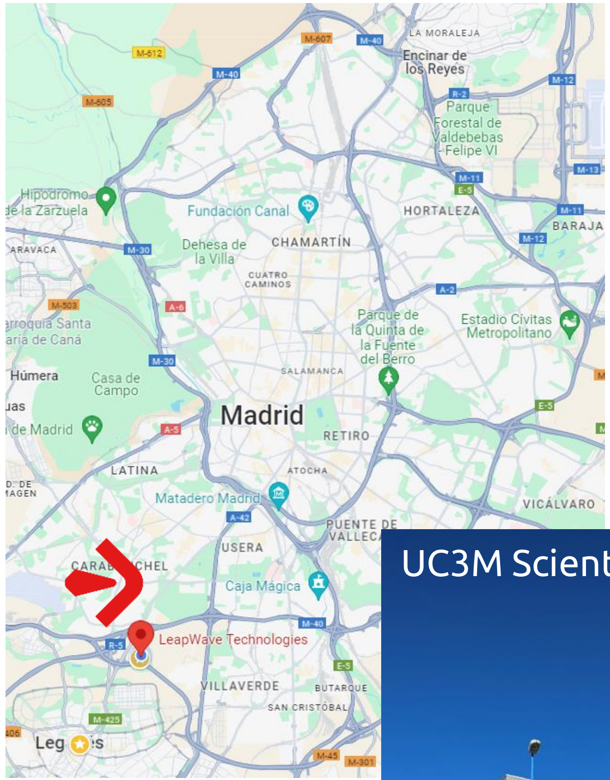
Breaking the barriers for high frequency packing

PIC International 2024

LEAPWAVE

Who we are



UC3M Scientific Park

- **Spin-off** company from Universidad Carlos III de Madrid (UC3M)
- **Deep-tech** company with vision to bring a paradigm shift in high-speed interconnects.
- **Solutions**:
  - Assembly and packaging (mmW and THz)
  - Broadband RF interconnections
  - MMW & THz Instrumentation
- **Applications**:
  - Communications
  - Sensing
  - High-speed data links
  - Non-destructive testing

LEAPWAVE

The Founders

Guillermo Carpintero, Prof.

Photonics and Millimeter Wave Expert

Alejandro Rivera, PhD

RF and Cleanroom Fabrication Expert

Muhsin Ali, PhD

RF and Assembly Expert

Daniel Gallego, PhD

Photonics and Instrumentation Expert

Alvaro Jimenez, PhD

Photonics Integration and Assembly Expert

Santiago Gómez, MSc

Electronics Expert

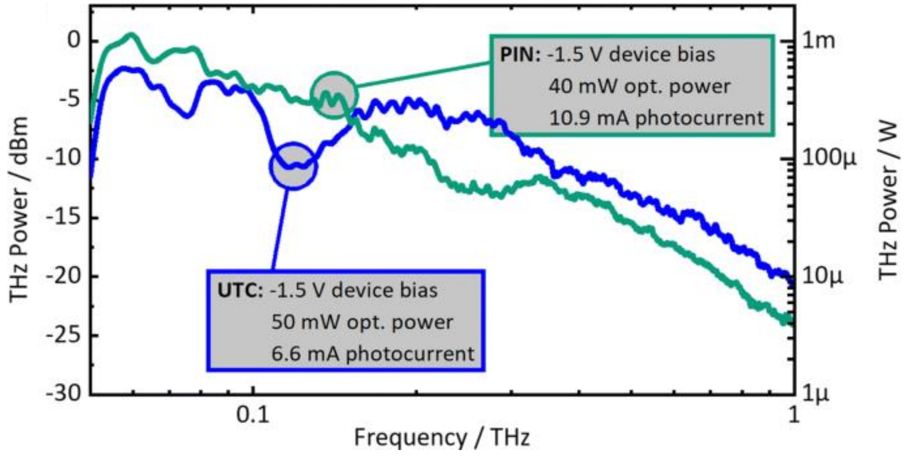
Backed by: Bullnet capital

Photonics is broadband

Photonic components have shown extremely large available bandwidth up to 1 THz

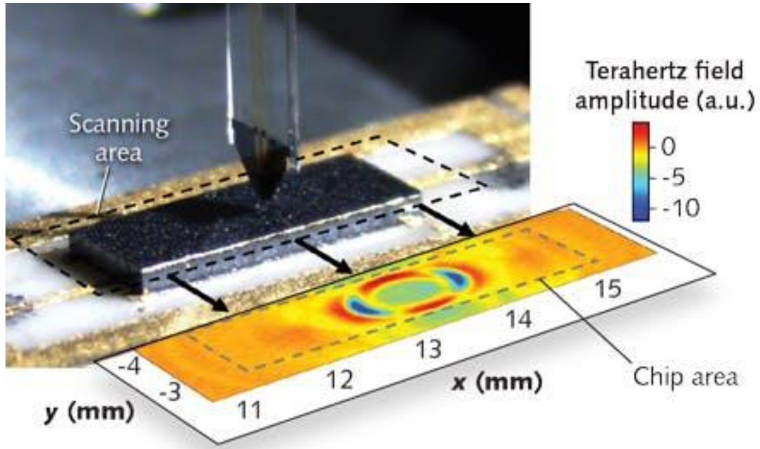
RF output interfaces

High-Speed Photodiodes (PIN, UTC-PD)



