Newsletter #5

TERRAMETA

Co-funded by the European Union

6G SNS

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TERahertz ReconfigurAble METAsurfaces for Ultra-high-rate wireless communications

As TERRAMETA enters its final phase, the project continues to achieve important milestones in sub-THz communications and reconfigurable intelligent surfaces (RIS) for future 6G systems. This edition highlights recent advances in memristor-, microfluidic-, CMOS-, and Schottky-diode-based RIS technologies, long-distance D-band wireless links, and scalable manufacturing approaches for future high-frequency systems.

The newsletter also showcases TERRAMETA's strong dissemination activities through workshops and international events such as EuCAP and EuCNC & 6G Summit, together with the publication of several open-access datasets supporting reproducible research on sub-THz RIS and metasurface technologies.

Read on to discover the latest TERRAMETA achievements and activities!

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https://terrameta-project.eu/

INESCTEC · National and Kapodistrian University of Athens (Established in 1827) · University of Oulu · BT · uni.lu University of Luxembourg · Intracom Telecom · Technische Universität Braunschweig · CST Think Ahead · University of Hertfordshire UH · Dell Technologies · instituto de telecomunicações · NOVA School of Science & Technology · cea leti

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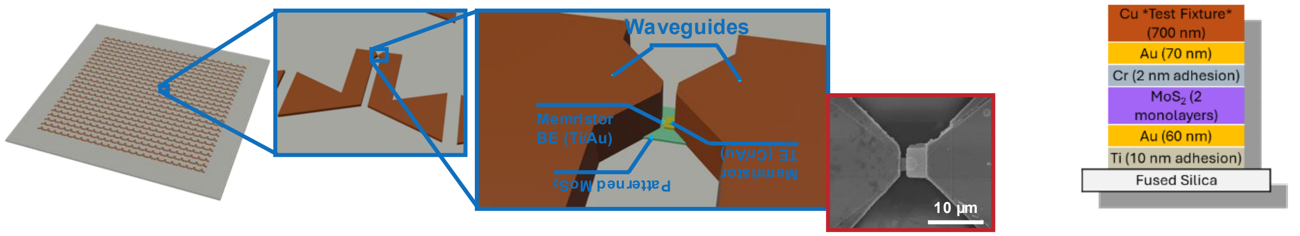
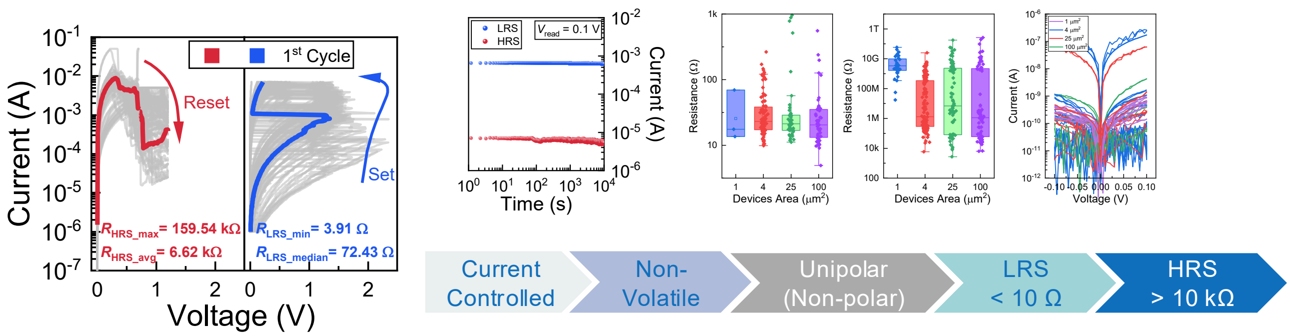
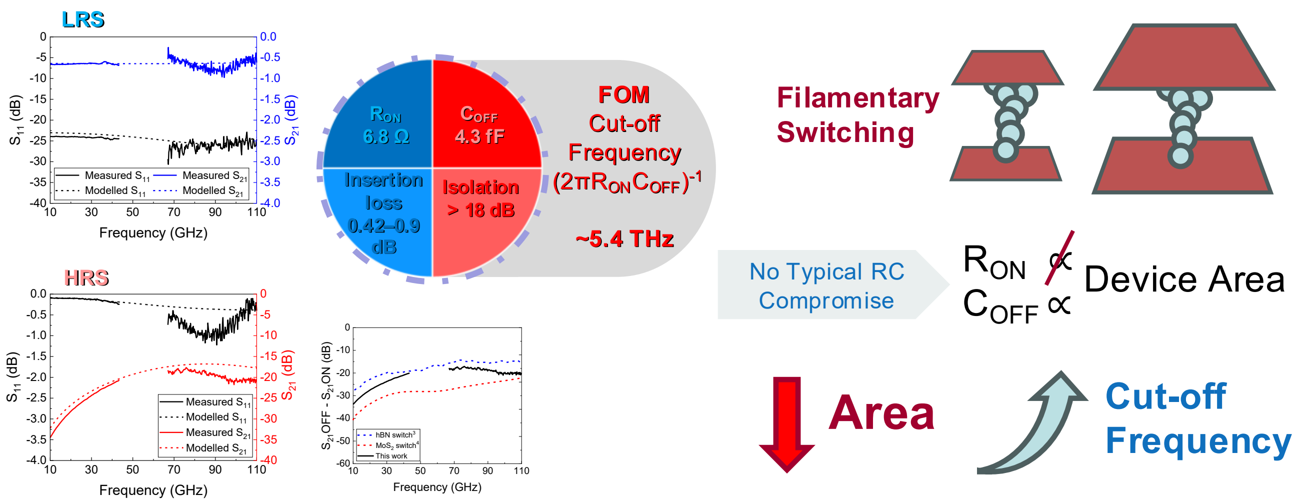
Memristor-based RIS prototyping and Measurements



