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

Submission Title: [THz Wireless Beyond 10 Gbps]
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Re: [THz Call for Applications, IEEE P802.15-09/0534r3.]

Abstract: [This presentation will introduce the recent research developments in the THz Science & Technology program (supported by SERC), on the next generation wireless communications beyond 10 Gbps. Issues on circuits and systems designs operating at 135 GHz and 300 GHz will be discussed. Results on 300 GHz wideband propagation channel with tens GHz bandwidth will also be presented.]

Purpose: [Inputs for future IEEE 802.15 THz Study Groups]

THz Wireless Beyond 10 Gbps

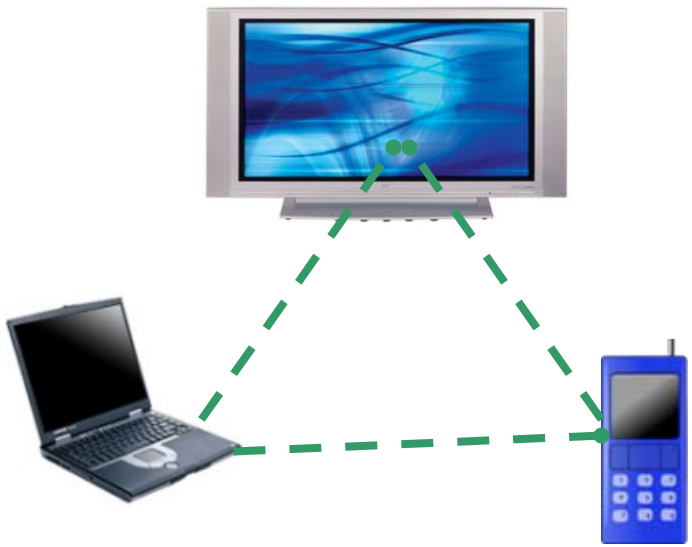
By .Dr. Michael Yan-Wah CHIA

Institute for Infocomm Research, A*STAR

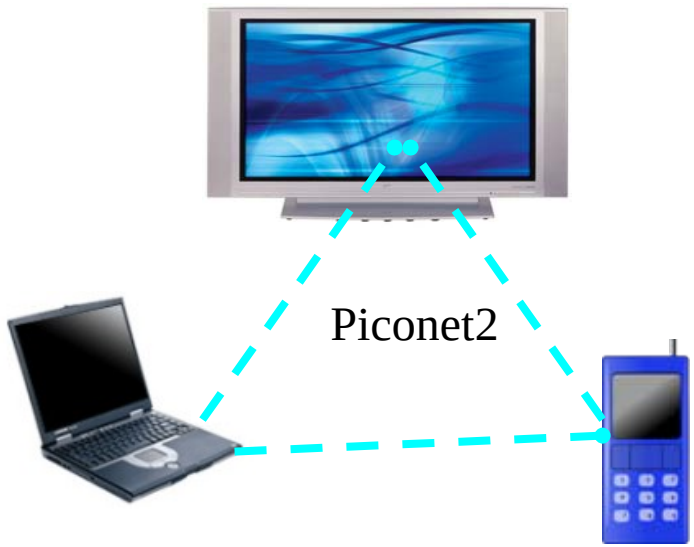
Introduction

- Motivations
- Possible Circuits and System implementations
- THz Wireless channel for 10 Gbps
- Preliminary results
- Conclusions

Wireless Piconets (High Speed?)



