

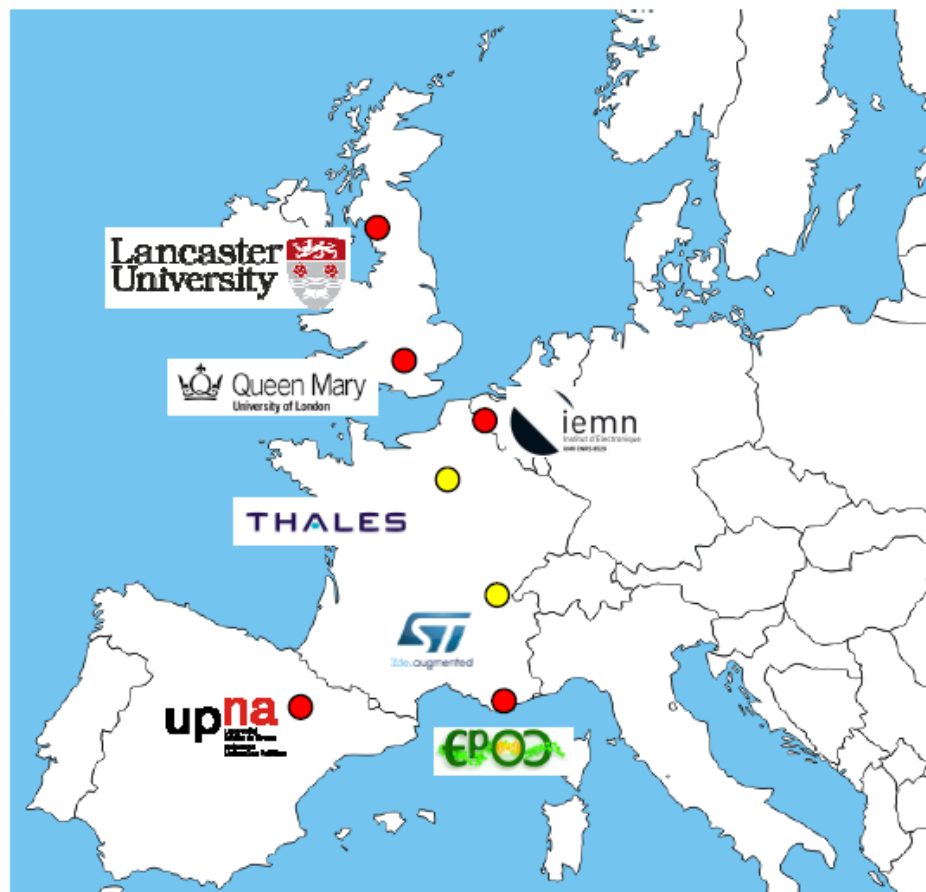
TMCS 2015

Terahertz Band for Next-Generation Mobile Communication Systems (TMCS)

Partner ●

Industrial
support ●

UC Davis/DMRC:
(USA)



TMCS 2015

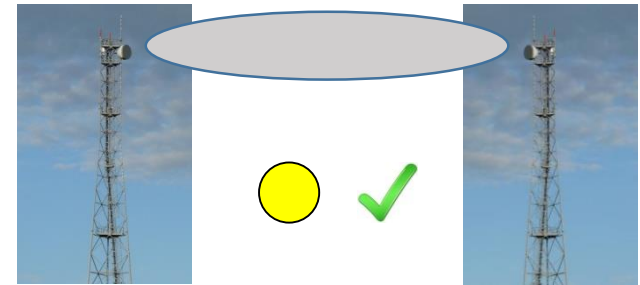
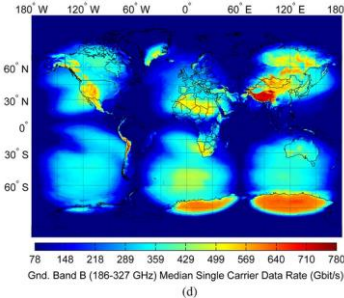
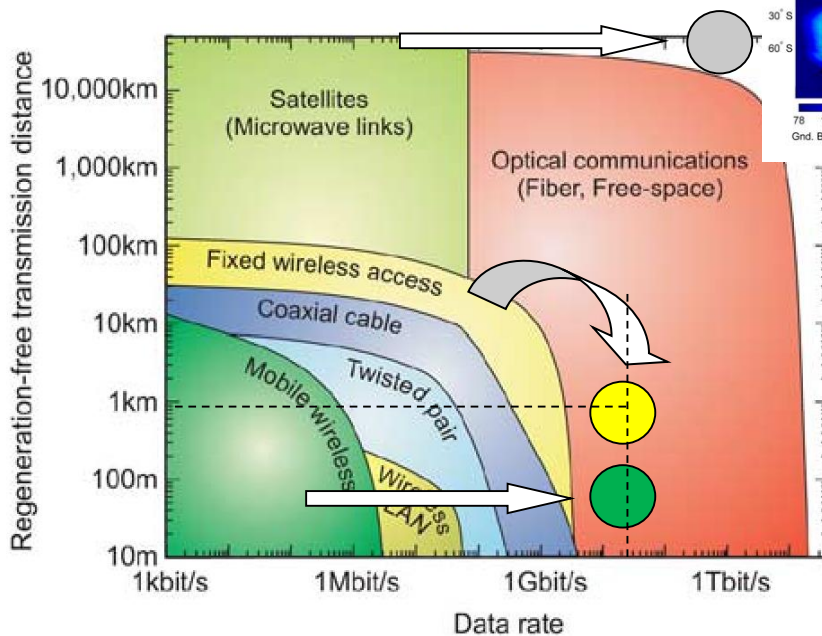
Terahertz Band for Next-Generation Mobile Communication Systems (TMCS)