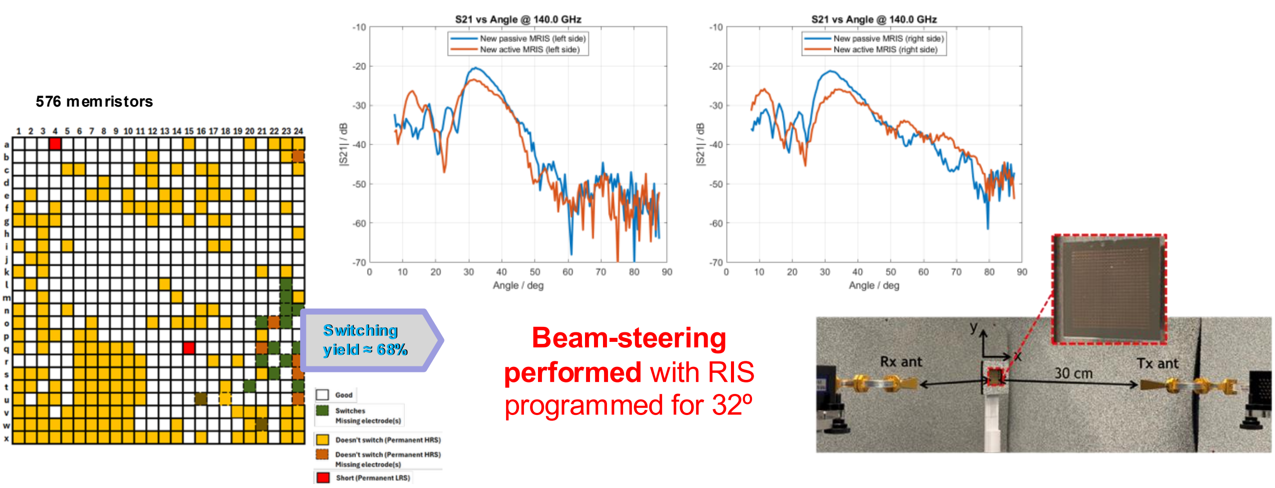
DC Characterization



RF Characterization



System Level 24 × 24 RIS Array



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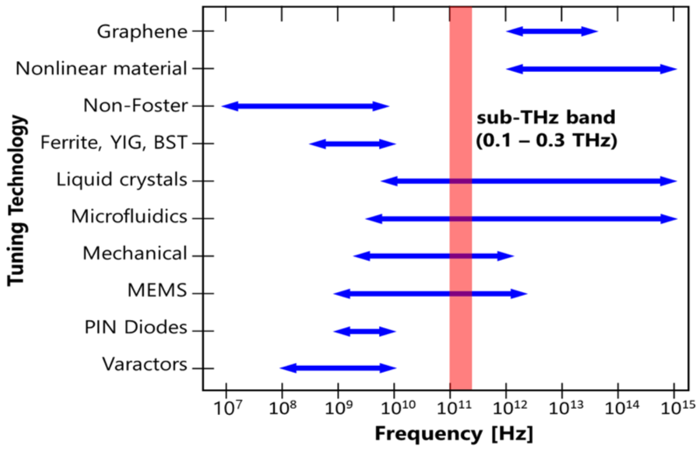
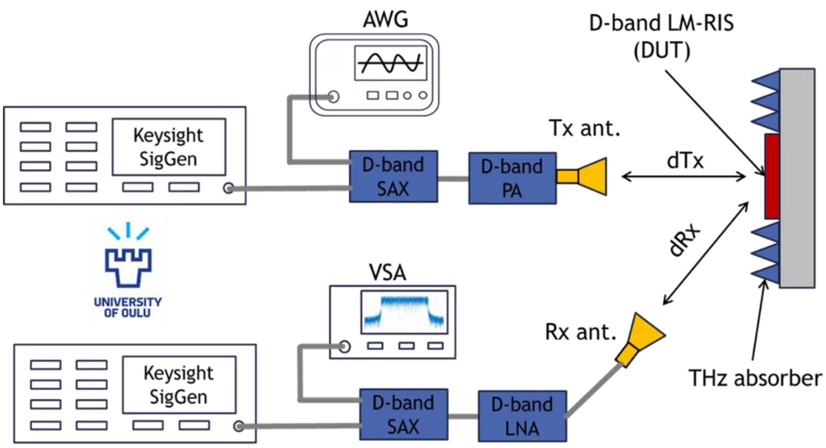
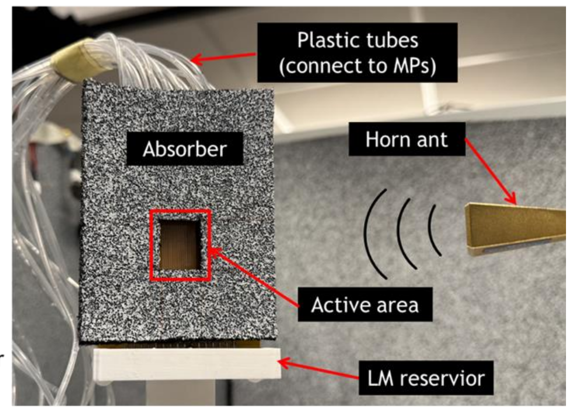
Microfluidics based RIS Development