Piconet 1

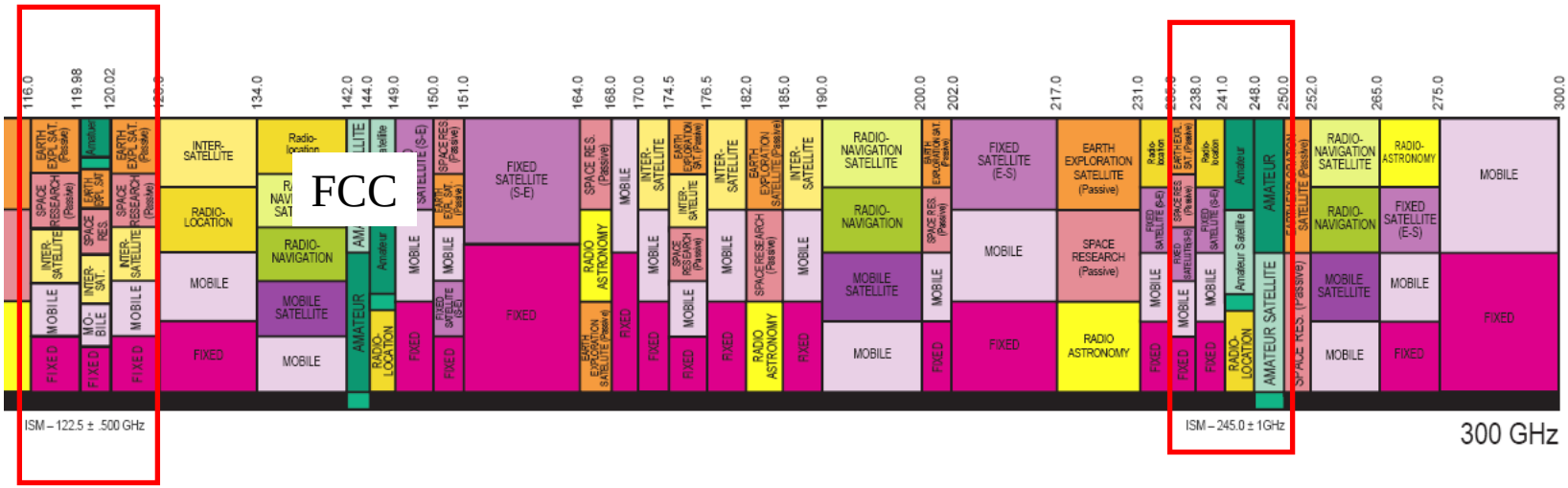


Piconet2

Motivations

- Demand for Gbps high speed communications. High Speed Wired/Optical communications system has been steadily increasing in speed from 10 Gbps to100 Gbps..
- Short range 60 GHz wireless at Gbps for cable replacement for HDMI,etc is a potentially huge market.. But spectrum is still limited at 60 GHz band for applications that require >10 Gbps.
- Rapid advancement of silicon IC designs & fabrications towards 500 GHz (ft)..
- Even III-V solid state devices can achieve >300 GHz for PA and LNA..(industry), ft > 1THz (2 years ago)…Steadily extending to 600 Ghz supported by DARPA.
- Today, many hand-phones & Wireless LAN in the mass market still use III-V Ga-As FET for RF Power Amplifier front-ends..
- It is conceivable that a hybrid Silicon and III-V devices can provide an interim solution at the RF front-end for potential mass market Gbps communications especially for 300 GHz..
- Great Potential remains untapped at THz for commercial or industrial applications.

Motivation ..Spectrums



IEEE 802.15 maybe able to help the regulatory to exploit THz bands ..(IEEE IGTHz , David Britz).

IDA

Wide ISM bands at THz are availiable in Singapore so far!

IDA has been active in ICT. They have contributed to UWB standardizations to ITU in esp. in the early phase ..Deployment of 1 Gbps fiber to every home in Singapore by 2010.,.etc..

Motivations ..finally

- SERC of Agency for Science Technology and Research, (A*STAR) of Singapore, has initiated a new THz science and technology program with 5 Research Institutes, I^2R, IME,DSI,IMRE and IHPC (more than 30 researchers) since 2008..which spans from THz photonics to electronics..(10 Gbps THz is a major part of this program)
- Background..

-I^2R has been an active contributor to wireless standards:

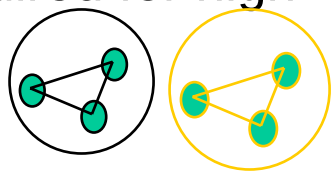
-IEEE 802.22-spectrum sensing, 802.11n, 802.15.4-coding and channels schemes, 802.15.3-OFDM,later UWB-ECMA.)…

-Recently, we have been developing Gbps transceivers for 60 GHz, IEEE 802.15.3c..