Outline

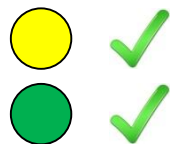
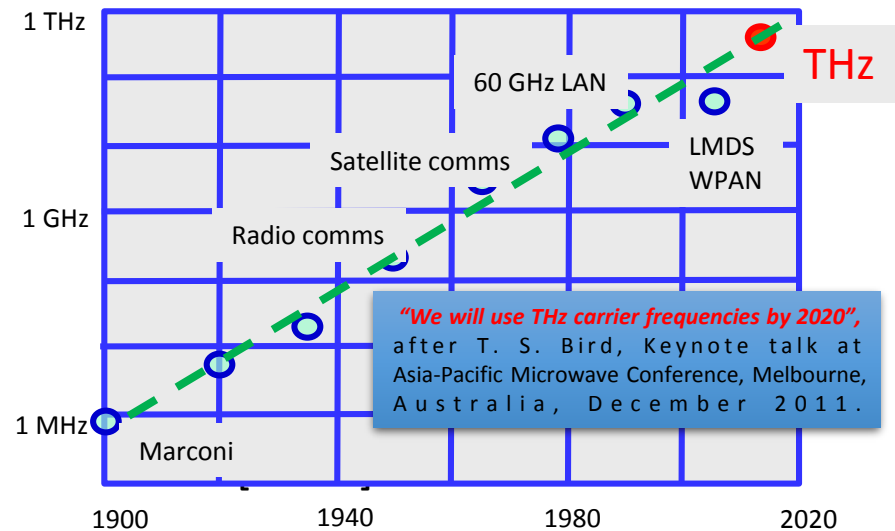
- Scientific background
- Key challenges and potential impact of the project
- Presentation of each partner of the consortium with their specificity and added value
- Main scientific results, dissemination and other output
- Sustainability/Valorisation

