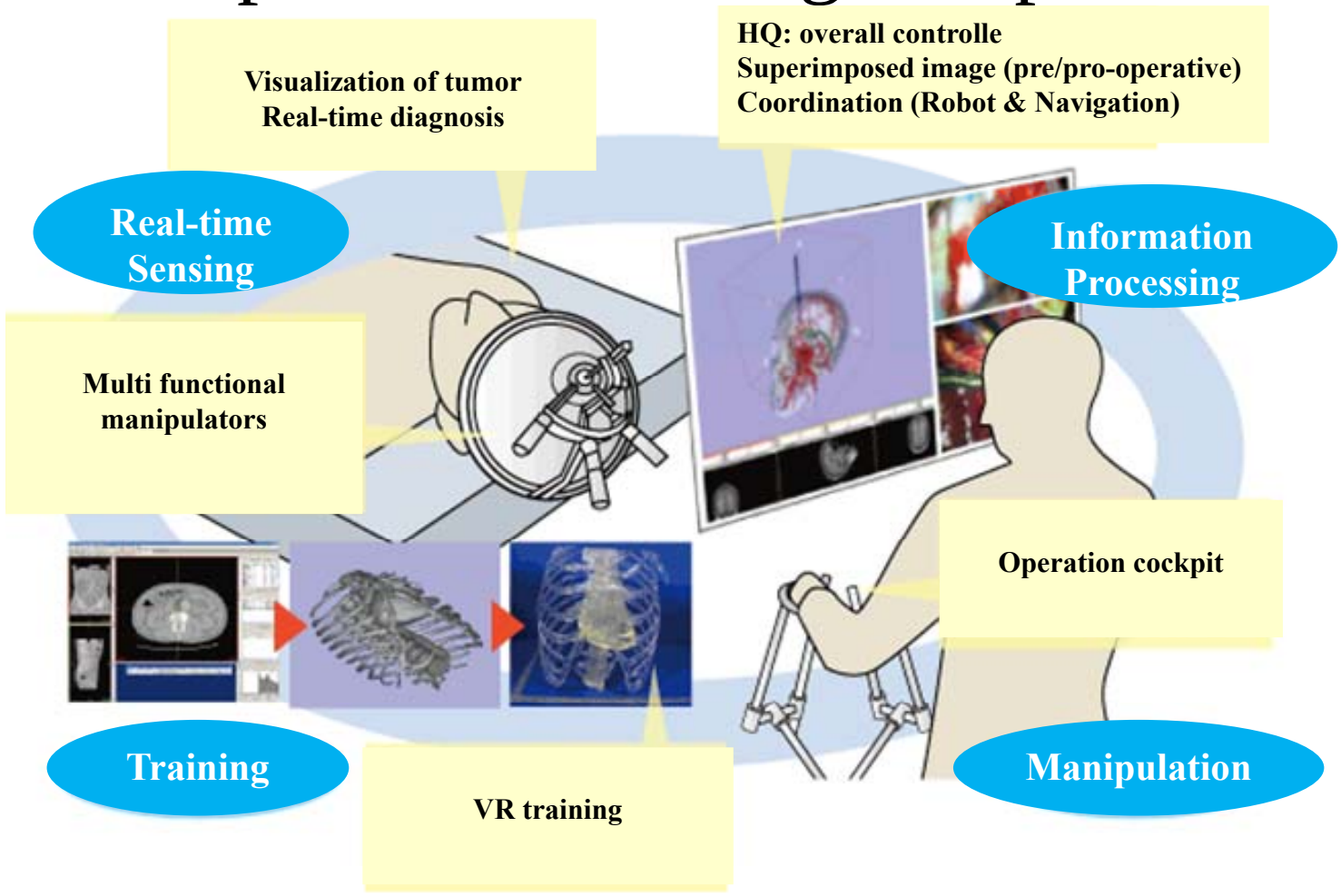
Possible Contributions for “Human life”

- Medical
  - Needs of advanced ICT at operation room and diagnosis-site
  - Realization of cable-less operation room
  - High speed access to the medical information data-base(cloud) during operation and diagnosis
  - Telemedicine system by SHD-image transfer
  - Instant data transfer of medical images
- Regional revitalization
  - Teleworking : Action for depopulation
  - Remote education by 3D image contents

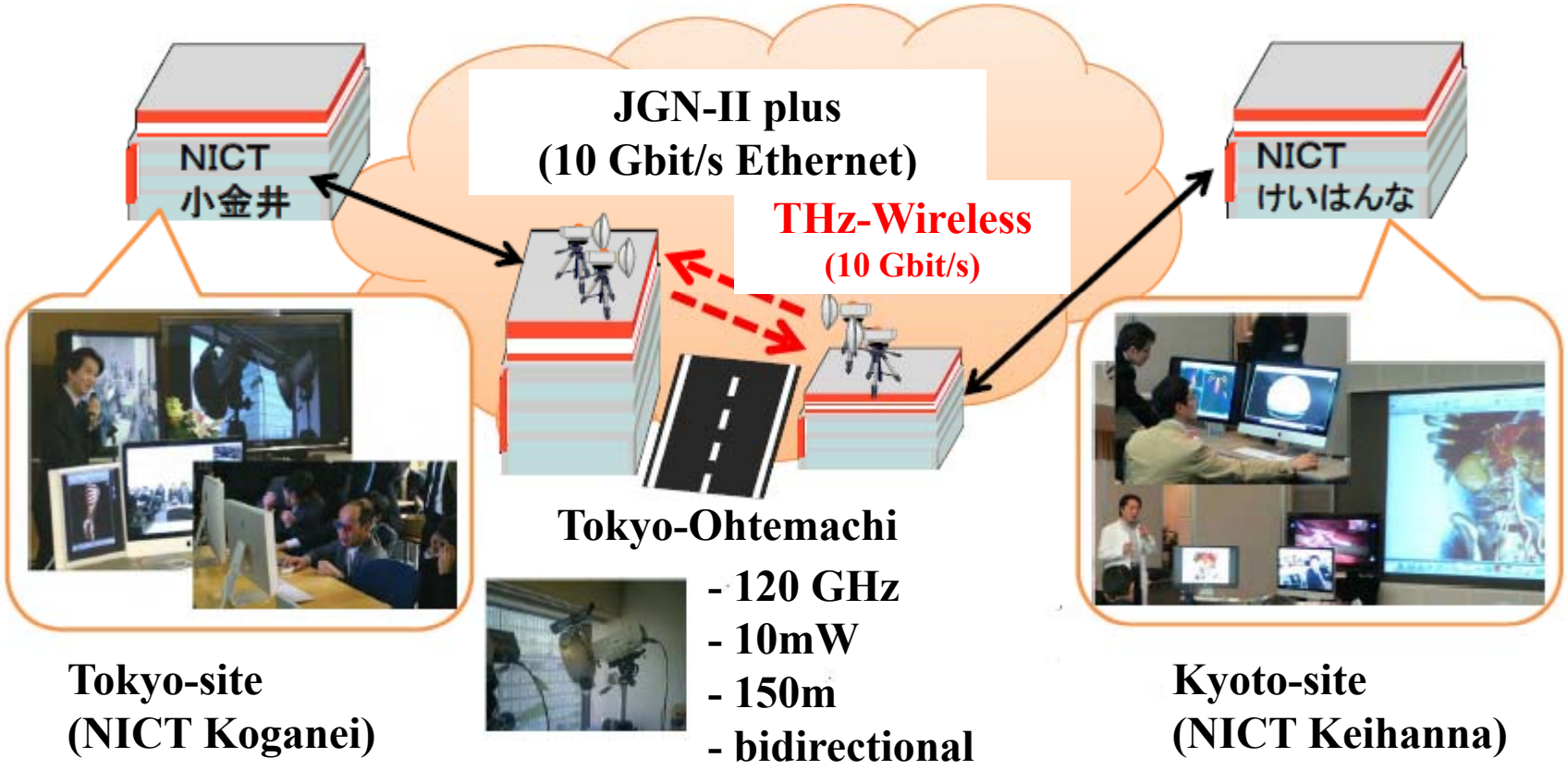
http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