-THz is part of roadmap for next generation wireless at 10 Gbps.

Possible parameters for high speed wireless communications at THz

- Difficulty in implementing modem for wireless at >10 Gbps to 100 Gbps.
- Simple digital modulation schemes are required for high speed minimum
- Amplitude Shift Keying (ASK)..
- Binary Phase Shift Keying (BPSK), etc



- Assuming a 5 to 10 GHz channel to cater for >10 Gbps..
- We will need many channels for multiple devices to cater to a multiple access piconet scenario with many users.
- E.g. re-use of 4 piconets may require 4X10 GHz(40 GHz spectrum) channels, which is very wideband.
- Today, for 60 GHz system to cater 10 Gbps, will consume most of the 7+ GHz spectrum for one piconet..
- 300 Ghz is 5 times higher than 60 GHz! How wide are these channels for >10 Gbps? ...

Brief review of the state of the art- THz devices & circuits

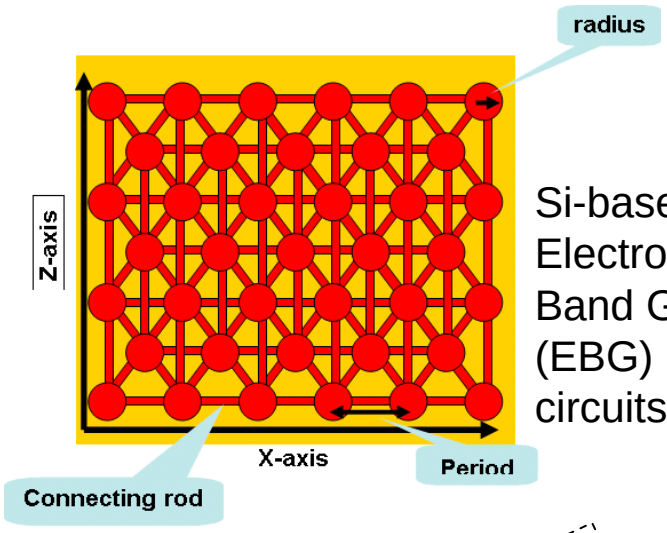
- III-V solid state device exist today for 340 GHz LNA and PA (Northrop-funded by DARPA)
- 600 GHz III-V solid state circuits are undergoing development-expect appear within 2 years time by 2011.
- III-V Diode based circuits is used in remote sensing up to several THz….Expensive still due to limited usage..
- Automotive radar transciever using SiGe at 76-81 GHz band is already available..
- Currently, the European consortium, DOTFIVE is pushing for SiGe (ft is 500 GHz) by early 2011.. if not earlier..
- SiGe diode based for RF front-end for subharmonic mixers (e.g..IBM,etc) is possible..
- There are some works on circuit for Silicon CMOS demonstrated at 400 GHz but the output power remains low.
- Digital CMOS is capable of processing 10 Gbps data but Design for Data converters (ADC & DAC) to sample such wideband data remain challenging but technically feasible..

Our THz Si-Based Wireless RF Module

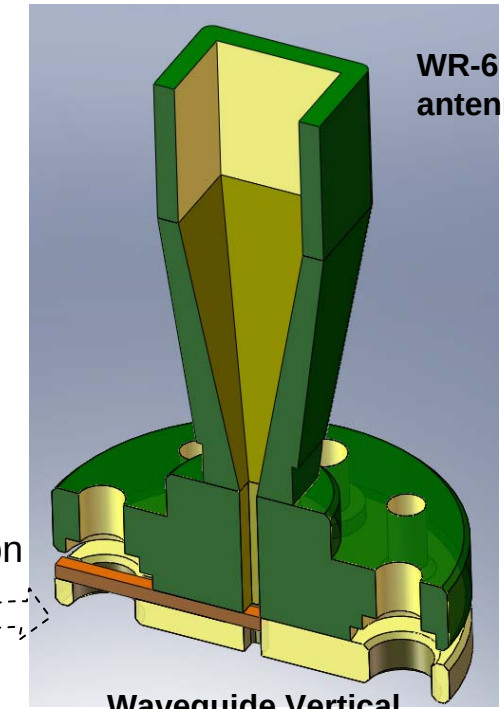
- Motivated by ISM bands by spectrum regulators at 100+ GHz bands..
- Technology Driven (based on Silicon)
  - As the SiGe transistor is approaching THz - f_T ~500GHz
  - Potential of 3D integration and Si micromachining technologies
    - Lower loss, higher operating frequency and cost effective
- We aim to develop Silicon based technology for next generation wireless comms module
  - 135GHz SiGe Transceiver IC at A*STAR.
  - Si based high frequency passive circuit, interconnect and 3D integration