- **Scientific background: why THz frequencies?**

- Context: **Possible interest for THz?**



- Line of sight, Point to point

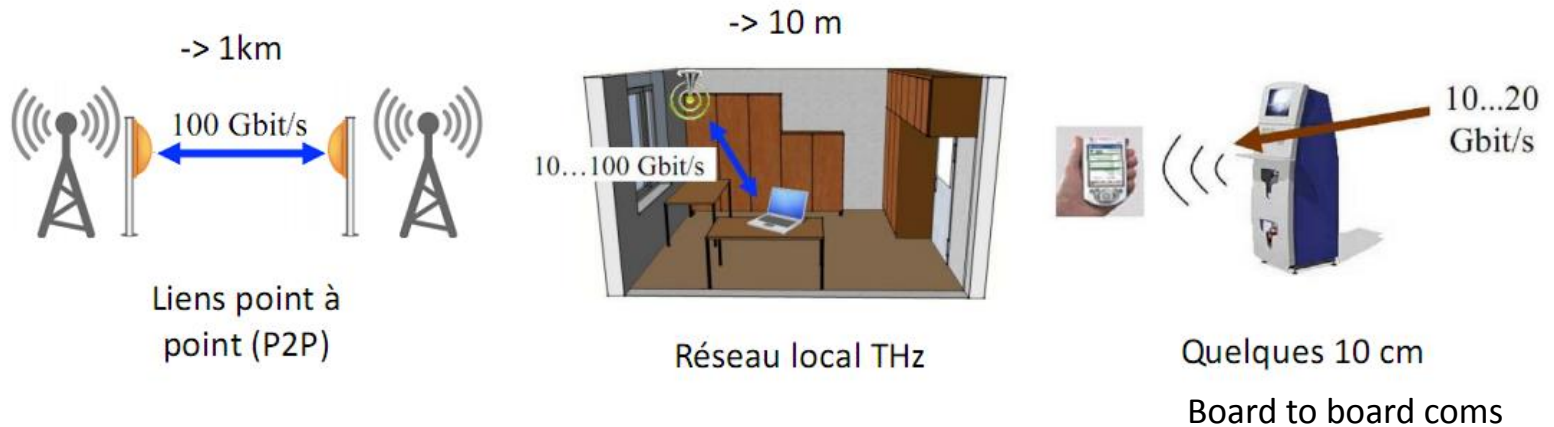


Future P2P links



Future mobile wireless links

- **Scientific background: why THz frequencies?**



Fiber-optic compatible (1.55 μm).

Alternatives

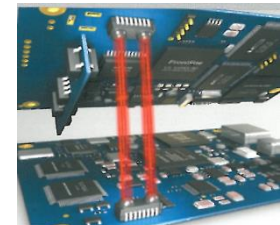


« FSO »
(Free Space optics,
0.4 / 0.78 μm)
(ex: Intellimax) ~ Gbit/s

Backhaul Q & E-band

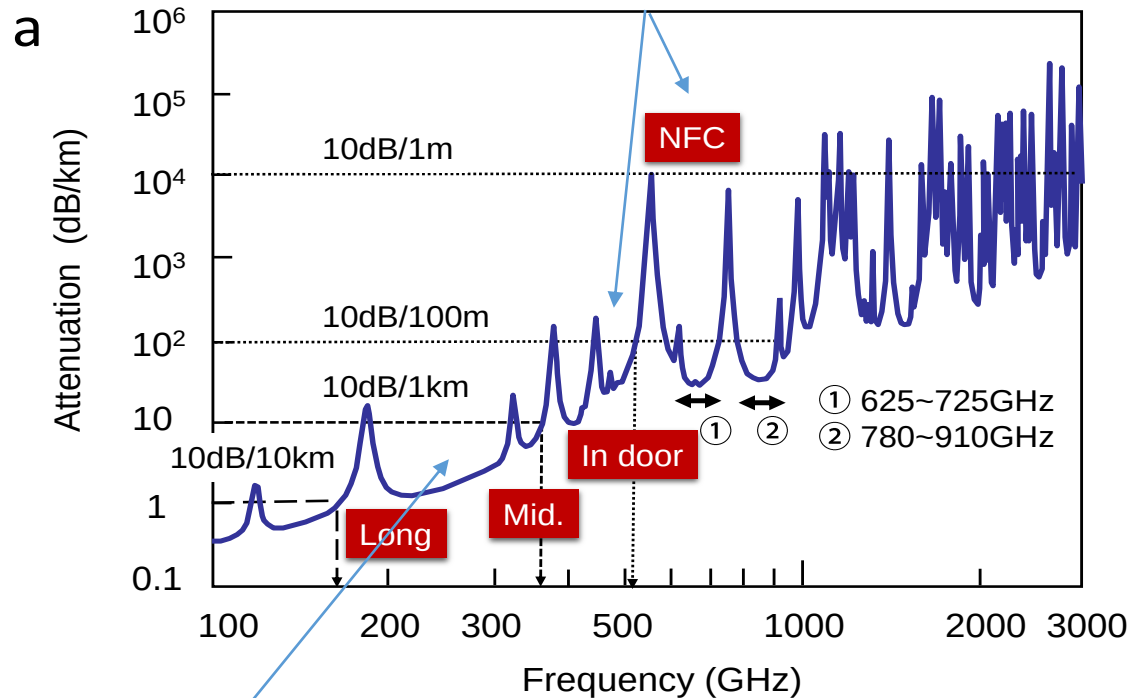
ELVA: 10 Gbps / 10
km (clear sky)

Compete with:



Indoor THz : small cells, frequency re-use.