- ❖ High complexity, significant power consumption
- ❖ Limited tuning range
- ❖ Limited suitable tuning/fabrication technologies and materials





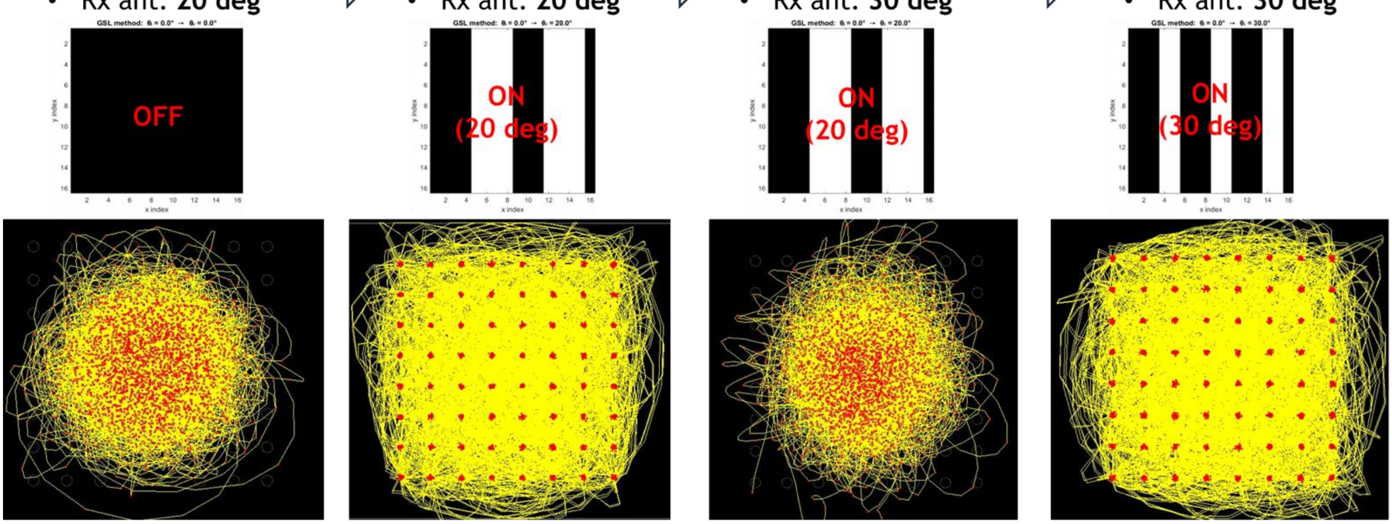


- Tx ant: 0 deg
- Rx ant: **20 deg**

- Tx ant: 0 deg
- Rx ant: **20 deg**

- Tx ant: 0 deg
- Rx ant: **30 deg**

- Tx ant: 0 deg
- Rx ant: **30 deg**



- Bit rate: 3 Gbps
- EVM: 22.1%

- Bit rate: 3 Gbps
- EVM: 1.7%

- Bit rate: 3 Gbps
- EVM: 20.1%

- Bit rate: 3 Gbps
- EVM: 1.8%

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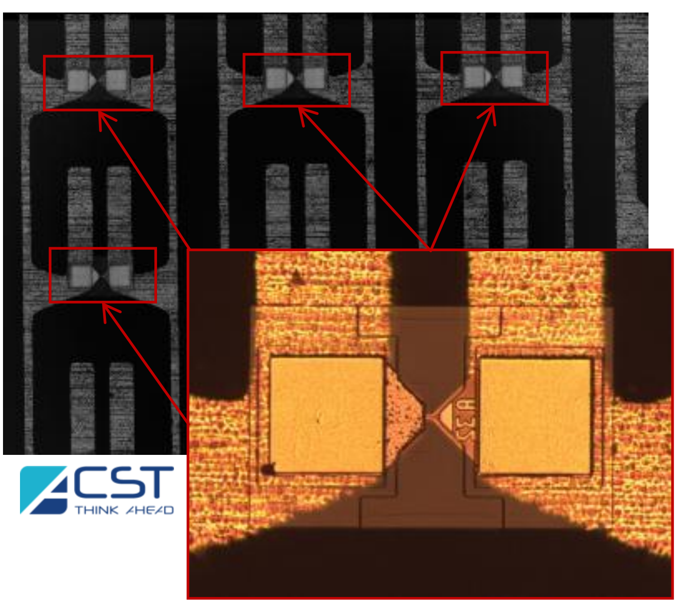
Automated Assembly of Schottky-Diode based D-Band RIS

TERRAMETA achieved an important milestone toward scalable manufacturing of sub-THz reconfigurable intelligent surfaces (RIS) through the successful automated assembly of Schottky diodes for a hybrid D-band RIS demonstrator.