Silicon based 135GHz RF front-end

Low cost!



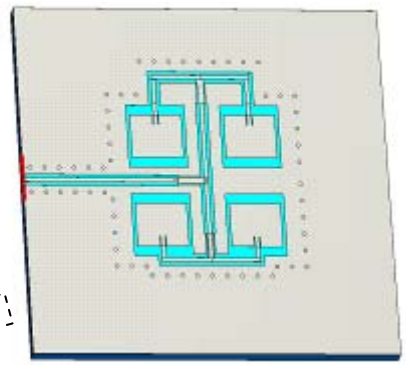
Si-based Electronic Band Gap (EBG) passive circuits



WR-6 high gain horn antenna

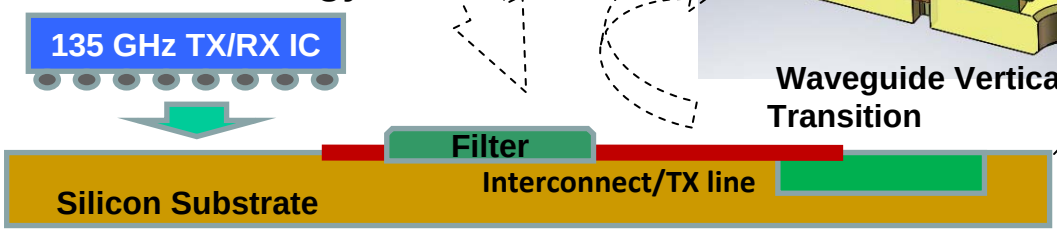
Source: IME,,IHPC,I2R

Si-based array antenna



Direct Integration

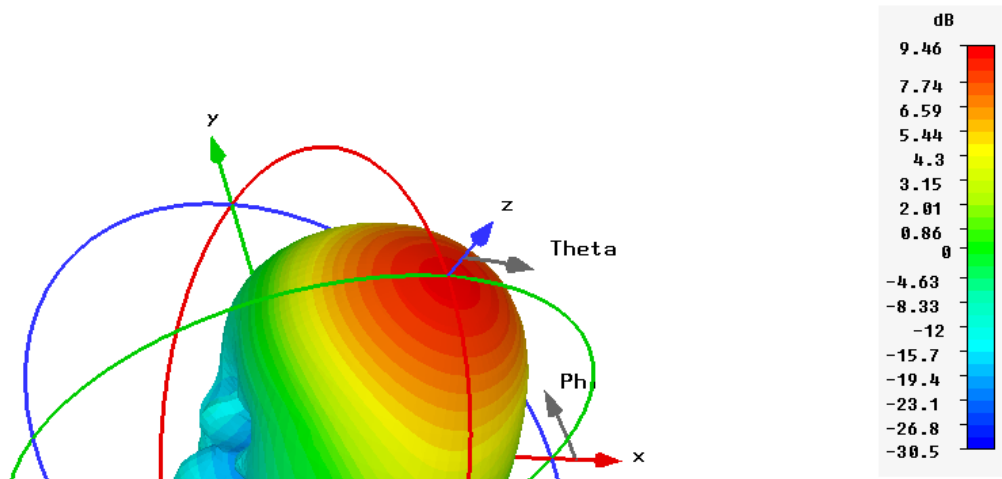
SiGe technology



Waveguide Vertical Transition

High circuit and functional integration, Normal Silicon micromachined substrate with polymer