S Nellen et al. "Experimental Comparison of UTC- and PIN-Photodiodes for Continuous-Wave Terahertz Generation" J Infrared Milli Terahz Waves 41, 343–354 (2020)

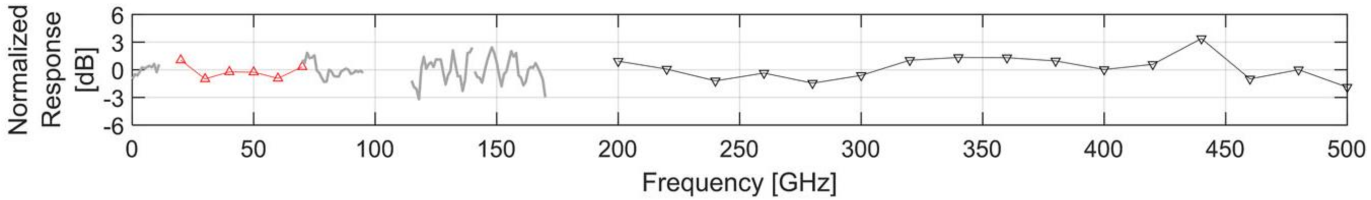
THz spectroscopy systems (Quality control, Art)



Michael Nagel et al "Photonics Applied: Terahertz Imaging: Terahertz imaging tackles solar cell and semiconductor process inspection" Laser Focus World, Oct. 12, 2017

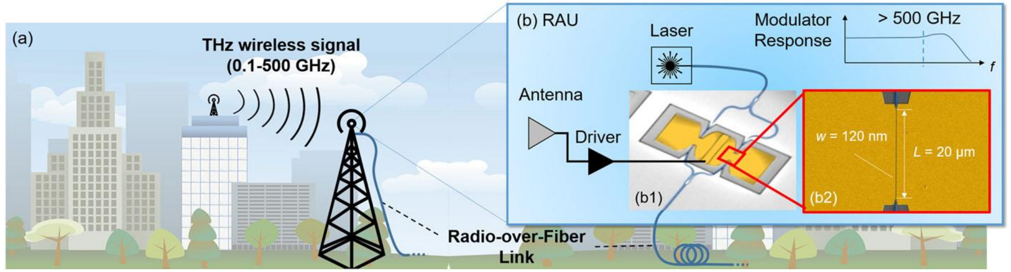
RF input interfaces

High-Speed Optical Modulators (Plasmonic, TFLN)



M Burla, et al "500 GHz plasmonic Mach-Zehnder modulator enabling sub-THz microwave photonics" *APL Photonics* 1 May 2019; 4 (5): 056106

For high-speed communications (5G, 6G, …)



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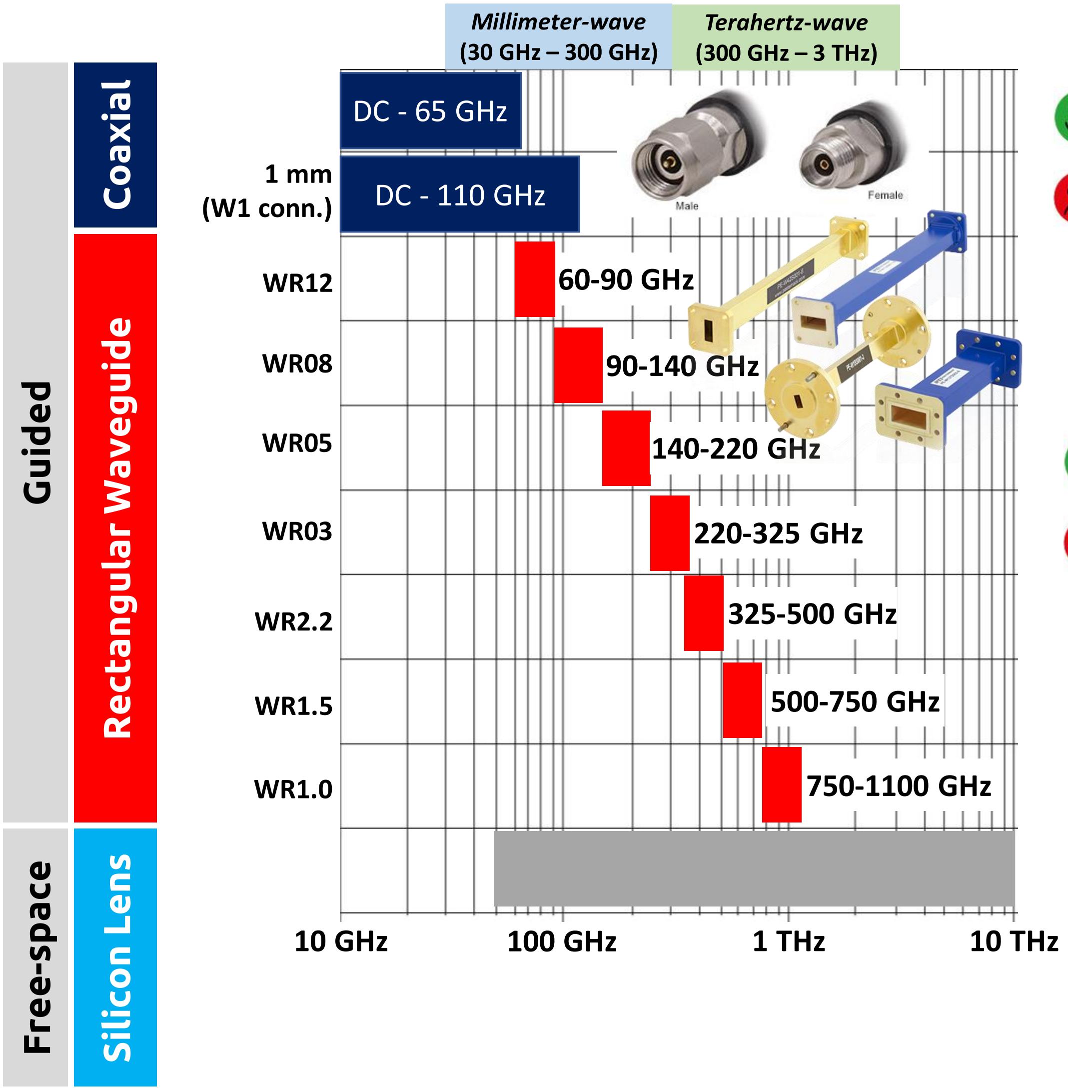
Connectors are not