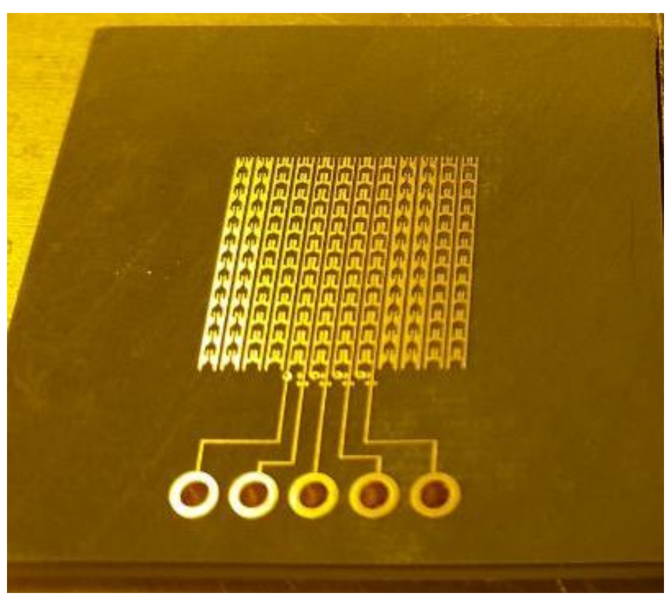
For the first time, arrays of sub-THz Schottky diodes developed by project partner ACST were mounted using an automated pick-and-place process. The approach is compatible with future scaling toward even higher frequencies, including sub-millimeter-wave systems.

After initial process optimization using Astra substrates, the final demonstrator was fabricated on Rogers substrates, enabling significantly improved placement accuracy and repeatability. The resulting prototype integrates a **4 × 12 diode array (48 diodes)** and is currently being characterized within the project.

The developed process also demonstrated strong scalability potential. While the initial assembly process was intentionally conservative due to the novelty of the technique, further optimization is expected to reduce mounting times to below 5 seconds per diode, opening the path toward practical manufacturing of large RIS apertures for future 6G systems.



Detail of demonstrator
with mounted ACST Schottky diodes.

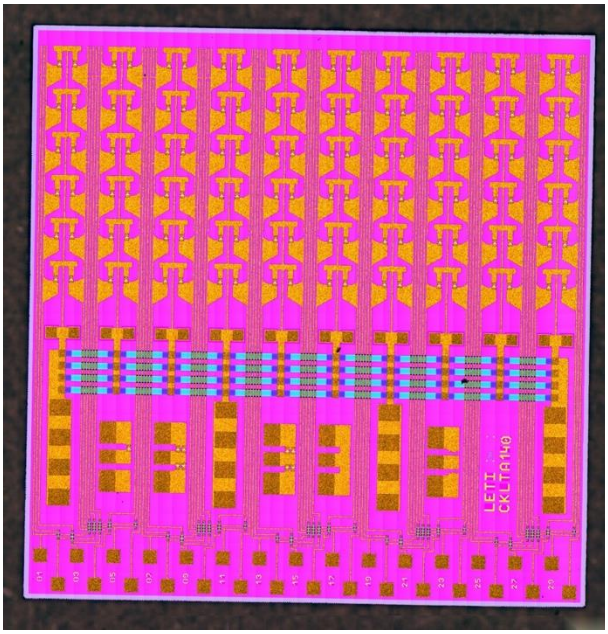


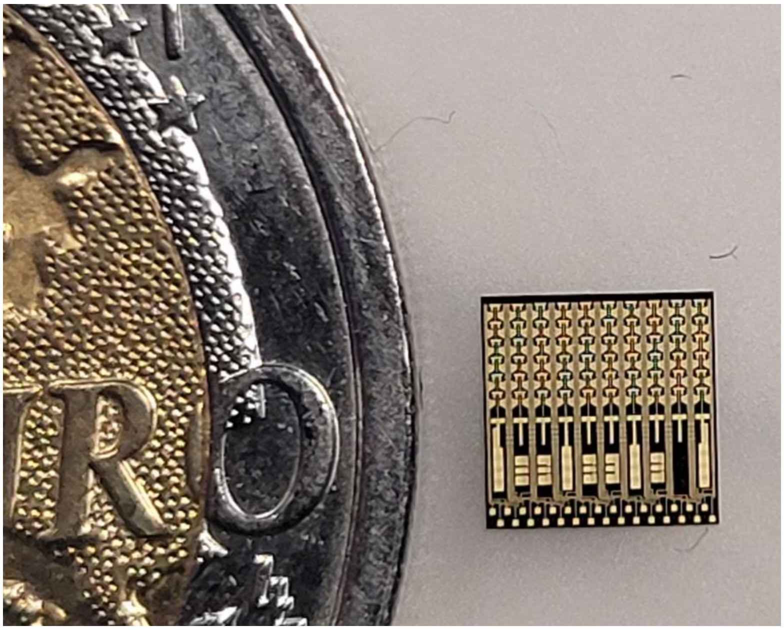
Rogers substrate with hybrid RIS structures
for project demonstrator.

Innovative GaAs Schottky-Diode-Based RIS for D-Band

TERRAMETA has successfully fabricated a new transmissive reconfigurable intelligent surface (T-RIS) based on integrated GaAs Schottky diodes for D-band communications. The developed architecture combines compact unit cells, integrated switching, and scalable tiled-array design to enable dynamic beam steering at sub-THz frequencies.