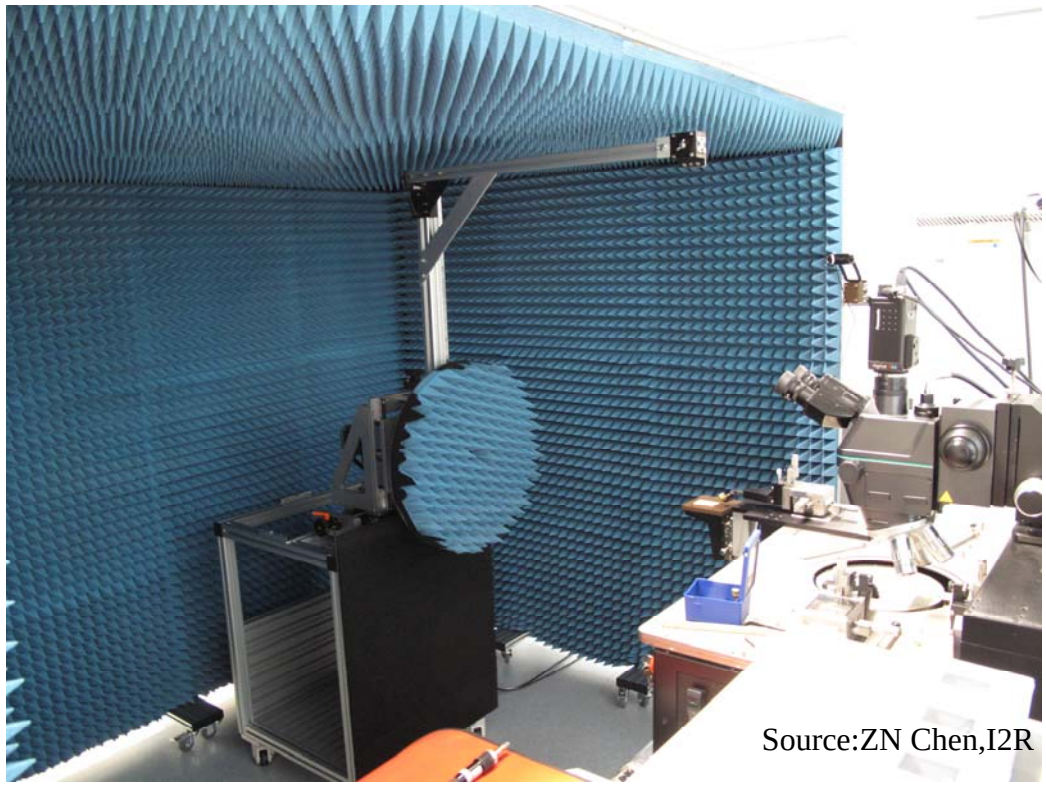
Antenna Radiation Pattern at 135 GHz



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=135) [1]
Component	Abs
Output	Gain
Frequency	135
Rad. effic.	-2.940 dB
Tot. effic.	-2.949 dB
Gain	9.456 dB