- **Scientific background: why THz frequencies?**



Point to point

T. Nagatsuma, G. Ducournau, C.C. Renaud

Nature Photonics 10, 371–379 (2016)
doi:10.1038/nphoton.2016.65

Major interest in 300 GHz-band:

- Technologies start to be available
- Link budget is ok for km-range links
- Frequencies not allocated > 275 GHz

- ***A new paradigm at THz frequencies?***

THz frequencies: one (big) difference with usual radio waves:

$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

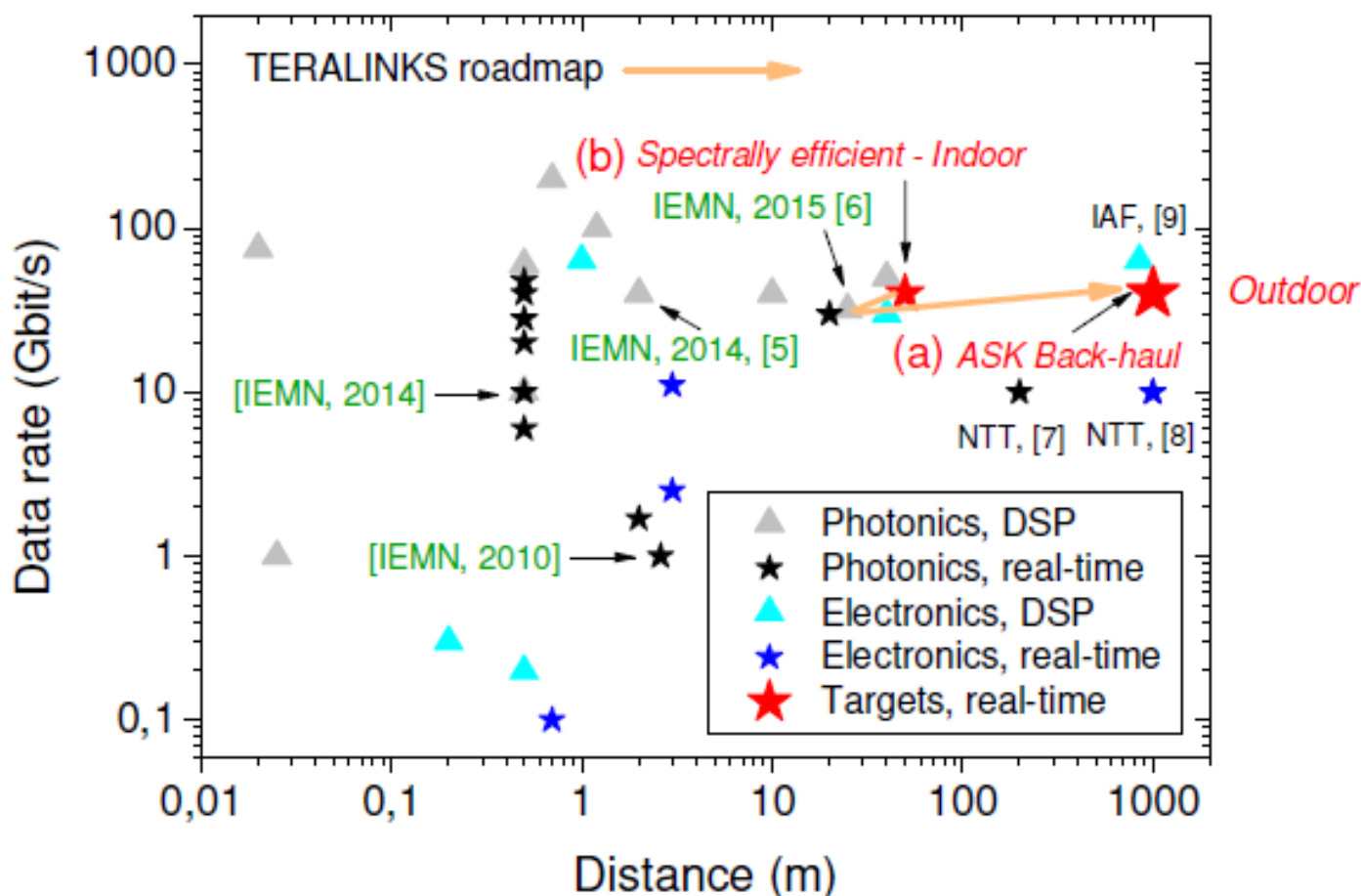
From Shannon theorem: B bandwidth, S/N = signal to noise ratio, C = channel capacity

RADIO: **Small B**, thus high **S/N required/complex modulations**

THz: **Huge B**, thus more margin on S/N (in theory)...
However THz power is often limited
=> **Importance** of amplifiers, as SSPA, Tube, LNAs...)

	RADIO	THz
B		
$\frac{S}{N}$		

- **Potential impact of the project: where we want to go within TERALINKS?**



- ***Potential impact of the project: strong interest for THz datacoms, as a new IEEE standard has been released***

IEEE STANDARDS ASSOCIATION



IEEE Standard for High Data Rate
Wireless Multi-Media Networks

=> IEEE 802.15.3d

Amendment 2: 100 Gb/s Wireless
Switched Point-to-Point Physical
Layer

F.A.Q. (Frequently asked questions)

Do we really need this?