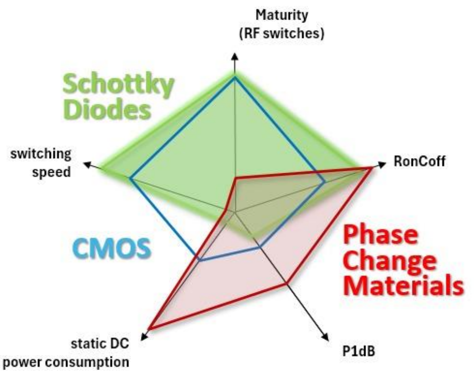
The prototype demonstrates a simplified and highly scalable approach for future 6G RIS implementations, supporting both transmission and reflection operation with low insertion loss and wide bandwidth. The fabricated GaAs integrated circuits represent an important step toward practical high-frequency reconfigurable metasurfaces for beyond-5G and 6G wireless systems.



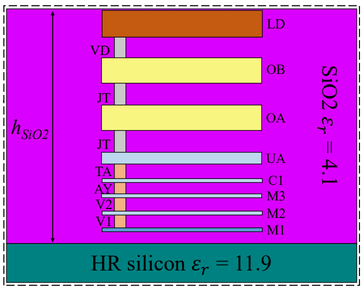


CMOS-based transmissive EM surface prototyping

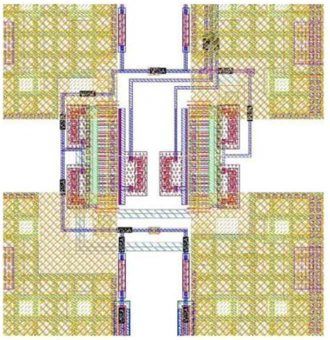
D-band CMOS switch design



GF RF-SOI 45 nm



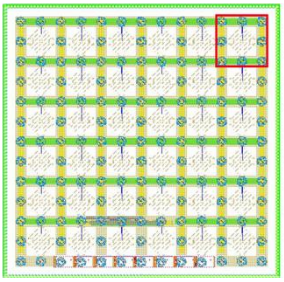
RF switches

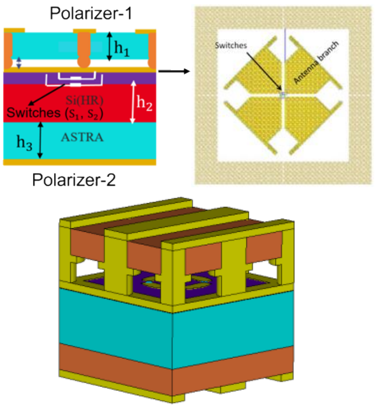


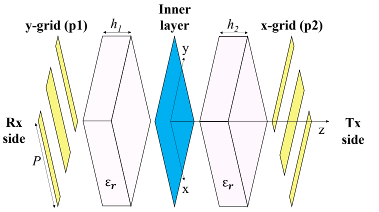
$R_{on} = 6.8\ \Omega$ $C_{off} = 21.4$ fF

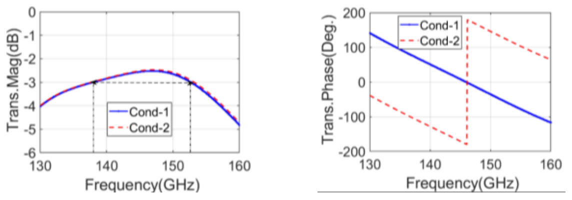
1-bit programmable unit-cell on hybrid CMOS-PCB technology

6 × 6 unit cell IC

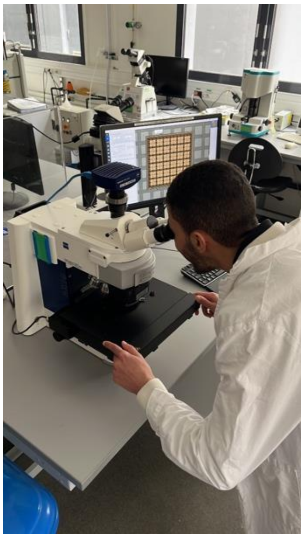


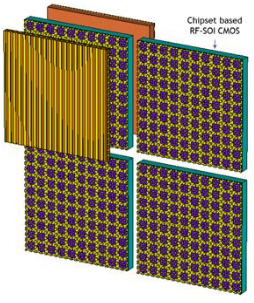


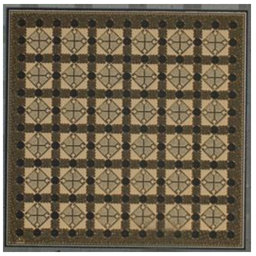


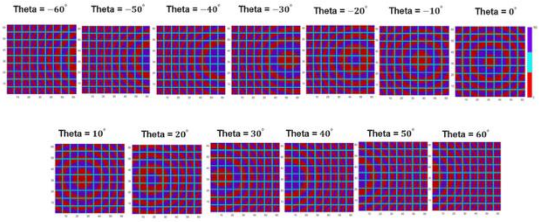


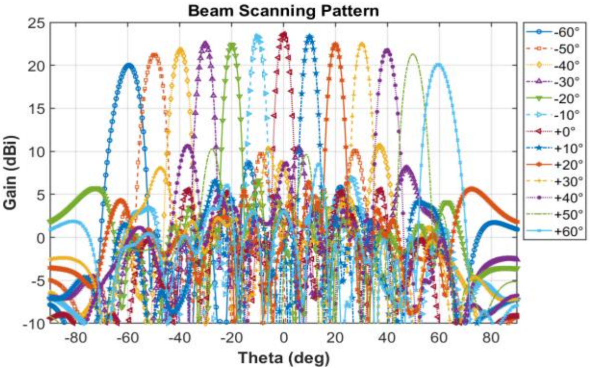
Programmable T-RIS simulation and fabrication