Entire picture of intelligent operation



http://app2.infoc.nedo.go.jp/kaisetsu/bio/bio02/p01.html

Open experiment: Bidirectional high speed line consisting of wired & wireless



http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

Open experiment: Bidirectional high speed line consisting of wired & wireless

da Vinci system

3D image from da Vinci system

OsiriX image manipulation at Kyoto

OsiriX image viewing at Tokyo

http://www.soumu.go.jp/soutsu/kinki/studygroup/2010/THz/index.html

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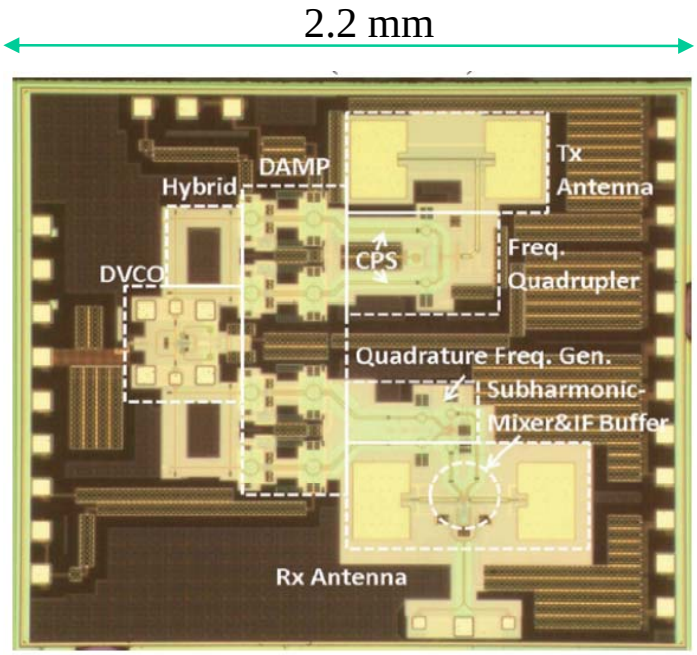
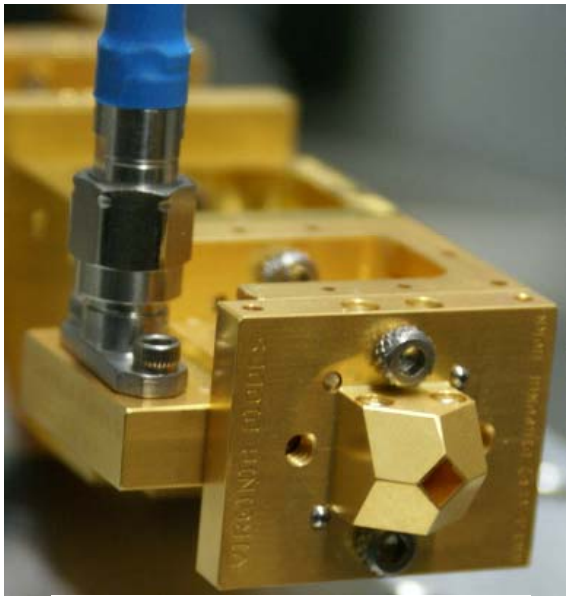
Small size instrumentations (Antenna, Chip), Possible to install on the mobile terminals.

Horn Antenna @ 300GHz



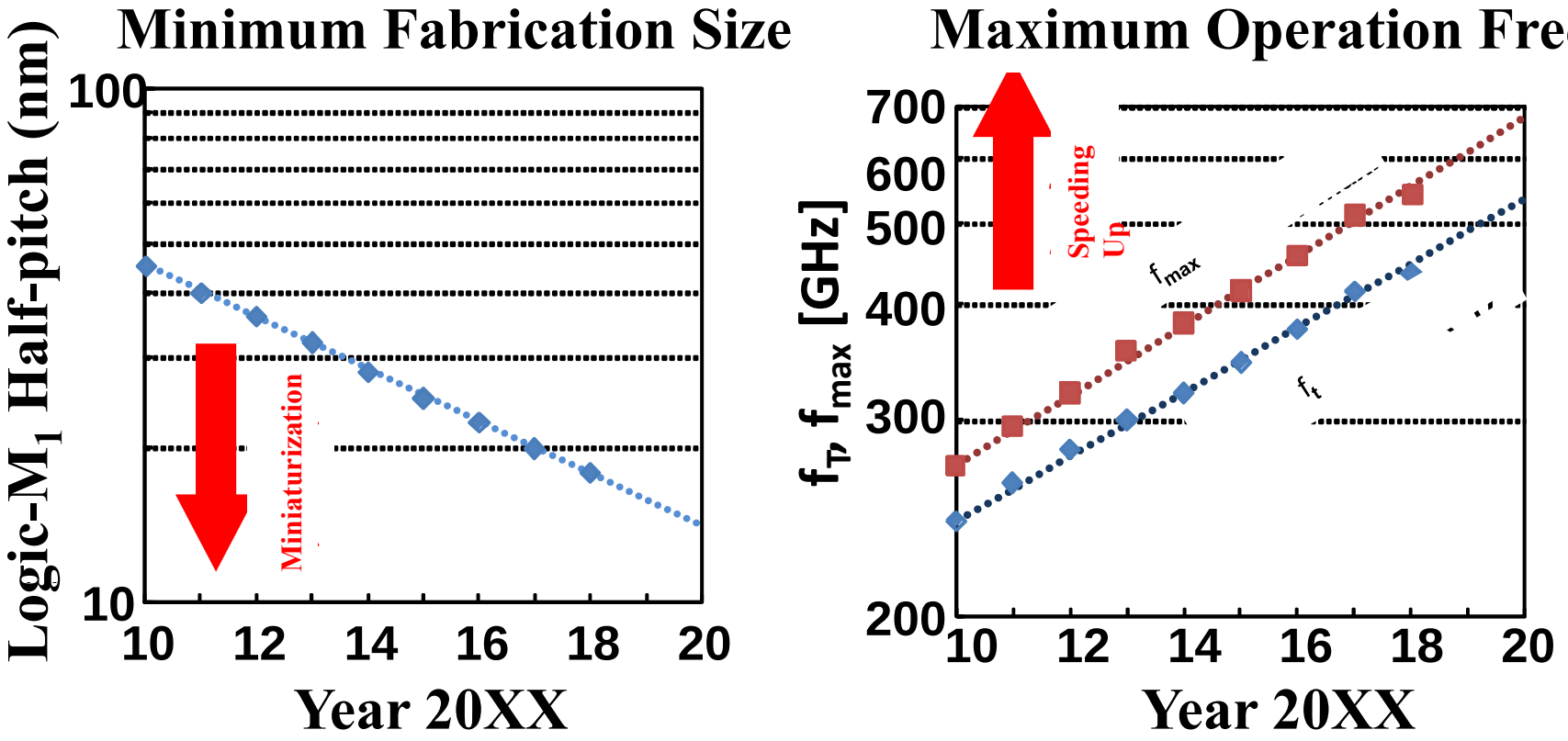
Patch Antenna @ 380GHz



Horn Antenna @ 600GHz

Further improvement on antenna is necessary (Needs 25dBi at least)