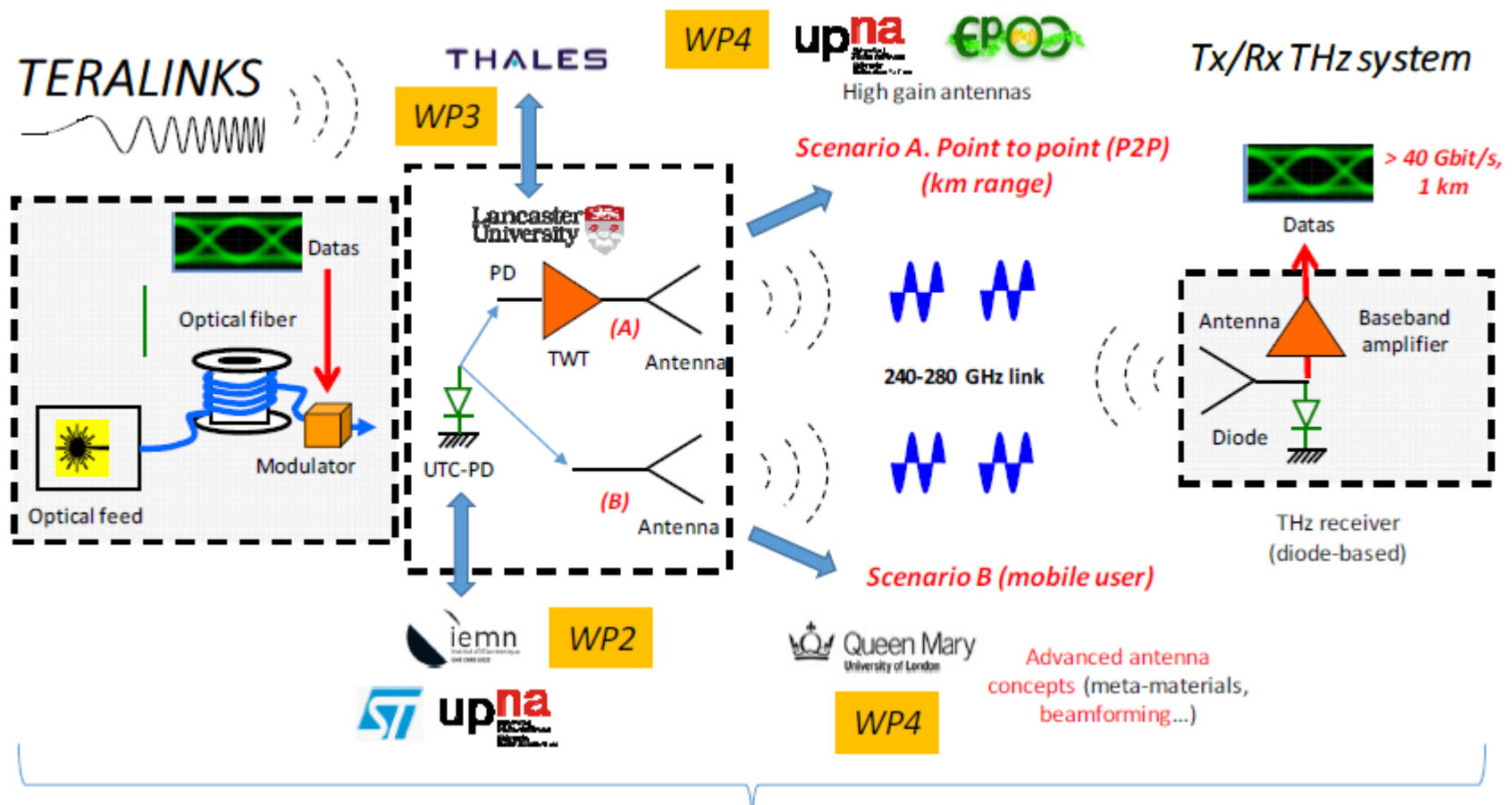
300 GHz coms... are on the way

5G: 10 Gbps per mobile user (expected)

Window = 250-320 GHz

*100 users in a cell => 1 Tbit/s to be aggregated...
So we need THz bands*

- **Presentation of each partner of the consortium with their specificity and added value: system-view of teralinks project**