Frequency range of available connector standards are limiting the available bandwidth



Bandwidth

Loss at high freq.

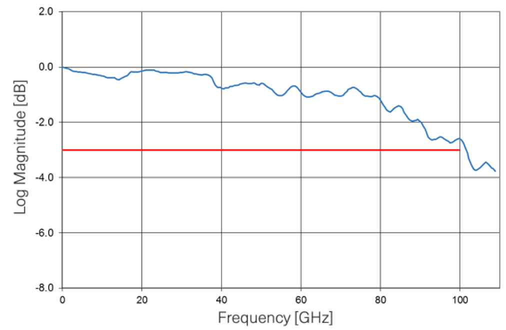
18 dB/m @ 110GHz

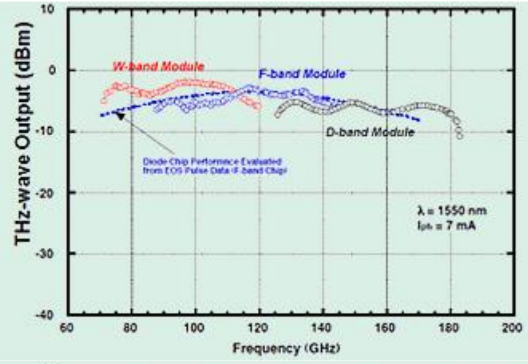
Low loss **0.4 dB/cm**

Bandwidth

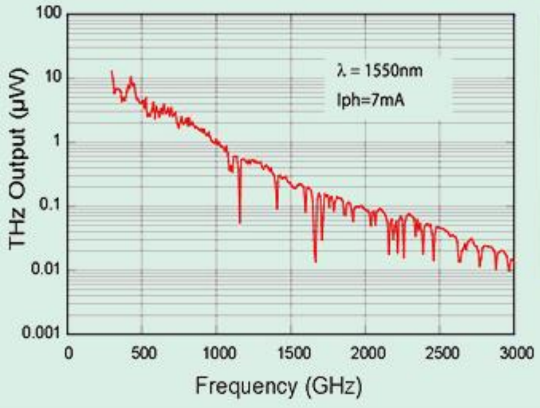
Ultrabroad Bandwidth

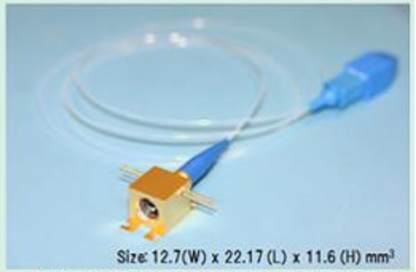
Uncalibrated
Alignment sensitive





Waveguide Coupled Photomixer Module





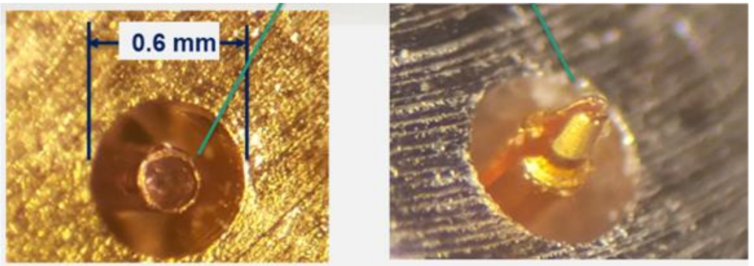
Antenna Integrated Photomixer Module

And standardized connectors are at their limit

Guided

Coaxial

Currently, for operation at 220 GHz, a 0.6 mm outer diameter is required. The 0.6 mm coax connector interface has been defined, which is a demanding alternative approach to the design of the connector interface.