High speed electronics (MOS, GaN, InP, Vacuum) will be ready to use within 5/10 years



CMOS will reach over 600 GHz in near future

http://www.soumu.go.jp/soutsu/kinki/studygroup/2009/THz/report.html

RF-CMOS for Optical Fiber Communicarion

(For low power consumption, downsizing, and low-cost)

Kanda et al., “A single-40Gb/s Dual-20Gb/s Serializer IC with SFI-5.2 Interface in 65nm CMOS, ” IEEE ISSCC Dig. Tech. papers, February 2009, pp. 360-362.

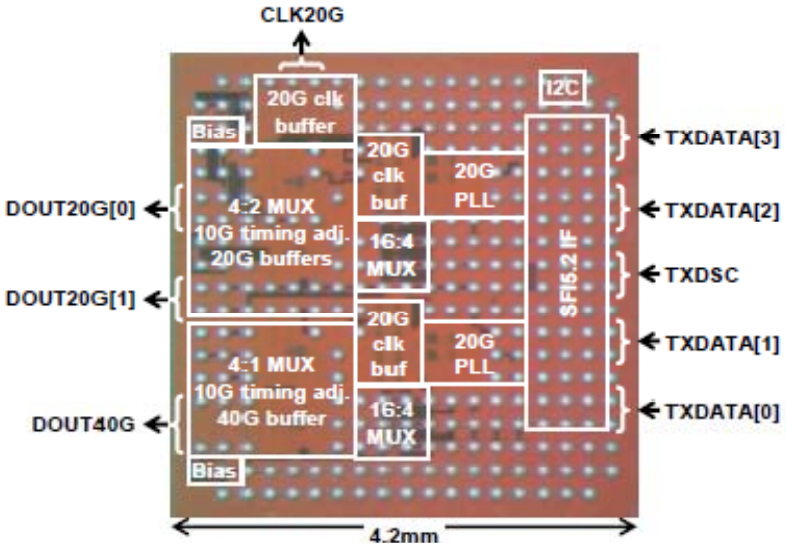
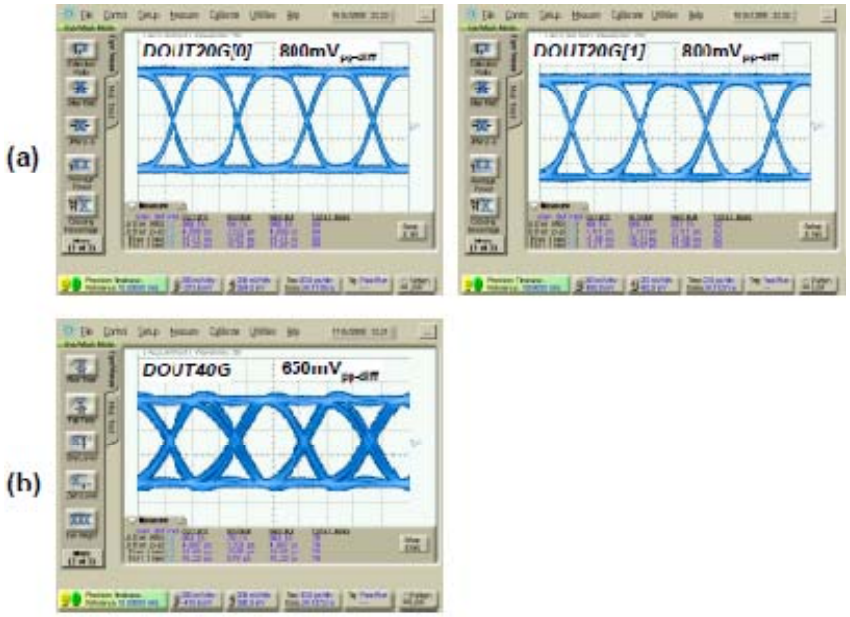


Photo. of 40 Gbit/s Tx IC

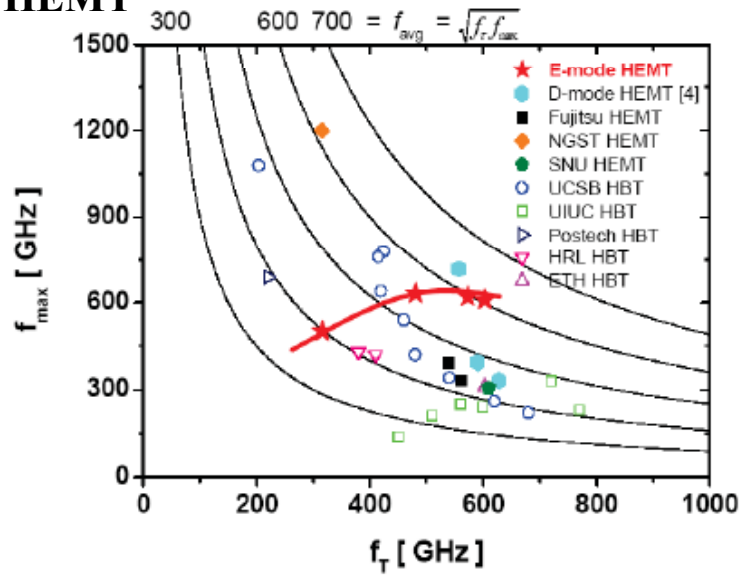


Output waveform of 40 Gbit/s Tx IC
(a) 20 Gbit/s×2、(b) 40 Gbit/s×1

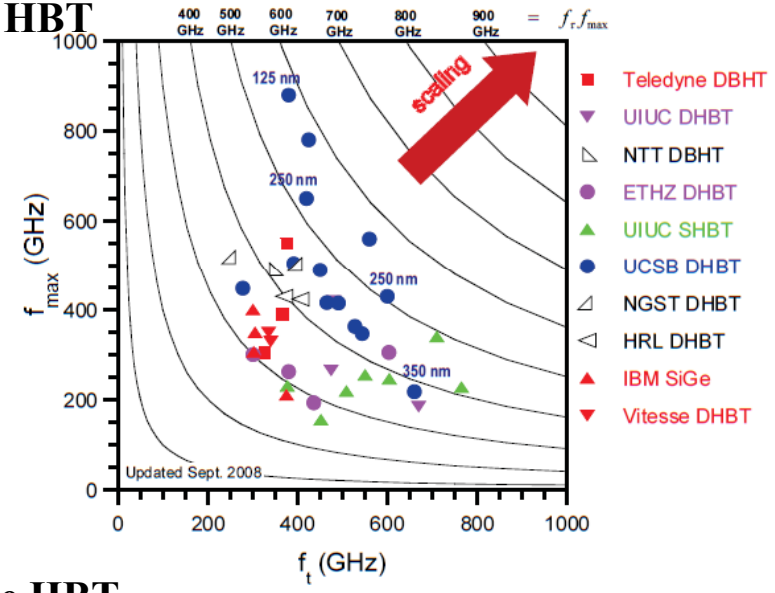
- 65 nm CMOS
- Chip ：4.2×4.2 mm^2
- Power Consumption：1.8 W