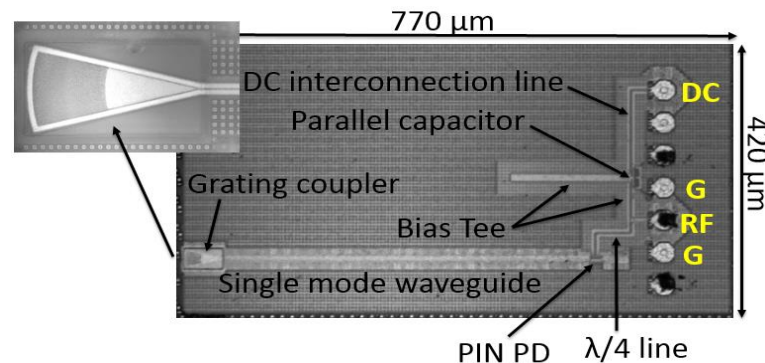


Complementary know-how associated towards THz links

- **Main scientific results, dissemination and other output**

THz Sources:

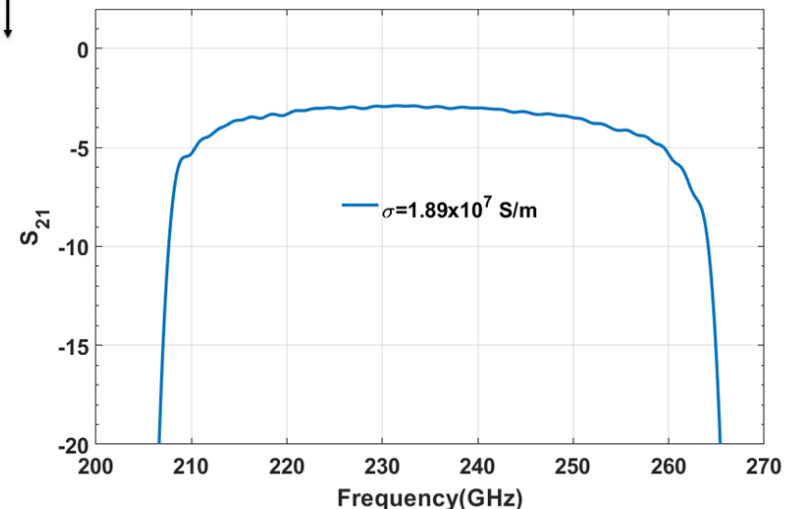
Investigated technologies: photodiodes (III-V, silicon) for photomixing up to THz range (300 GHz).



Tube amplifier:

The design specification for the TERALINKS TWT are at the state of the art. The wide frequency band, 220 GHz -260 GHz will permit a very high data rate with a low modulation scheme.

Waveguide structure design validated->



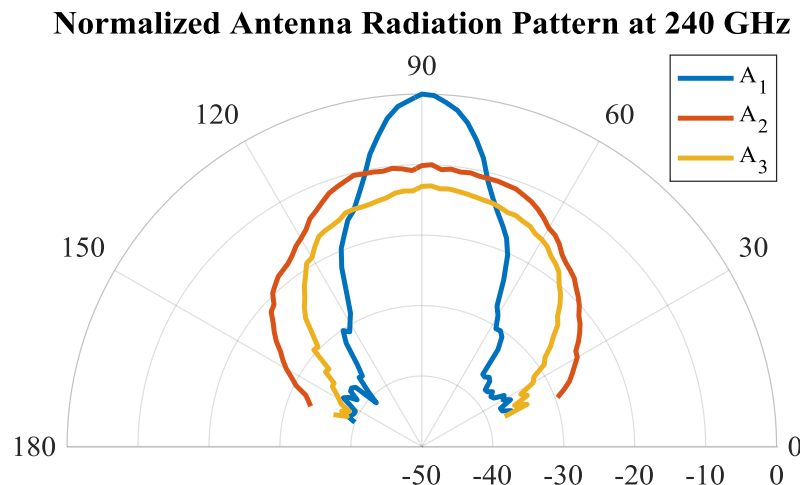
- **Main scientific results, dissemination and other output**

Antennas;

For antennas, especially, a new antenna measurement system is developed for TERALINKS ° innovative antenna approaches.

Several antennas are needed for measurements/calibration purposes.

Year 1, several metal-coated and non-metal 3D printed high-gain antennas as lenses, reflectors and horns has been achieved, and characterized at TERALINKS central frequency:



240 GHz horns, characterized with the new testbed) for THz links

- **Main scientific results, dissemination and other output**

System characterizations + Package has started in year #1

System-level testing towards 40 Gbit/s – amplitude mode in progress.