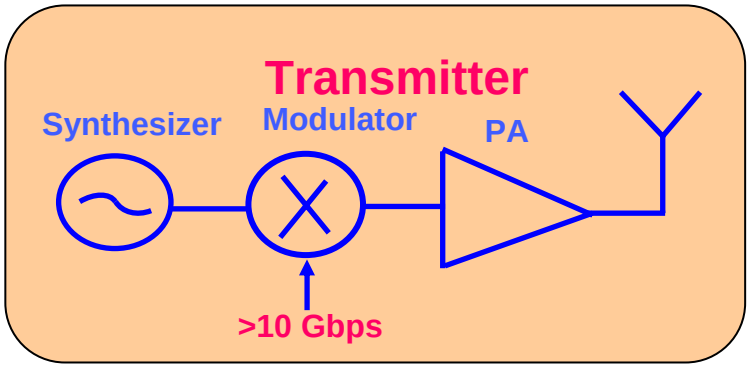
Source: Chen ZN,I^2R

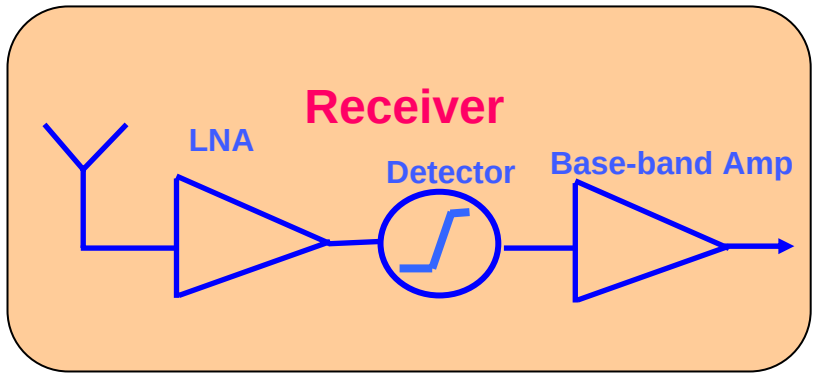
One of the Anechoic chamber at A*STAR for mmwave antenna measurements



Source:ZN Chen,I2R

Silicon based Transceiver at 135 GHz





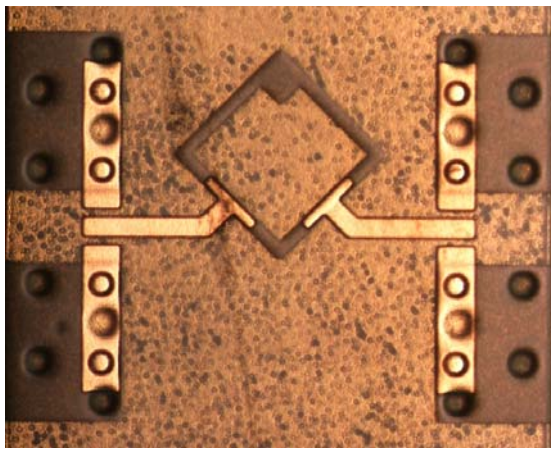
Source: Xiong YZ, IME

Short range wireless communications

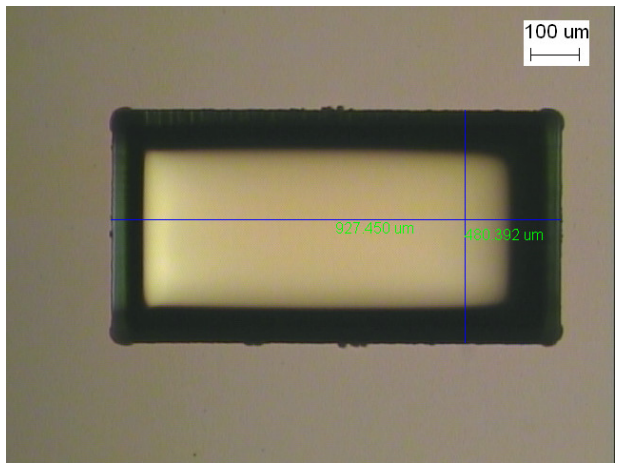
SiGe is our interim RFIC solutions..