Trends of III-V HEMT & HBT, SiGe HBT

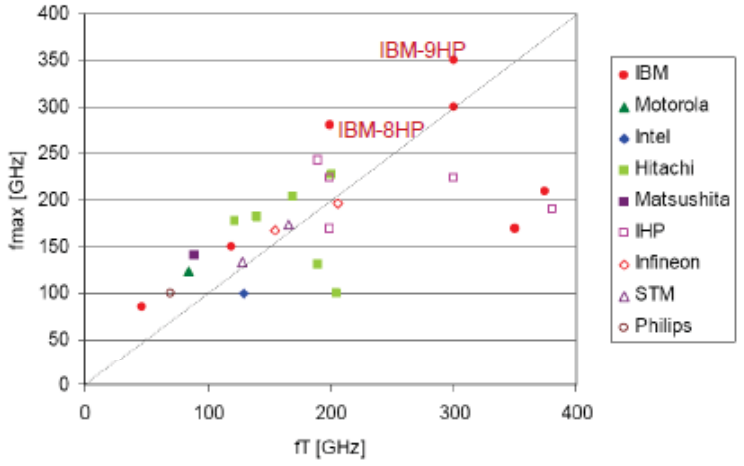
HEMT



III-V HBT



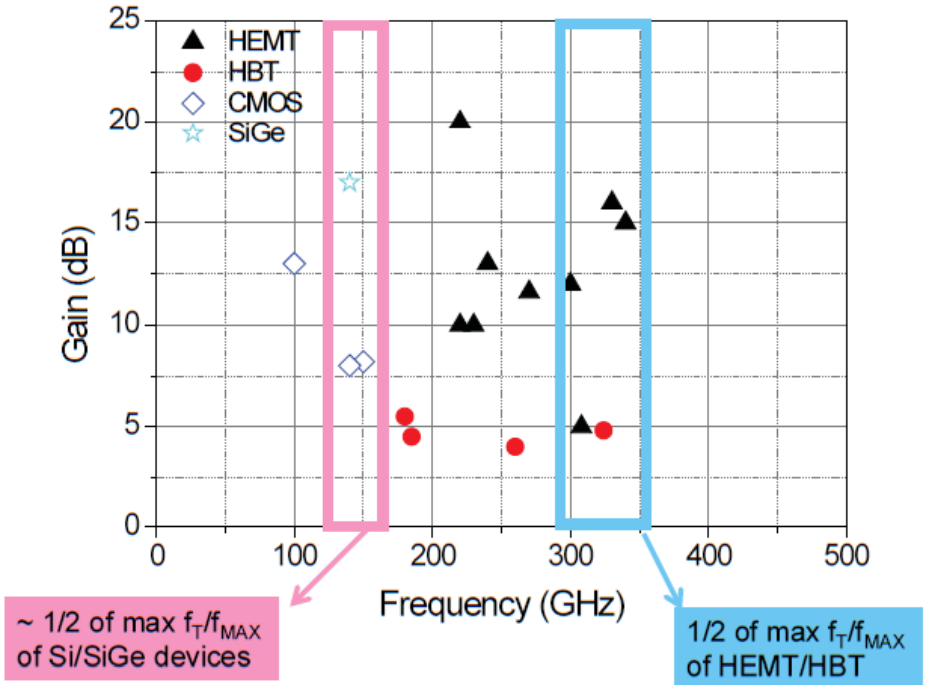
SiGe HBT

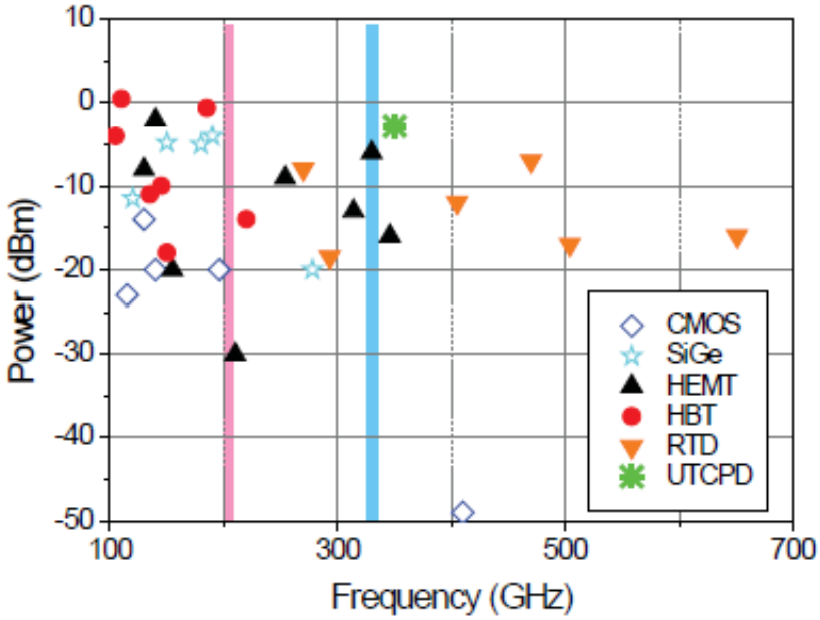


State of the art III-V devices provide 300-GHz ICs.