Exemples of dissemination / system-level

- IEEE MWCL: silicon-photonics based link demonstrated at 300 GHz (2018, Q1)

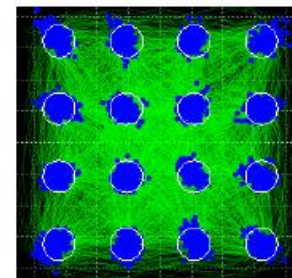
- 100 Gbit/s over lab distance (meter)
280 GHz

-> 2018, Q2 (April 2018)

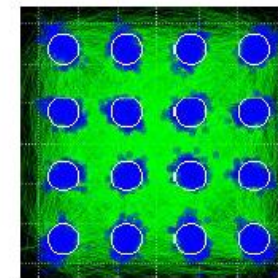
Single channel 100 Gbit/s transmission using III-V UTC-PD photodiodes for future IEEE 802.15.3d wireless links in the 300 GHz band

10 Gbps indoor THz communications using Industrial Si Photonics Technology

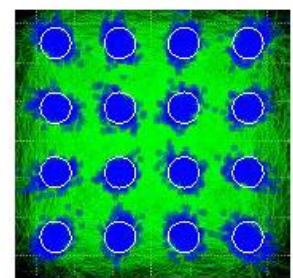
IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS,



56 Gbit/s
14 GBaud
BER = $5 \cdot 10^{-7}$



80 Gbit/s
20 GBaud
BER = 10^{-5}

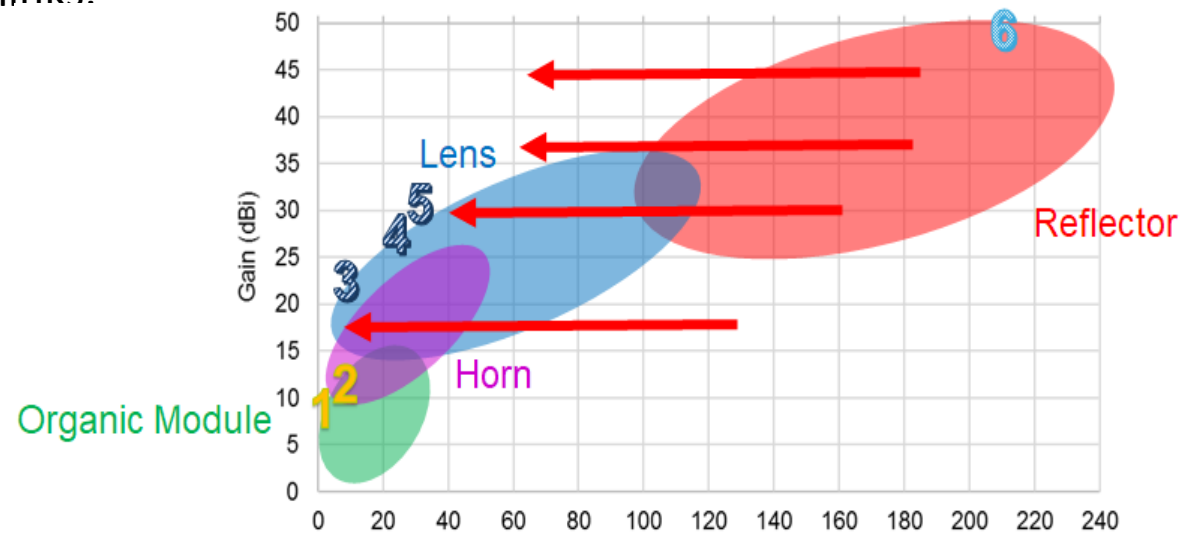


100 Gbit/s
25 GBaud
BER = 10^{-4}

- **Next steps**

Year 2: assembly of the technologies (source, tube amplifier, antennas, receiver, ...)
Towards outdoor (long range) links.

-> Higher gain antennas



- > Power capability of tube
- > Driving power of THz sources
- > Indoor (lab) & Outdoor tests

- ***Sustainability/Valorisation***

According to the new standard, initial live demos to be shared in the study groups (IEEE)

Common Eu-projects proposals

Website:

The website of TERALINKS projects is already operative.