Slot-less <0.4mm female center conductor

Slotted <0.4mm male pin center conductor

Rectangular Waveguide

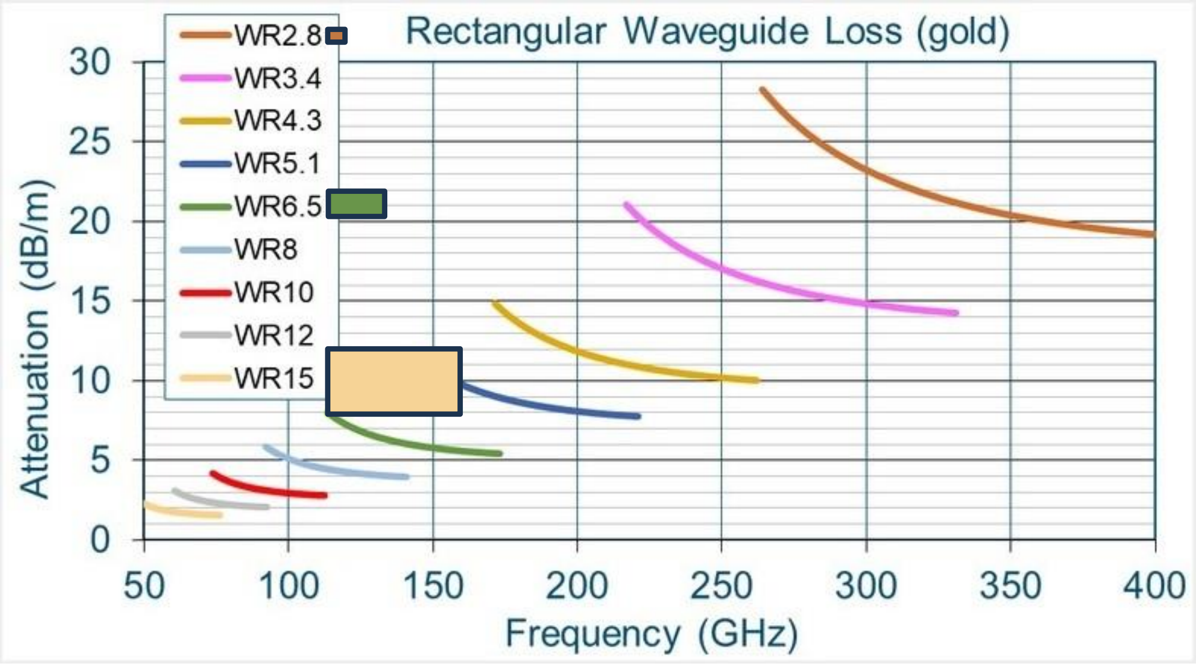
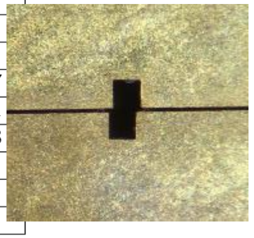


Table 2.1: Rectangular Waveguide sizes and frequency bands.

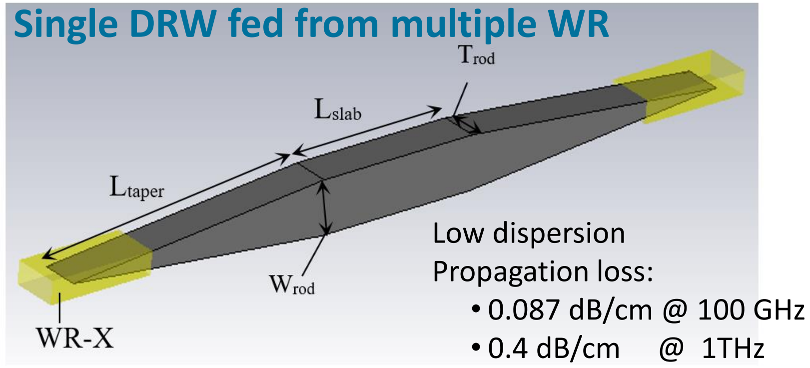
Frequency Band	Waveguide Standard	Frequency Limits (GHz)	Inside Dimensions (inches)	(mm)
C-band	WR-137	5.85 - 8.20	1.372x0.622	34.8488x15.7988
H-band	WR-112	7.05 - 10.00	1.122x0.497	28.4988x12.6238
X-band	WR-90	8.2 - 12.4	0.900x0.400	22.86x10.16
Ku-band	WR-62	12.4 - 18.0	0.622x0.311	15.7988x7.8994
K-band	WR-51	15.0 - 22.0	0.510x0.255	12.954x6.477
K-band	WR-42	18.0 - 26.5	0.420x0.170	10.668x4.318
Ka-band	WR-28	26.5 - 40.0	0.280x0.140	7.112x3.556
Q-band	WR-22	33 - 50	0.224x0.112	5.6896x2.8448
U-band	WR-19	40 - 60	0.188x0.094	4.7752x2.3876
V-band	WR-15	50 - 75	0.148x0.074	3.7592x1.8796
E-band	WR-12	60 - 90	0.122x0.061	3.0988x1.5494
W-band	WR-10	75 - 110	0.100x0.050	2.54x1.27
F-band	WR-8	90 - 140	0.080x0.040	2.032x1.016
D-band	WR-6	110 - 170	0.0650x0.0325	1.651x0.8255
G-band	WR-5	140 - 220	0.0510x0.0255	1.2954x0.6477
-	WR-4	170 - 260	0.0430x0.0215	1.0922x0.5461
-	WR-3	220 - 325	0.0340x0.0170	0.8636x0.4318
Y-band	WR-2	325 - 500	0.0200x0.0100	0.508x0.254
-	WR-1.5	500 - 750	0.0150x0.0075	0.381x0.1905
-	WR-1	750 - 1100	0.0100x0.0050	0.254x0.127