http://www.soumu.go.jp/soutsu/kinki/studygroup/2009/THz/report.html

- Trend of Amplifiers & Oscillaters -



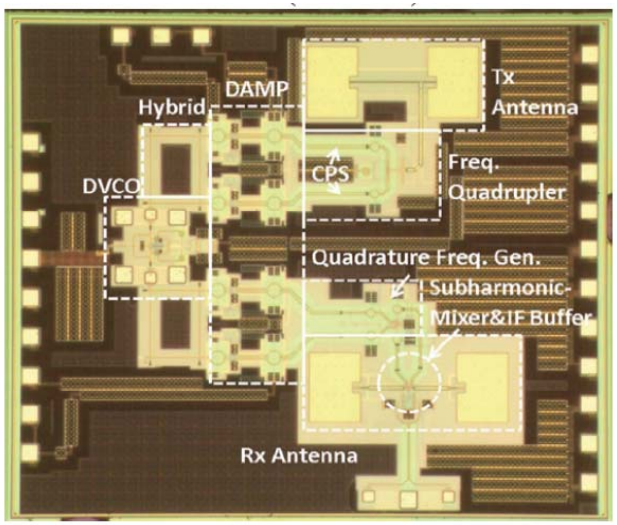


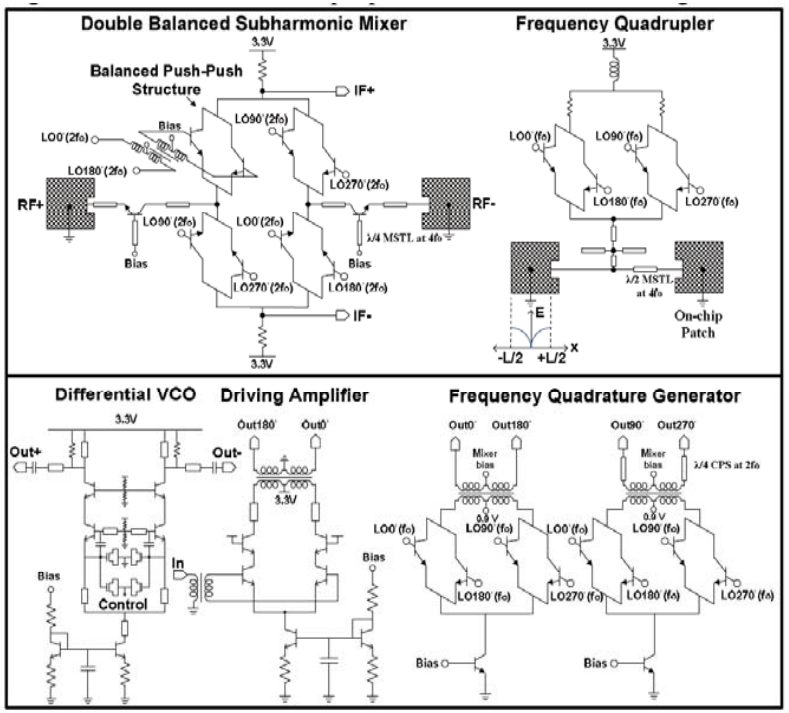
http://www.soumu.go.jp/soutsu/kinki/studygroup/2009/THz/report.html

‘A 0.38 THz Fully Integrated Transceiver Utilizing Quadrature Push-Push Circuitry’ (Park, U.C. Berkeley)

2011 Symposia on VLSI Technology and Circuits

- **130nm SiGe BiCMOS**
- **4 x LO (90 GHz) just in front of antenna**
- **Push-Push structure for multiplier and mixer**
- **On chip patch antenna**
- **Chip size: 2.2mm x 1.9mm**
- **Power consumption : 364mW**
- **For FM-CW Rader**





‘20 nm Metamorphic HEMT with 660 GHz f_T’ by A. Leuther *et al.* (Fraunhofer IAF, Germany)

IPRM2011 Tu-4.2.2 （by A. Leuther *et al.*）

Details of the HEMT with f_T=660 GHz
Metamorphic HEMT（mHEMT）（on GaAs）
Channel：$In_{0.8}Ga_{0.2}As$（double δ doping）
2DEG Density：6.1×10^{12} cm^{-2}
L_g=20 nm, L_{sd}=500 nm
R_s=0.1 Ωmm
W_g=2×10 μm
g_{m_max}=2.5 S/mm、
f_T=660 GHz ($@V_{ds}$=1 V)

・ 4 stage LNA (SMMIC)
(Sub-Millimeter-wave Monolithic Integrated Circuit)
W_g=2×4 μm (mHEMT), Gain = 10 dB @ 500 GHz
and Gain > 8 dB @ 470 ~ 500 GHz
cf. TMIC (Terahertz Monolithic Integrated Circuit)

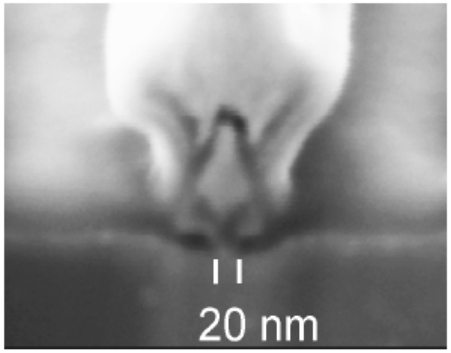


Fig. 2. SEM cross section of the 20 nm gate foot.

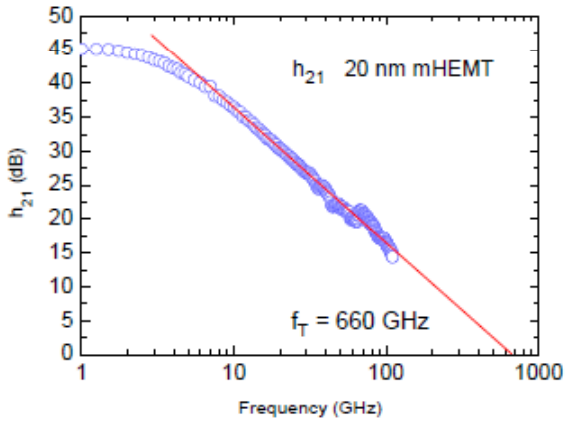


Fig. 5. Current gain h_{21} versus frequency with extrapolated cut-off frequency f_T of 660 GHz for a 2 x 10 μm mHEMT.

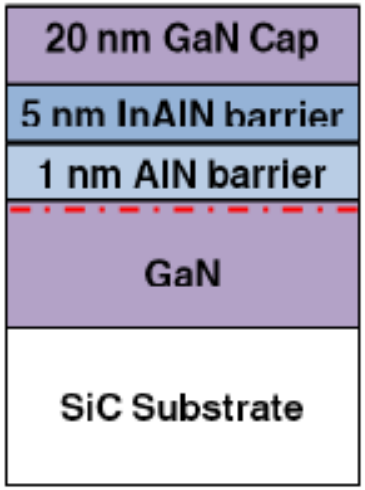
‘New Technologies for mm-Wave InAlN/GaN Transistors’ by D. S. Lee *et al.* (MIT, USA & IQE LLC, USA)

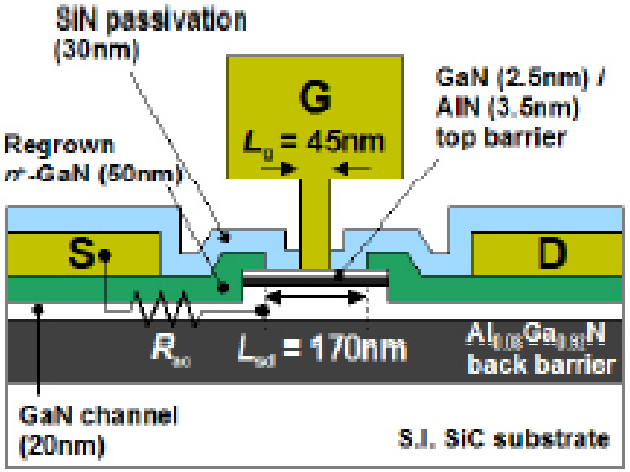
ISCS2011 Mo-2B.5 （ by D. S. Lee *et al.* ）

Tomas Palacios’s Group at MIT
Research on high speed GaN-HEMT

InAlN/AlN/GaN(/AlGaN) HEMT
L_{sd}=1.3 μm
L_g=30 nm, f_T=270 GHz （ AlGaN with back barrier ）
→WR f_T
Ion implantation → R_c=0.04 Ωmm

cf. Invited Talk by HRL Group
（ K. Shinohara *et al.*, Tu-2A.1 ）
AlN/GaN/AlGaN HEMT
L_g=45 nm, f_T=260 GHz、f_{max}=394 GHz
Ohmic n^+-GaN re-growth by MBE
→$R_{ac}=R_c+R_{2DEG}$=0.08 Ωmm