<https://www.teralinks.eu/>

- **Dissemination list (5 papers (journal), 10 international conferences)**

International publications on scientific journals:

1. X. Li, X. Huang, S. Mathisen, R. Letizia and C. Paoloni, “71-76 GHz Double Corrugated Waveguide Traveling Wave Tube for Satellite Downlink”, accepted **IEEE Trans. on Electron Devices**, Special issue, June 2018
2. R. Waring, C. Paoloni, “Lagrangian Simulator for Millimetre Wave TWT based on Non-Rotationally Symmetric Slow-Wave Structure”, in **Journal of Electromagnetic Waves and Applications**, 31, 17, p. 1902-1913 12 p. September 2017.
3. J Ma, NJ Karl, S Bretin, G Ducournau, DM Mittleman, “Frequency-division multiplexer and demultiplexer for terahertz wireless links”, **Nature communications** 8 (1), 729, 2017.
4. E. Lacombe, C. Belem-Goncalves, C. Luxey, F. Giancesello, C. Durand, D. Gloria and G. Ducournau, “10 Gbps indoor THz communications using Industrial Si Photonics Technology”, to be published in **IEEE Microwave Wireless Component Letters**, Q2 2018.
5. 100 Gbit/s THz link, to be published in **Electronics Letters**, 2018.

- ***Dissemination list (5 papers (journal), 10 international conferences)***

International publications on scientific conferences

1. PIERS 2018: “Towards 100 Gbps in the 300 GHz band using linear Uni-travelling carrier photodiodes”, G. Ducournau et al., for upcoming next PIERS conference, **Invited**, 2018, Toyama.
2. Sub-THz source integrated in low-cost Silicon Photonic technology targeting 40 Gb/s wireless links
E Lacombe, F Giancesello, C Durand, G Ducournau, C Luxey, D Gloria, Radio Frequency Integrated Circuits Symposium (RFIC), 2017 IEEE, 77-80.
3. Sub-THz source integrated in industrial silicon Photonic technology targeting high data rate wireless applications, E Lacombe, F Giancesello, C Durand, G Ducournau, C Luxey, D Gloria, Silicon Monolithic Integrated Circuits in RF Systems (SiRF), 2017
4. High efficiency UTC photodiodes as photonic emitters for 300 GHz high spectral efficiency wireless communications, P Latzel, F Pavanello, S Bretin, M Billet, E Peytavit, JF Lampin, M. Zaknounge, G. Ducournau Antennas and Propagation (EUCAP), 2017 11th European Conference on, 1639-1641.
5. E.LACOMBE, C. BELEM-GONCALVES, C.LUXEY, **F. GIANESELO, C. DURAND, D. GLORIA, G. DUCOURNAU**, “300 GHz OOK Transmitter Integrated in Advanced Silicon Photonics Technology and Achieving 20 Gb/s”, in **Proc. Radio Frequency Integrated Circuits Symposium (RFIC 2018)**, Philadelphia, USA, pp. , June 2018.

- ***Dissemination list (5 papers (journal), 10 international conferences)***

6. E. LACOMBE, F. GIANESELLO, C. LUXEY, C. DURAND, D. TITZ, J.R. COSTA, C.A. FERNANDES, C. DEL RIO BOCIO, G. DUCOURNAU, H. GULAN, T. ZWICK, “THz Packaging Solution for Low Cost Si-based 40 Gb/s Wireless Link System”, Proc. 12th **European Conf. on Antennas and Propagation (EuCAP 2018)**, London, UK, 9-13 April 2018.
7. E. LACOMBE, F. GIANESELLO, A. BISOGNIN, C. LUXEY, D. TITZ, H. GULAN, T. ZWICK, J. COSTA, C. FERNANDES, “Low-Cost Plastic Lens Fabricated in FDM 3D-Printing Technology Targeting High Data Rate Wireless Links Above 200 GHz”, Proc. International Conference Electromagnetics Advanced Applications, **ICEAA 2017**, Torino, Italy, September **2017**.
8. E. LACOMBE, F. GIANESELLO, A. BISOGNIN, C. LUXEY, D. TITZ, H. GULAN, T. ZWICK, “240 GHz Antenna Integrated on Low-Cost Organic Substrate Packaging Technology Targeting High-Data Rate sub-THz Telecommunication”, **EuMW 2017**, Ulm, Germany, September 2017
9. E. LACOMBE, F. GIANESELLO, C. LUXEY, H. GULAN, T. ZWICK, A. BISOGNIN, D. TITZ, J. COSTA, C. FERNANDES, “Low-Cost 3D-Printed 240 GHz Plastic Lens fed by Integrated Antenna in Organic Substrate Targeting Sub-THz High Data Rate Wireless Links”, **IEEE International Symposium on Antennas and Propagation (AP-S 2017)**, San Diego, **July 2017**.
10. E. LACOMBE, F. GIANESELLO, C. DURAND, G. DUCOURNAU, C. LUXEY, D. GLORIA, “Sub-THz Source Integrated in Low-Cost Silicon Photonic Technology targeting 40 Gb/s Wireless Links”, in Proc. Radio Frequency Integrated Circuits Symposium (**RFIC 2017**), Honolulu, USA, June 2017.

THANK YOU