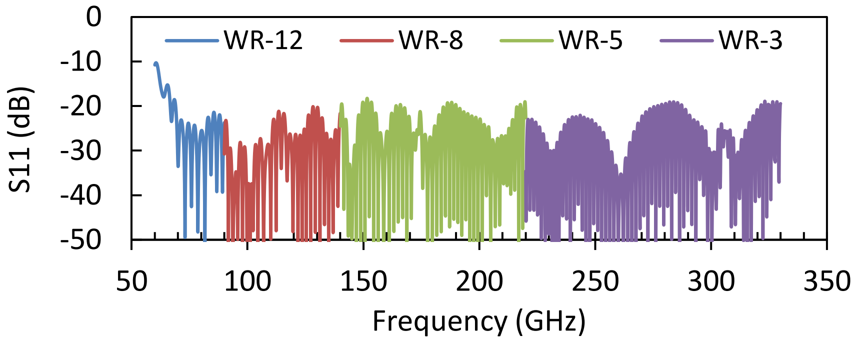


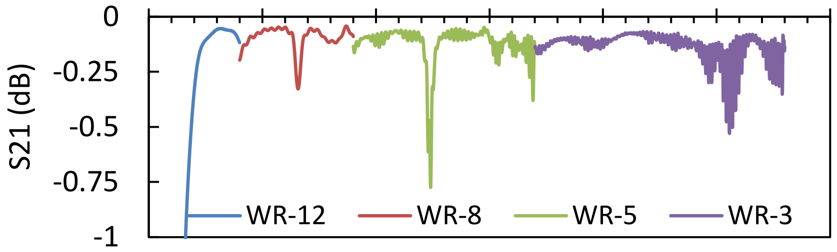
LEAPWAVE

LeapWave’s approach

Based on Dielectric Rod Waveguide (DRW), commonly interfaced with Rectangular Waveguides, . . .





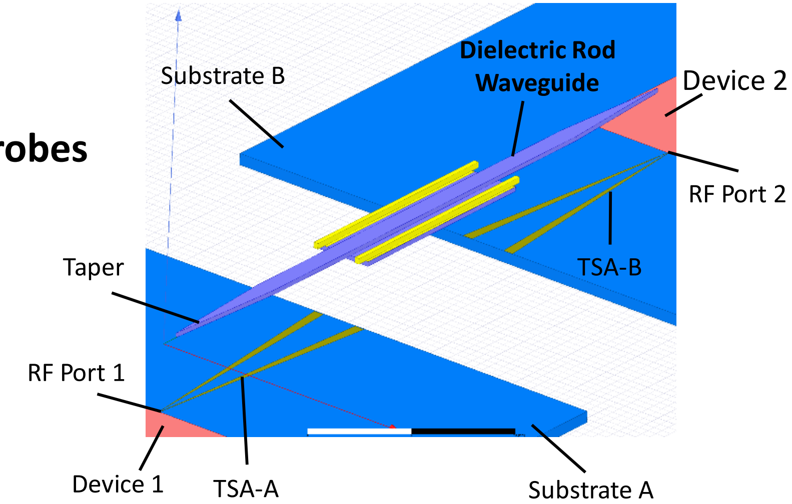


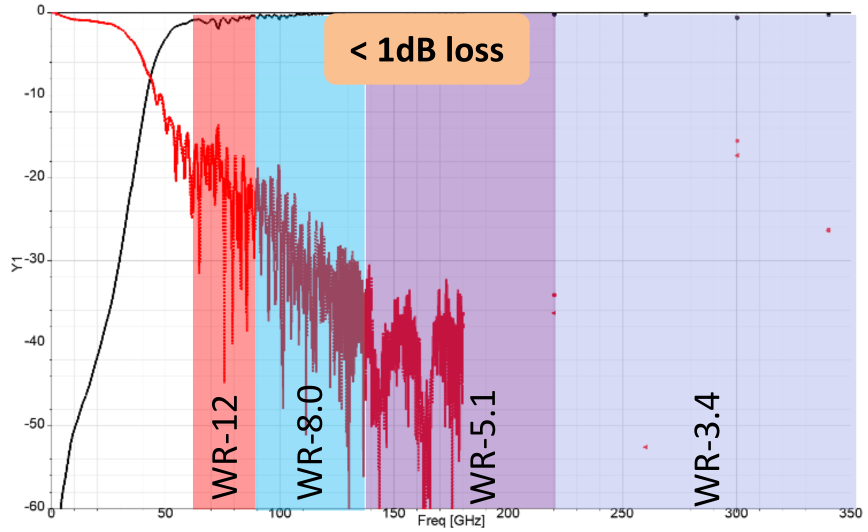
TERAmeasure

www.uc3m.es/research/terameasure

LEAPWAVE approach is enabling RF interconnect structure for:

- **Chip to chip**
- **Chip to package**
- **And contactless RF Test probes**





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LEAPWAVE

LeapWave's approach

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www.uc3m.es/research/terameasure