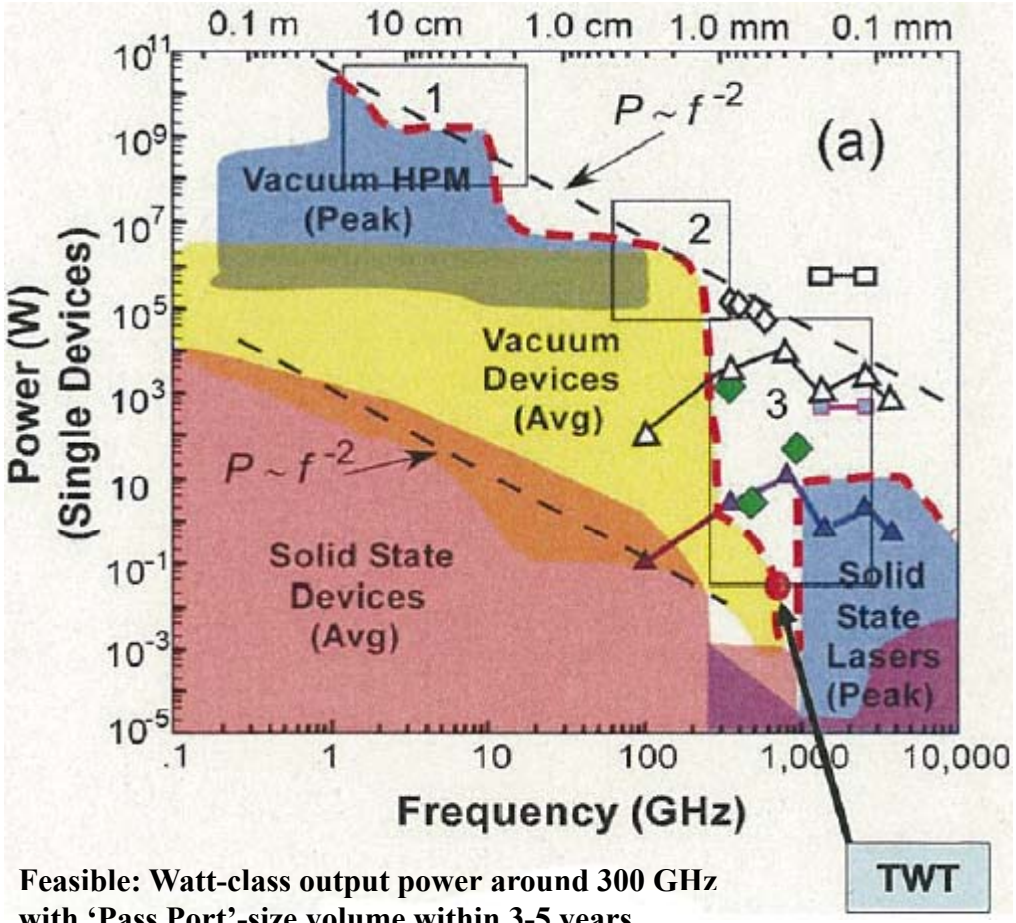
XII IEEE International Vacuum Electronics Conference
IVEC-2011, February 21 - 24, 2011
JN Tata Auditorium, National Science Seminar Complex, IISc Campus, C V Raman Avenue
Bangalore, India
Hosted by Microwave Tube Research & Development Centre (MTRDC), Bangalore, India

Plenary Talk: Dr. John Booske (Univ. Wisconsin-Madison, USA
"Vacuum Electronics Sources for High Power Terahertz-Regime Radiation"

Programs in USA
+ Darpa: HiFIVE (EIK, BWO, TWT, Gyrotron, FEL)

Elemental Technologies
+ MEMS
X-ray LIGA, UV-LIGA, DRIE, EDM, Laser Ablation
+ High Current Density Cathode
Dispenser, Reservoir, CNT, Spindt FEA,

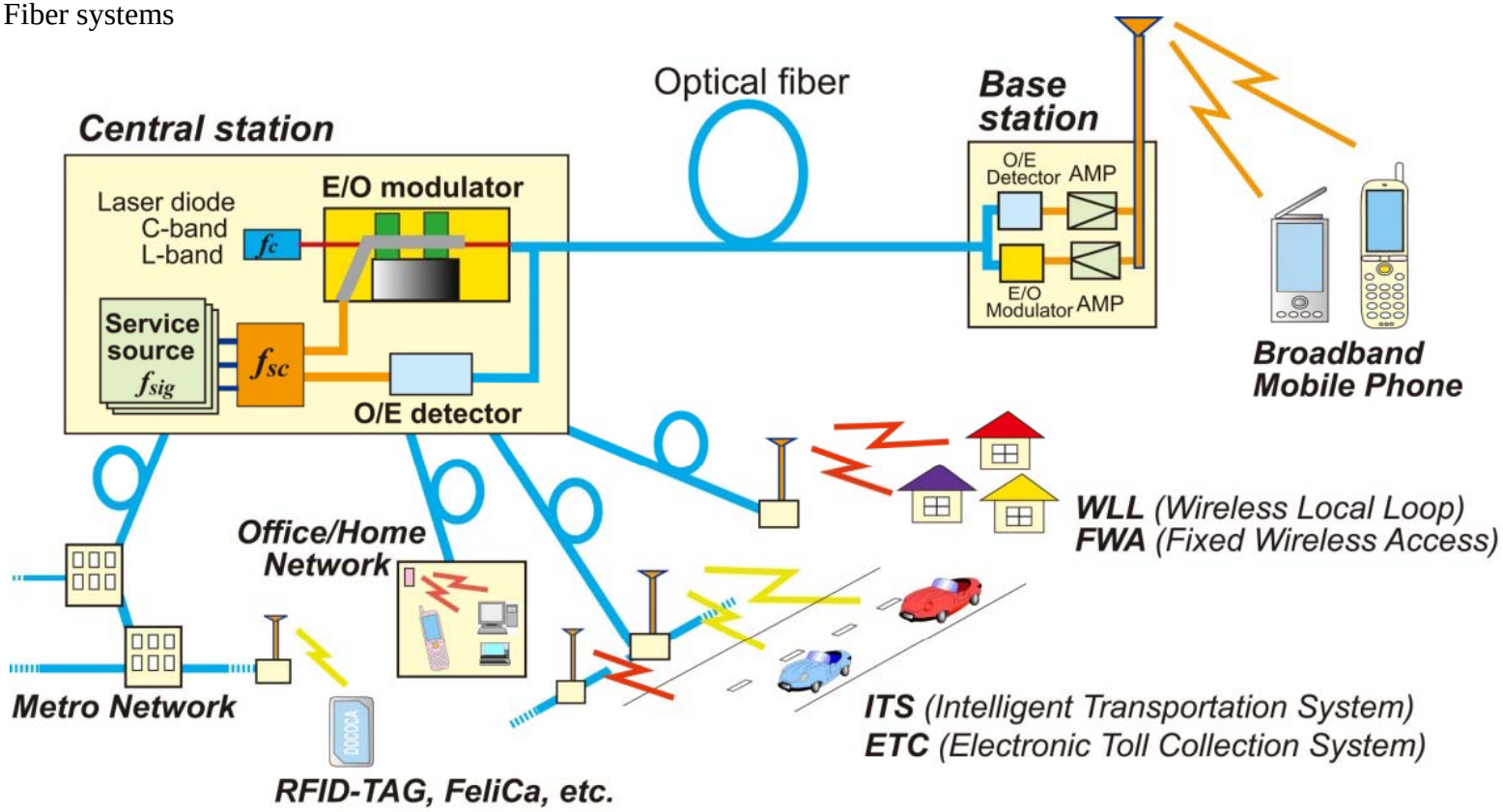
Contributed talks
- TWT AMP @220 GHz (NRL, USA)
- TWT AMP @220 GHz (UCD, USA)
- BWO @700 GHz(Istok, Russia)
- THz AMP@0.3-2THz (FP7 OPTHER)
(Gain 10-20dB, Output: 10dBm)