Increasing S/N is crucial to maximize the distance and performance for >10 Gbps

RF MEMS at A*STAR



TFMS filter

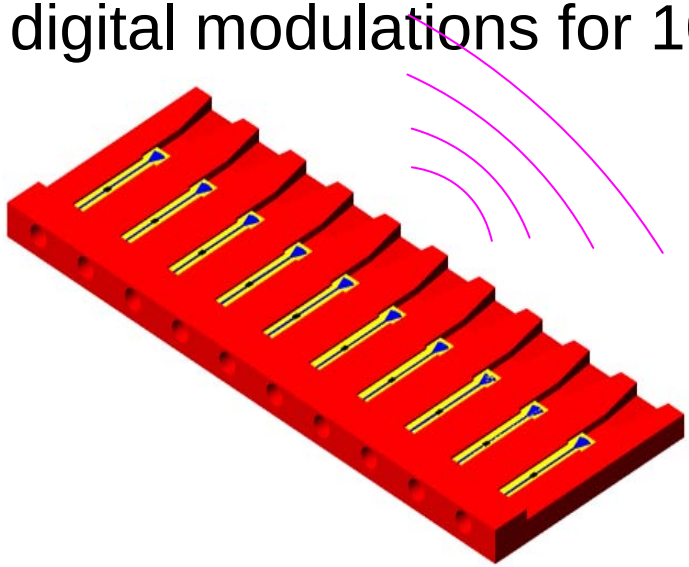


BCB structures

Source: TG Lim, IME

Wideband 300 GHz transmitter array for high speed 10Gbps & beyond

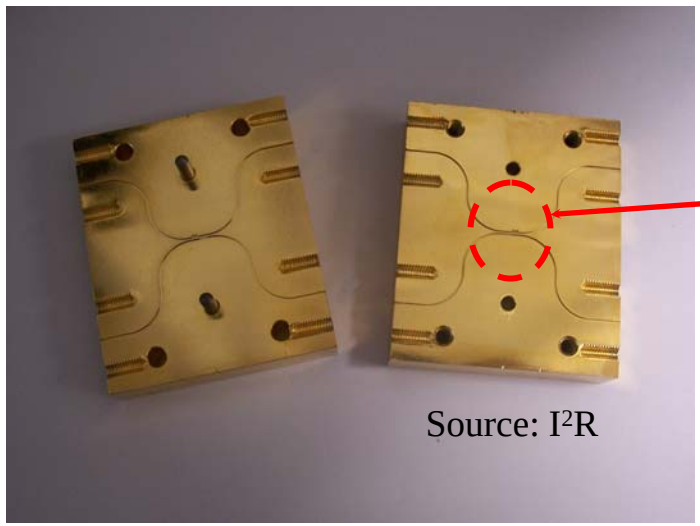
- Currently, THz solid state devices has limited RF output power.
- Developing transmitter array at 300 GHz to boost the desirable transmitted power..
- ASK & BPSK digital modulations for 10 Gbps and beyond...