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Full-System THz/RIS Demonstration in Lisbon

The Lisbon campaign moved TERRAMETA from component validation into a full application-level demonstration, integrating D-band and 300 GHz radio front-ends, baseband units, multiple RIS prototypes, and Dell's industrial robotics use case into one end-to-end platform.

In the smart-factory scenario, an autonomous mobile robot streamed high-bandwidth 3D sensor data to an edge server for real-time reconstruction, visualization, and AI-based perception, a strong example of the future Physical AI workloads that need multi-Gbps throughput, sub-ms latency, and robust wireless operation in cluttered industrial spaces.

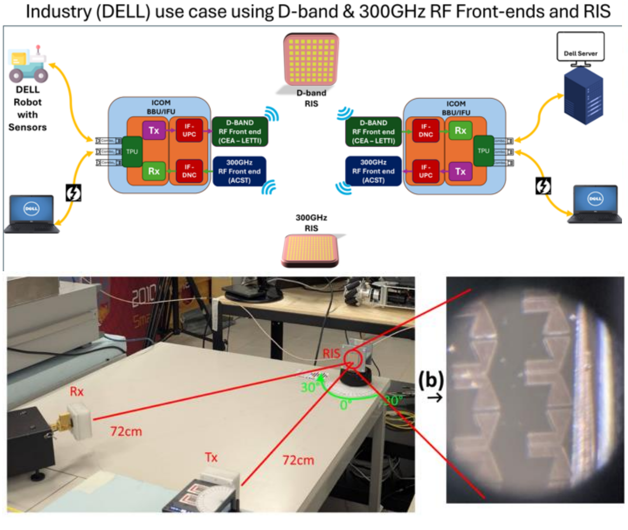
Key results included:

- **140 GHz LoS baseline:** 4.2 m link, 2 GHz bandwidth, 64-QAM, **7.1 Gbps throughput**, and **sub-ms round-trip latency**, with no noticeable penalty compared with fibre.
- **140 GHz RIS-assisted NLoS:** multiple RIS designs were tested. The active and passive memristor RIS designs created a functional wireless link, but showed sensitivity to mounting and environmental reflections, while the Schottky passive RIS achieved the strongest result: **32 dB SNR**, **128-QAM**, and **8.52 Gbps throughput** over a 72 cm + 72 cm reflected path.
- **Dual-band bidirectional demo:** a **140 GHz RIS-assisted uplink** carried the robot-to-edge sensor stream, while a **300 GHz RIS-assisted downlink** provided the return path at **2.09 Gbps** using 4-QAM, with the complete system maintaining **sub-ms latency**.

Controlled blockage tests confirmed that both wireless directions were actively used: blocking either link stalled the live sensor stream, while removing the blockage allowed the application to recover.

These results show that RIS-assisted sub-THz links can support real industrial robotics traffic at multi-Gbps rates, while also highlighting the practical deployment challenges — RIS alignment, packaging, mounting, and environmental scattering — that must be solved to make THz/RIS a reliable foundation for future 6G and Physical AI systems.