Feasible: Watt-class output power around 300 GHz with 'Pass Port'-size volume within 3-5 years
->>> Good for WLAN application!

Relieve bottlenecks of last-access
(No speed difference between wired and wireless)
Compatibility with optical network (Digital Coherent, RoF)

Radio on Fiber systems



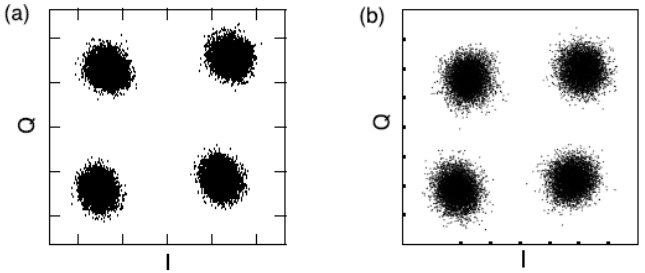
Recent Result at NICT (RoF)

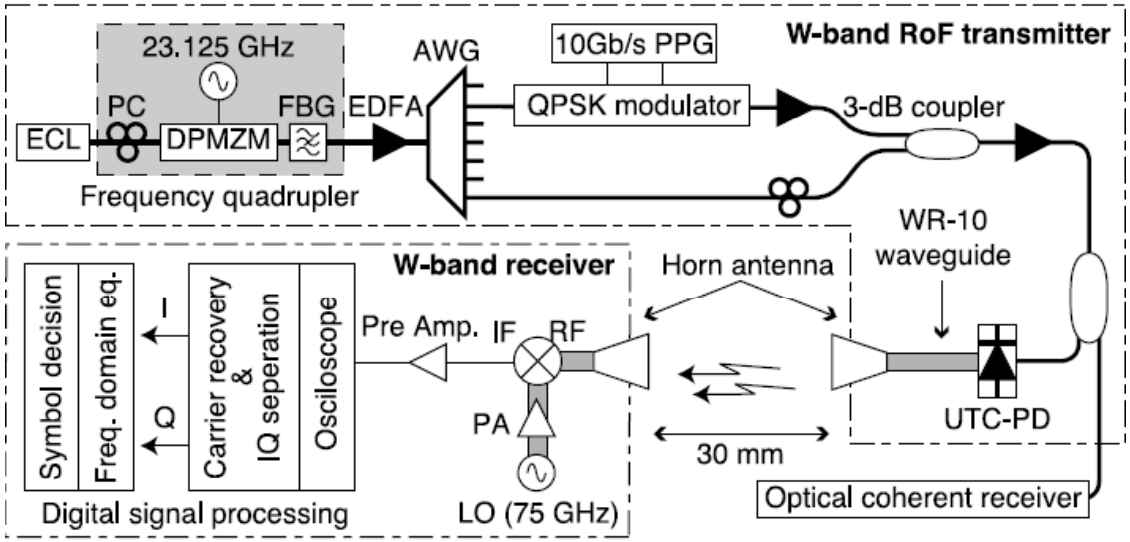
ELectronics EXpress

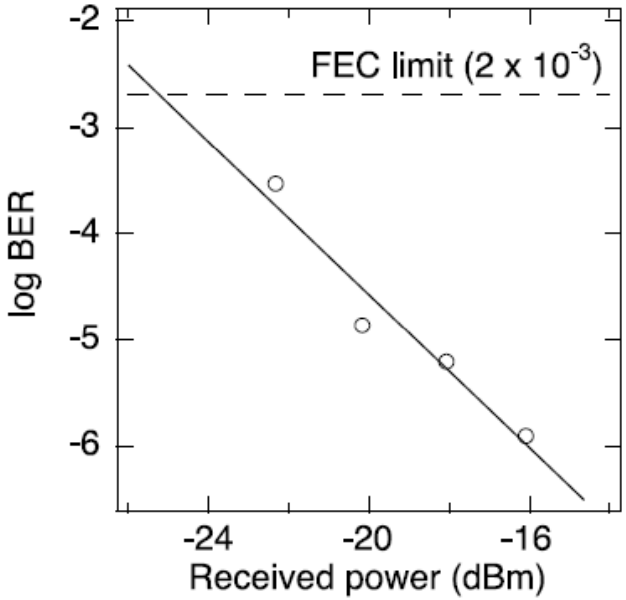
IEICE Electronics Express, Vol.8, No.8, 612–617

20-Gb/s QPSK W-band (75–110 GHz) wireless link in free space using radio-over-fiber technique