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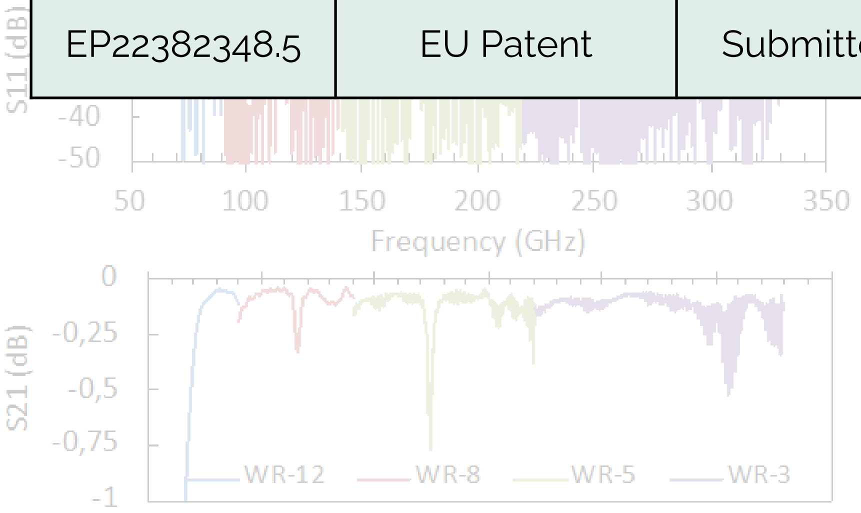
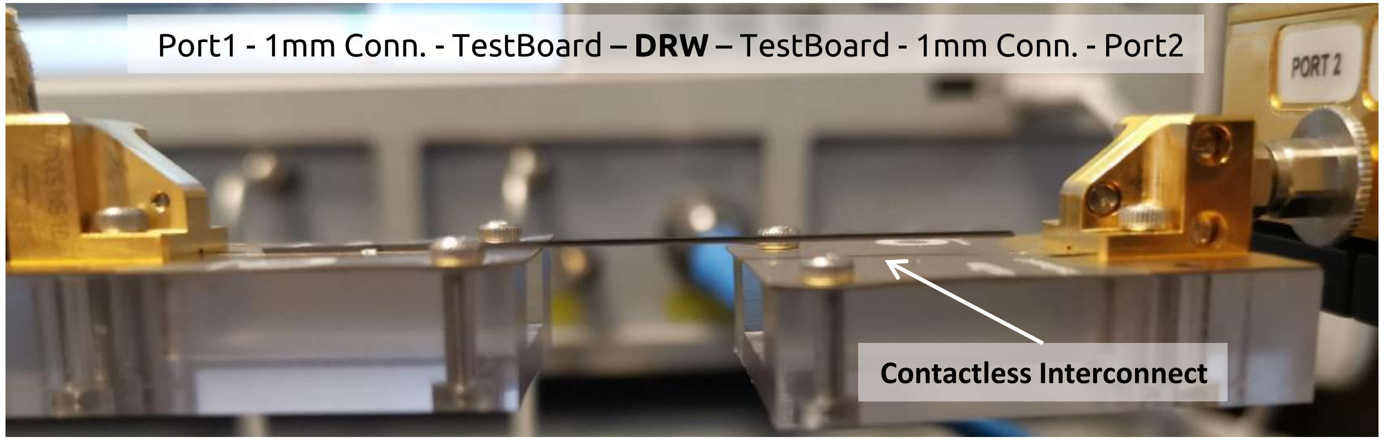
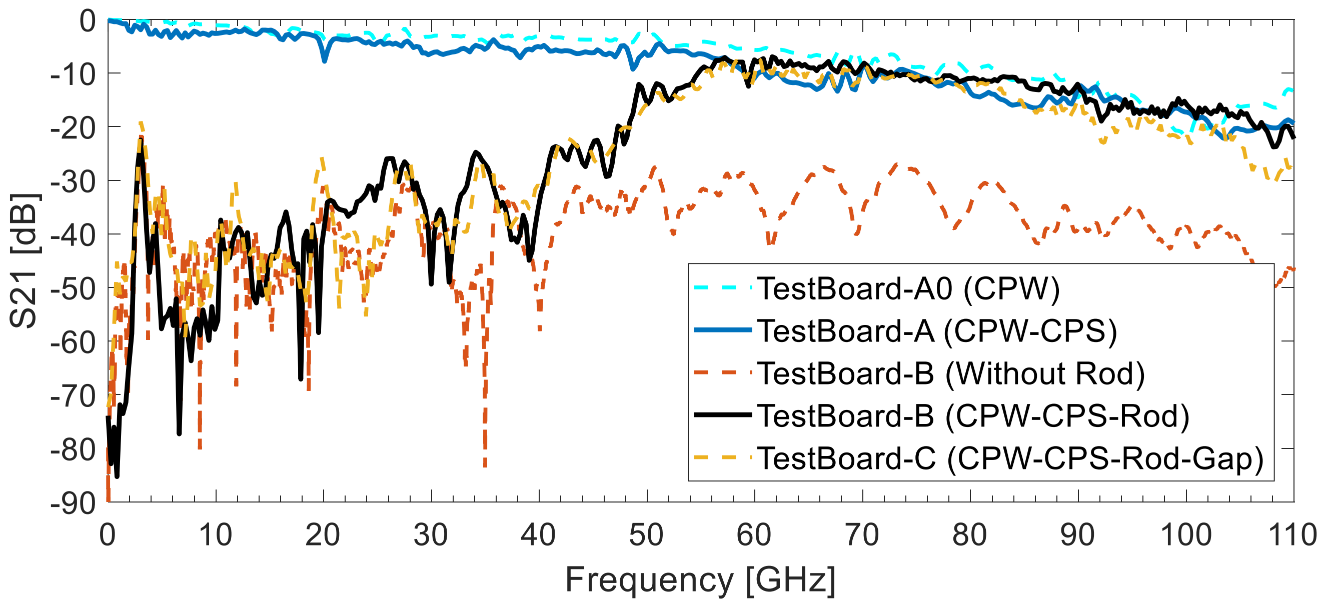
Intellectual Property			
IP ASSET ID	**Type**	**Status**	**Other relevant information**
EP20382960.1	EU Patent PCT	Submitted 5/11/2020 PCT extension request	Ultra-wideband interconnection probes, owned by LeapWave
EP21382573.0	EU Patent	Submitted 29/06/2021 PCT extension request	Dielectric radio frequency (RF) bidirectional coupler with power divider/combiner functionality, owned by LeapWave
EP22382348.5	EU Patent	Submitted 11/04/2022	Hybrid structure for ultra-wideband terahertz generation and reception with semiconductor, owned by LeapWave