Industry (DELL) use case using D-band & 300GHz RF Front-ends and RIS



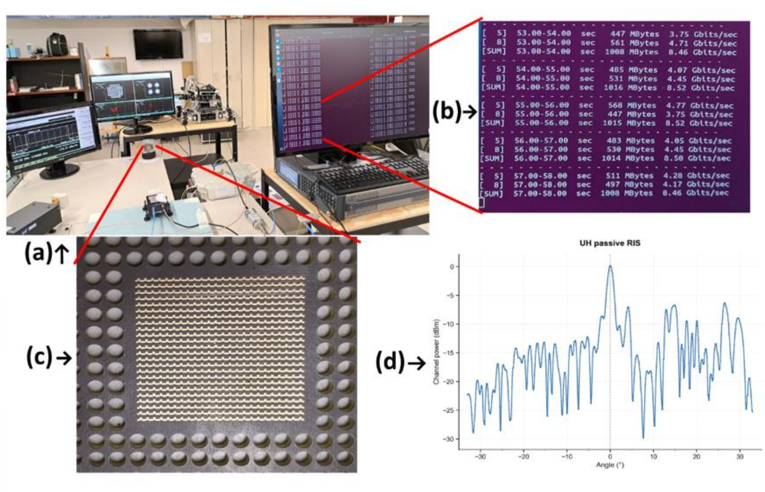


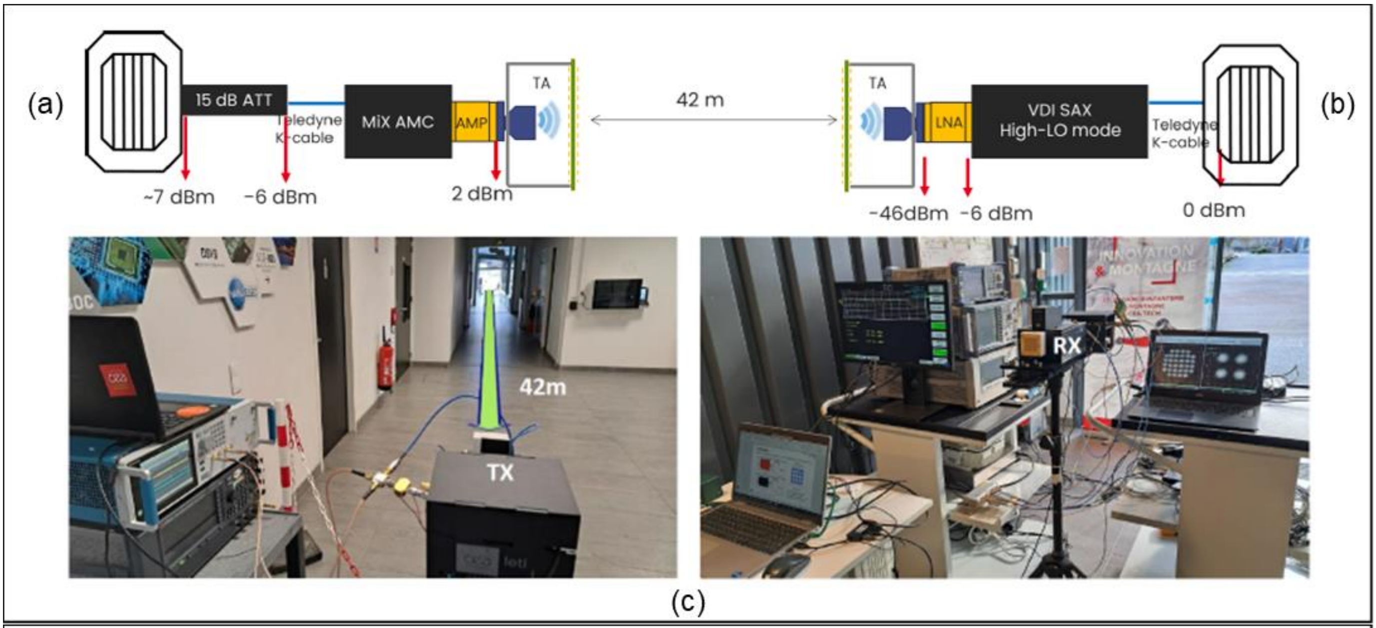
Fig. 4 NLoS Communications at 140 GHz Enabled by a Schottky-based RIS. (a) Physical setup of the Schottky RIS test in the 72 cm + 72 cm geometry. (b) Measured iperf3 throughput showing sustained application-layer data rate of 8.52 Gbps. (c) Zoomed-in view of the Schottky-based passive RIS. (d) Received channel power as a function of RIS angle, indicating an angular response consistent with the intended reflection geometry, with the maximum power observed at the nominal alignment angle and weaker responses at intermediate and Rx facing orientations.

42m point-to-point link operating in the D-band

A joint experiment between **CEA-Leti** and **ICOM** was performed at the end of March 2026 at CEA Leti Labs in Grenoble, where a Point-to-Point link at **42m**, operating in the **D-band (140GHz)** was demonstrated with real time processing. The transmitter section of the platform was composed of an I/Q mixer to an IF, a D-band up-converter, a D-band amplifier and custom transmitarray-based (TA) planar lens with gains up to **32dBi**. The D-band up-converter was a VDI MiX AMC module with intermediate frequency (IF) band ranging from DC up to 20GHz. The receiver section was composed of the same antenna, a D-band low noise amplifier (LNA), a D-band to IF downconverter and IF to baseband I/Q mixer. The baseband units performed all the baseband digital signal processing functions required for transmission and reception. These units have two modems with channel bandwidth up to 2000MHz capable of generating I/Q signals up to 512QAM reaching up to 30Gbit/sec.

The D-band front-end and the transmitarrays were provided by CEA Leti. The baseband units and the required equipment for traffic test experiments were provided by ICOM.

Traffic tests using iperf3 application were performed for this experimental setup where different constellation sizes were used. The maximum achieved throughput was **~6.5 Gbps** for the case of **32QAM** for the 1st and 4QAM for the 2nd modem.