Source: I^2R

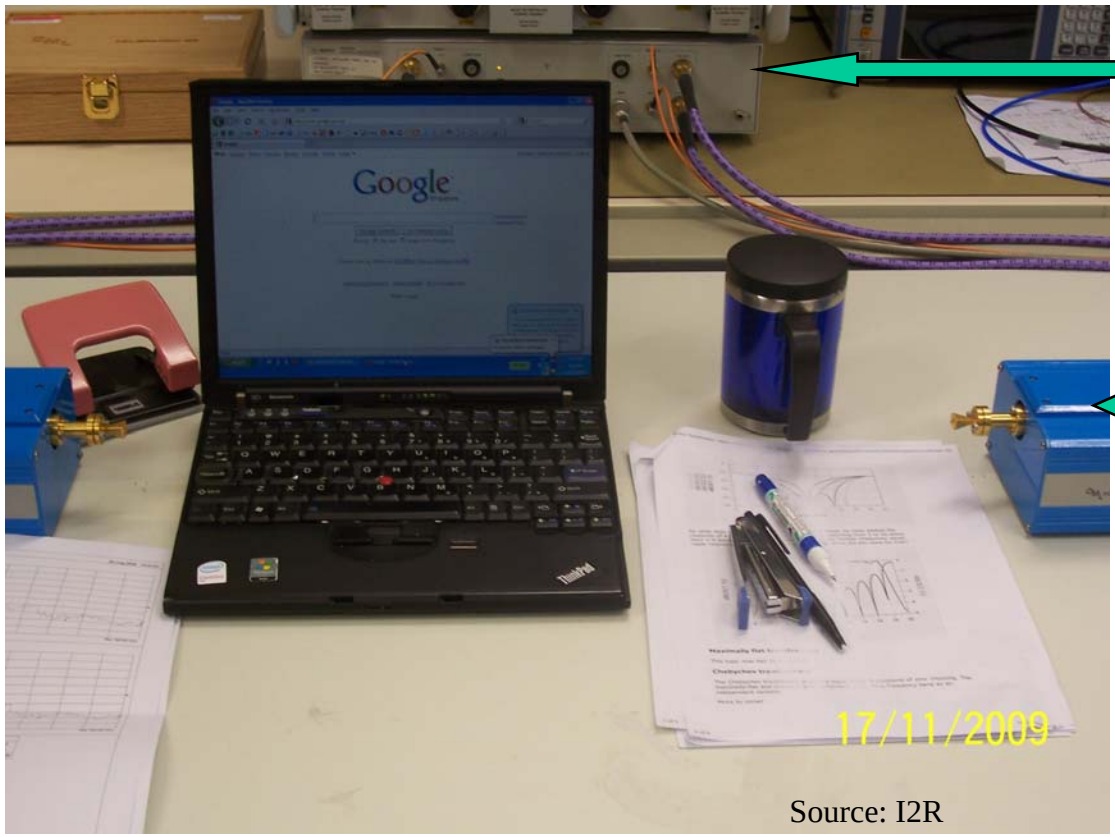
300 GHz transceiver designs

- A hybrid silicon circuits and III-V based circuits.
- Circuits integrated within WG modules at 300 GHz band



Submillimeter dimensions of micomachined passive circuits..

Propagation channel measurements (table-top) for typical office or lab environment..

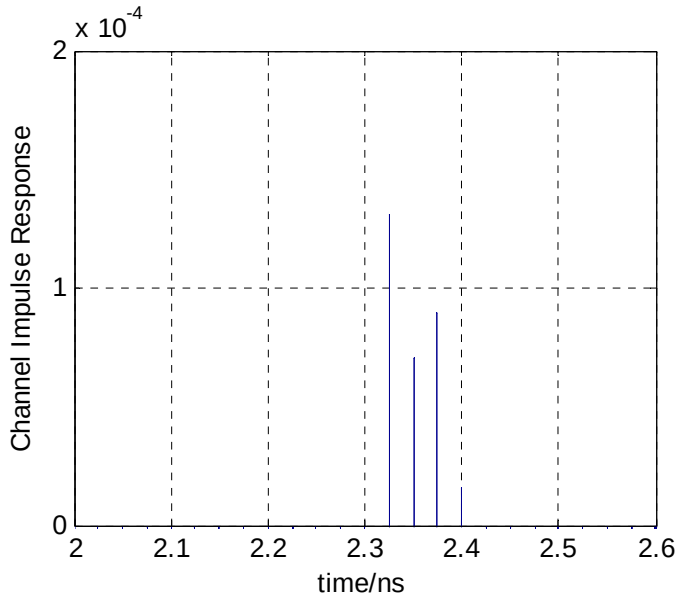


Source: I2R

Agilent Vector Network Analyser

OML head Up to 325 GHz

Preliminary Results



Source:I^2R

- Measured Channel Impulse Response at about 300GHz over tens of GHz bandwidth with resolutions in the order of picoseconds....
- Multiple delays of the THz signal i.e. multi-paths effects can be observed due to scatterings by the neighboring objects.

Conclusions

- Technically seems feasible to implement RF transceivers at 135 and 300 GHz..
- Low cost RF transceiver solutions using SiGe for 135 GHz seems economically possible for the nearer term..
- With Silicon (SiGe) device reaching 500 GHz ft in the near future, 300 GHz transceiver RFIC should be possible soon.
- Potential solutions using a hybrid silicon and III-V solid state devices can be considered for >300 GHz..
- Need to characterize and understand the realistic wideband propagation channels (tens GHz bandwidth over 300 GHz) ..to cater for multiple piconets operating at a minimum of 10Gbps.. More measurements and modeling studies are still required.

Acknowledgments

- Thanks to TG Lim (IME), CK Ang(I^2R), ZN Chen(I^2R), Jason Ng (IHPC), YJ Xiong (IME), Luo Bin(I^2R),Adrain(I^2R) and the various team members from project P3 & P4 for providing their inputs/slides.
- Funding support from the SERC (Science and Engineering Research Council) from A*STAR for the THz science & technology Inter-RI program in Singapore.

THE END of my presentation

THANK YOU

for your kind attention..

http://thz-program-singapore.i2r.a-star.edu.sg/serc.htm