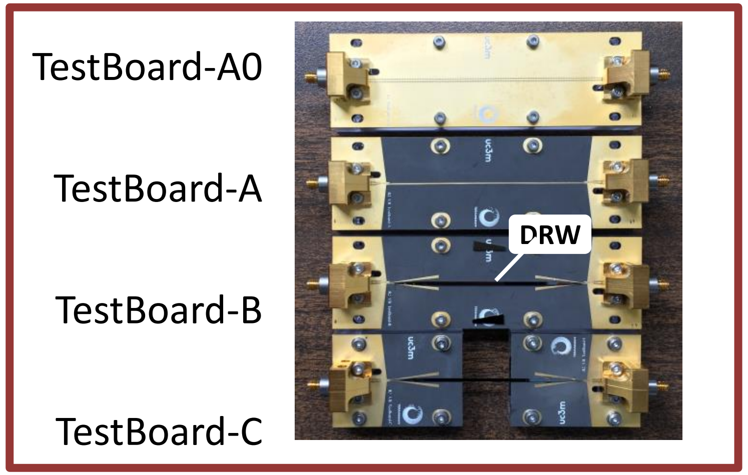
Ultra-broadband interconnect

Experimental validation





Test Structures



- Transitions (baluns) from Coax to TSA
- Different test structures included to establish the feed circuit losses

TestBoard-A vs. -B
No significant transmission losses from DRW

TERAmeasure

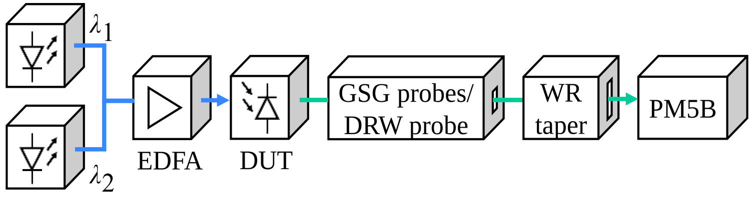
M. Ali, et al. IRMMW-THz, Th-P-96, 2022

Ultra-broadband interconnect

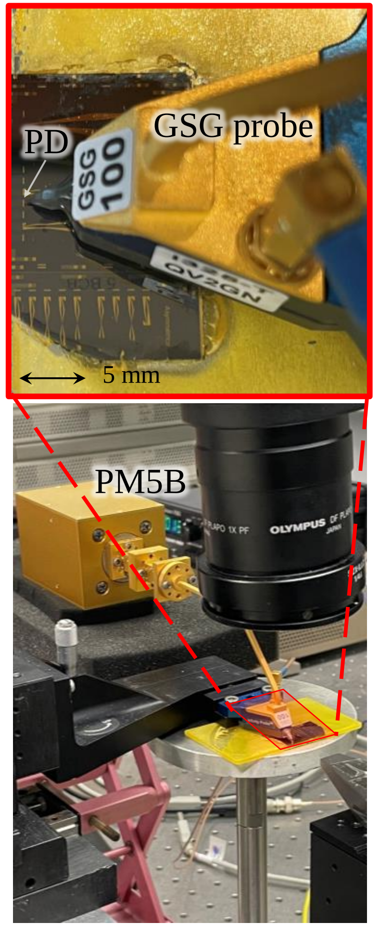
Demonstration on a UTC-PD: GSG RF probe vs. DRW

Probing up to 400 GHz demonstrated!