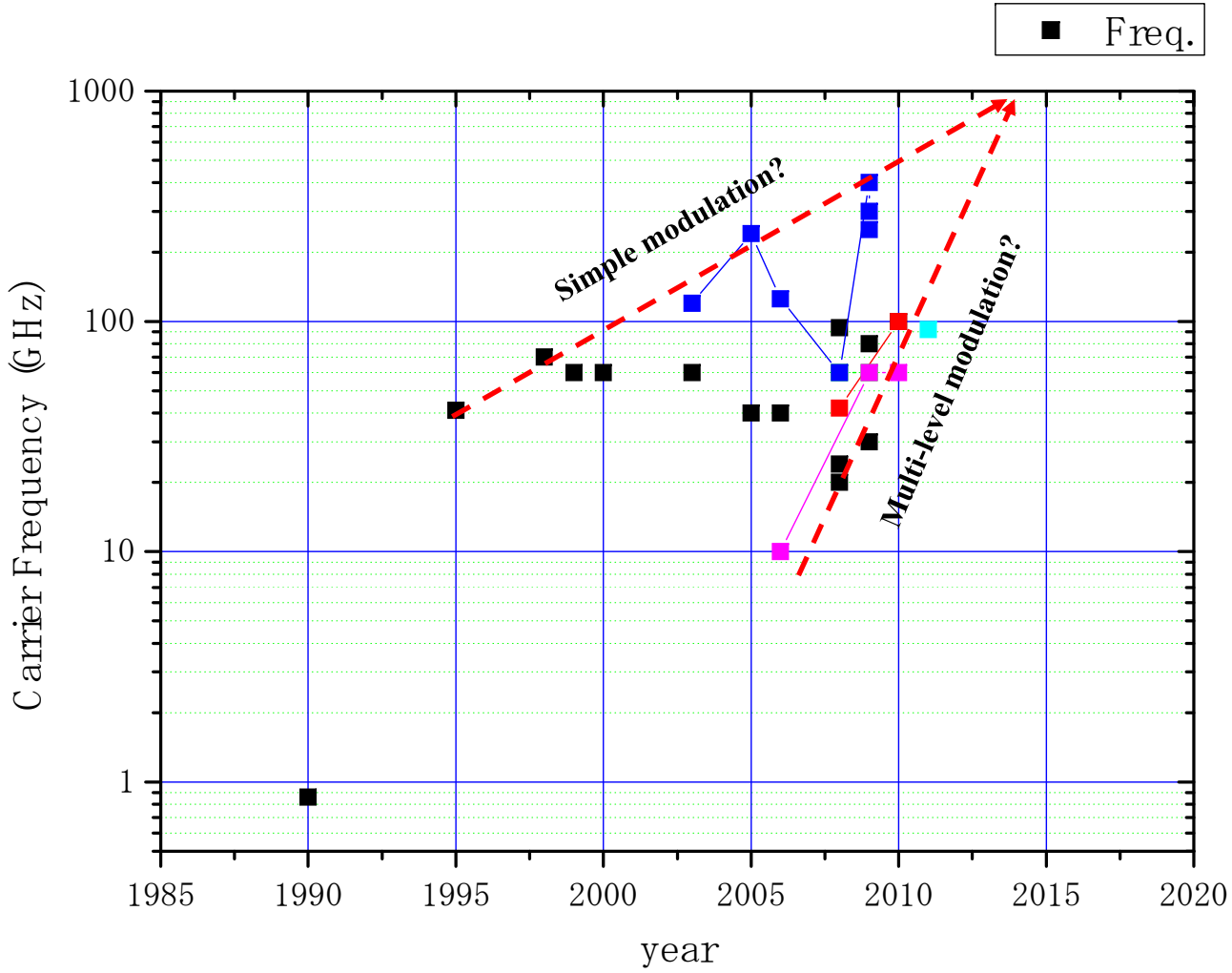
Atsushi Kanno[1a)], Keizo Inagaki[1], Isao Morohashi[1], Takahide Sakamoto[1], Toshiaki Kuri[1], Iwao Hosako[1], Tetsuya Kawanishi[1], Yuki Yoshida[2], and Ken-ichi Kitayama[2]



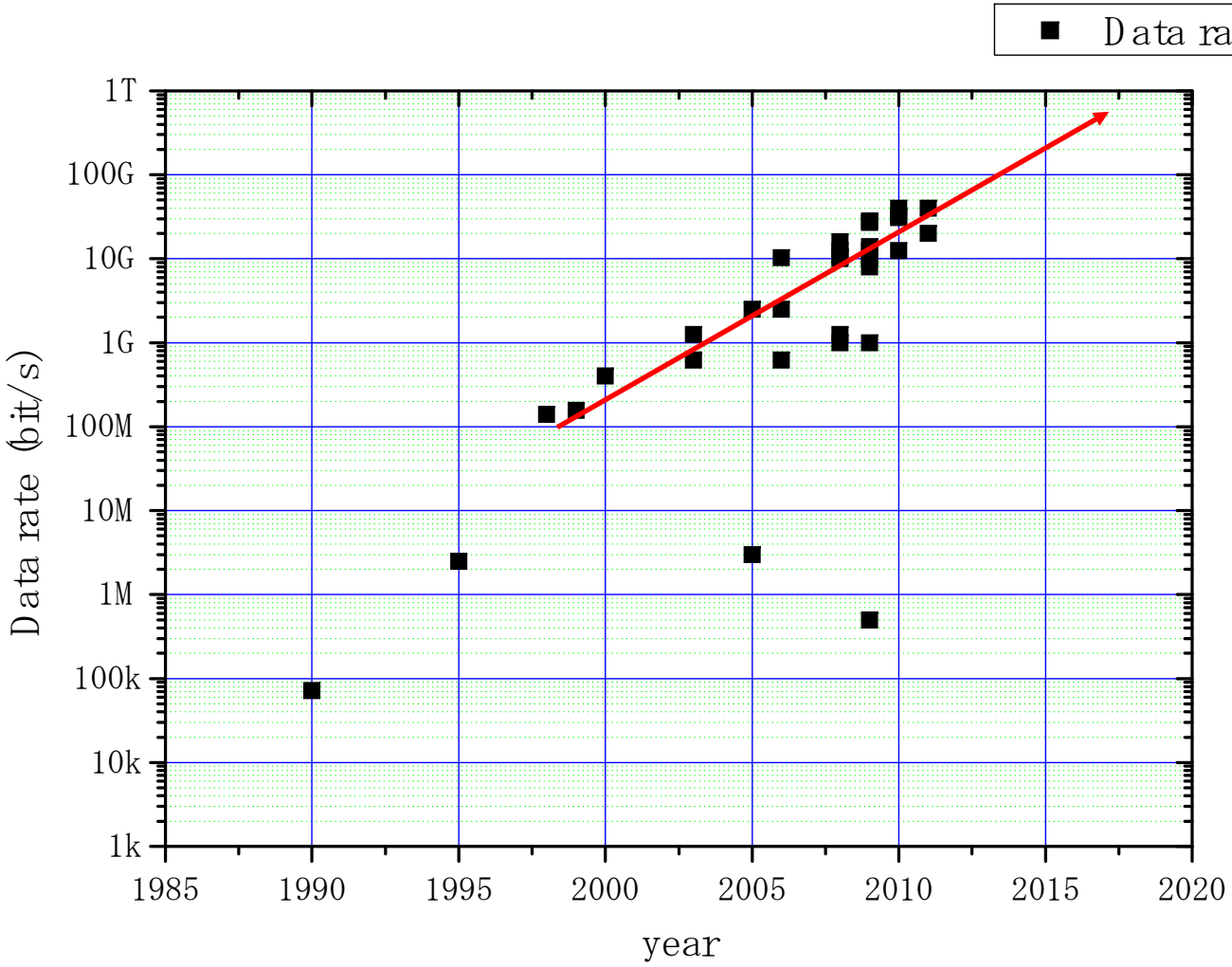




Trends of Radio on Fiber Technology: Carrier Freq.



Trends of Radio on Fiber Technology: Data rate



Summary of Discussions

Points !
(1) Ultra-high speed >> 10 Gbit/s, (Potentially 100 - 400 Gbit/s (multilevel modulation))
(2) Small size instrumentations (Antenna, Chip), Possible to install on the mobile terminals.
(3) High speed electronics (MOS, GaN, InP, Vacuum) will be ready to use within 5/10 years
(4) (Probably) Low power consumption / bit

Benefits
(1) Relieve bottlenecks of last-access (No speed difference between wired and wireless)
(2) Realize easy access to the cloud
(3) Ultra-high speed wireless interfaces (Probably, reconfigurable)
(4) Possible contributions to “Energy Saving” and “Human Life”

IEEE 802 Five Criteria

- Broad Market Potential
- Compatibility
- Distinct Identity
- Technical Feasibility
- Economic Feasibility

Thank you for your attention!