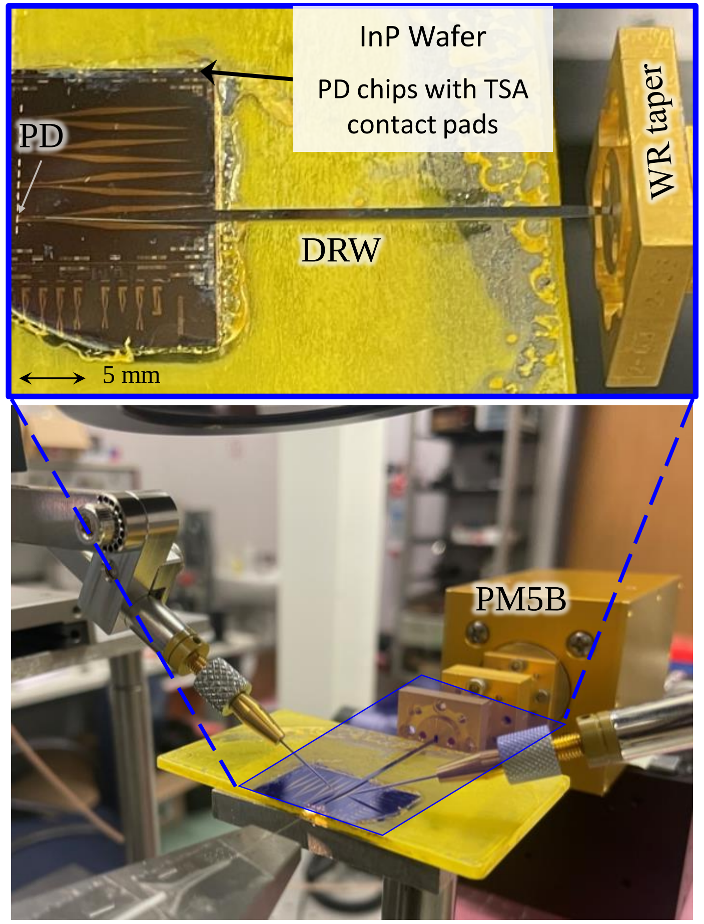
Experimental Setup



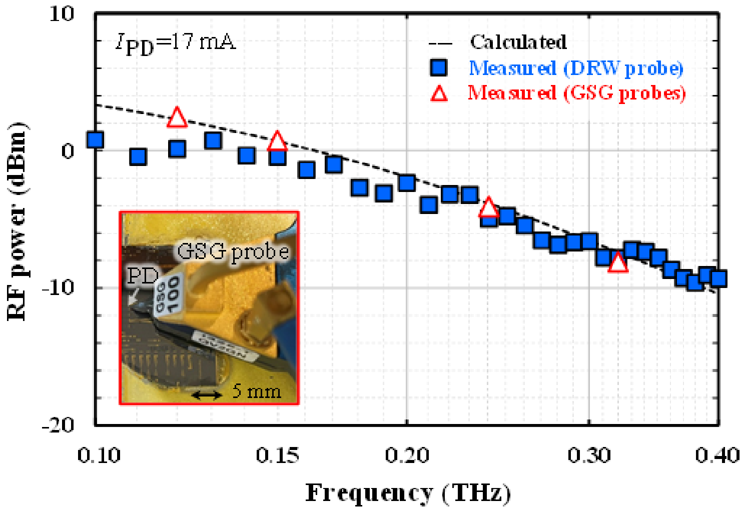
Various GSG Probes



Single DRW Probe



A good agreement has been achieved



doi.org/10.1364/OL.504354

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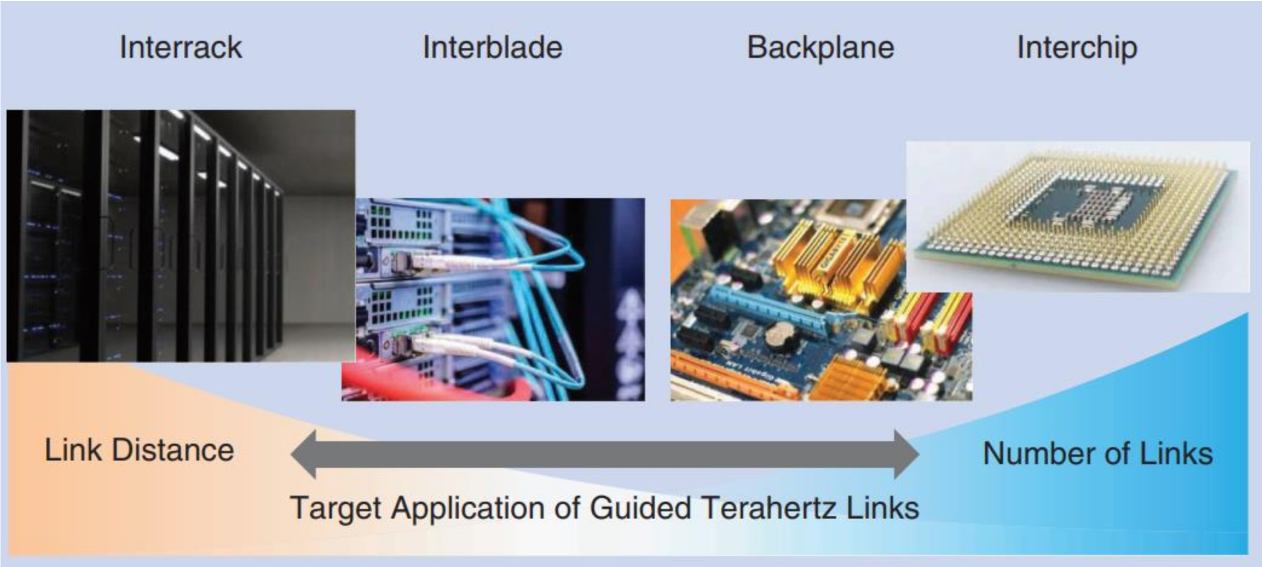
What is next?

Terahertz interconnects



Data centers and high-performance computing require moving **large amounts of data**

J.W Holloway, Georgios C. Dogiamix, R. Han, "Innovations in Terahertz Interconnects". IEEE Microwave Magazine, vol. 35, 2020.

High-speed interconnects scenarios

- Rack-to-rack
- Board-to-board
- Module-to-module
- Chip-to-chip

Main players: optical and electrical connections

Silicon dielectric waveguides are a possible solution!

- Compact
- Frequency transparent (100s of GHz)
- Low-cost
- Compatible with electronic and photonic platforms (DRIE process, few masks, less steps)

Use silicon to surf the wave

LEAP WAVE

leapwavetech.com