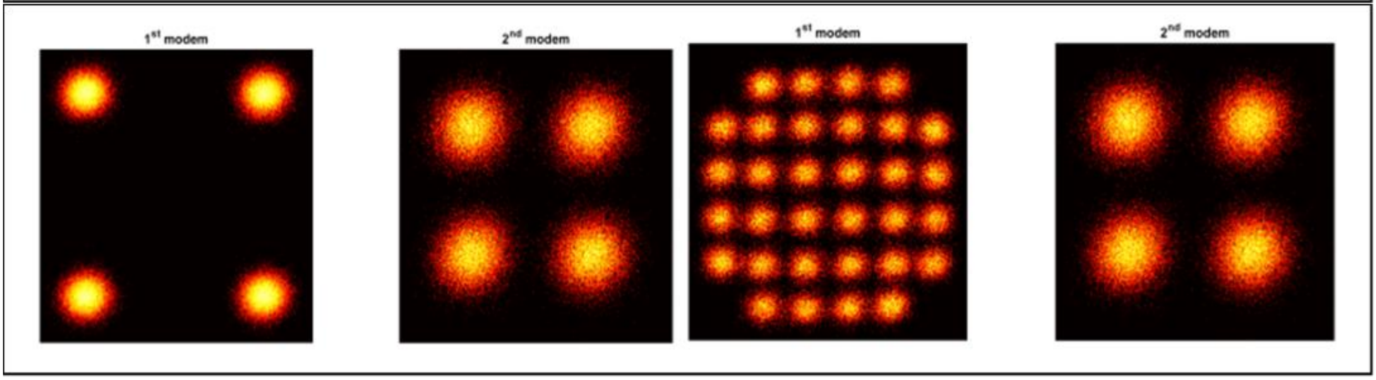
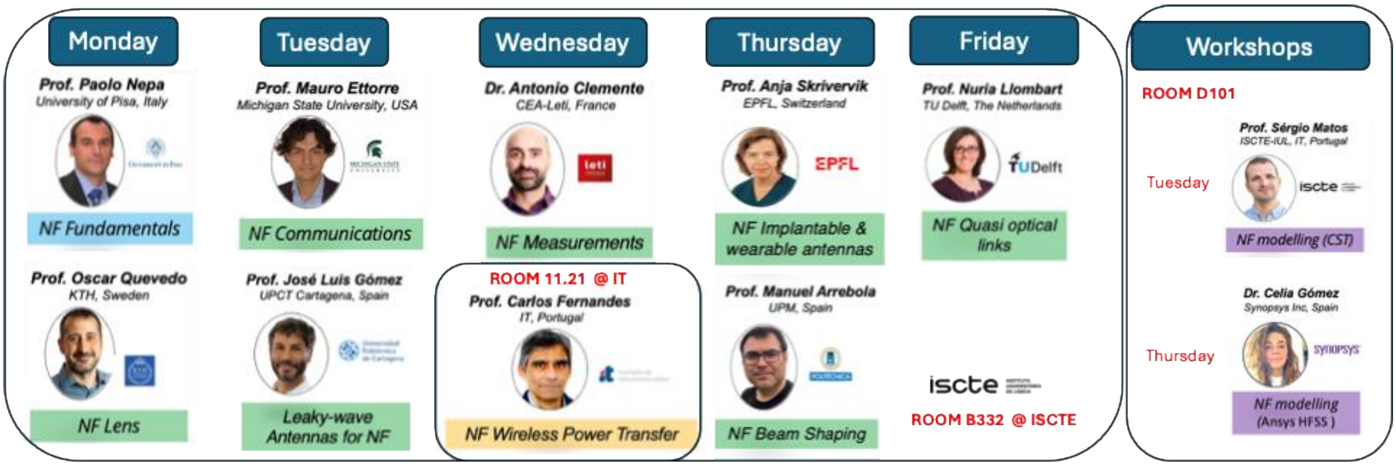
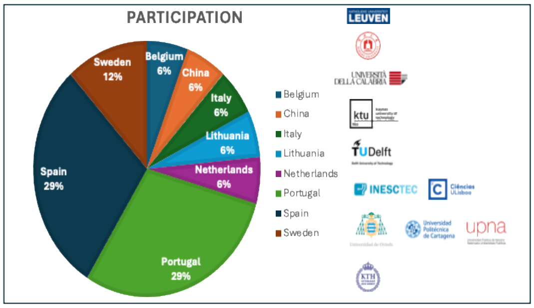


Fig. 1: a) The block diagram of the experimental setup, b) The transmitter side of the setup, c) the receiver side of the setup
Fig. 2: Constellation diagrams of the recovered QAM signals for the 1st and 2nd modem

ESoA school on near field antennas

With the support of TERRAMETA, a new *European School of Antennas and Propagation* (ESoA) course was launched under the *European Association on Antennas and Propagation*, focusing on **Near-Field Antenna Systems and Design**. The inaugural edition took place in Lisbon, Portugal, from April 6 to 10, 2026. Thanks to the success of this first edition, the course will continue beyond the TERRAMETA project as part of its legacy.





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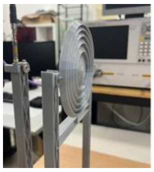
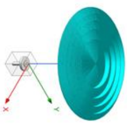
1 Lab

- ✓ **Students highly engaged in the course activities and networking**
- ✓ **Speakers provide high quality presentations and supporting materials**
- ✓ **A structured overview on Near Field topic from fundamental to applications**

Theory | *Workshop* | Applications | *Lab sessions*

- ✓ **The connection between workshops and labs was appreciated**





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TERRAMETA Workshop Highlights Emerging mm-Wave and sub-THz Antenna Technologies at EuCAP 2026

TERRAMETA was strongly represented at EuCAP 2026 through the organization of the workshop *“Emerging mm-Wave and sub-THz antenna arrays: recent technological advances and applications”*, coordinated by Luis Pessoa (INESC TEC) and Antonio Clemente (CEA Leti). The workshop brought together leading researchers from several major European initiatives working on antennas, metasurfaces, THz communications, sensing, and future 6G systems. The workshop featured invited talks from:

- **Antonio Clemente (CEA Leti)** – *Bridging PCB and III-V Technologies: Novel Bonding Strategies and On-Chip Metasurfaces for D-band Antenna Arrays* (TERRAMETA / SYSTERA / FUNTERA)
- **Luis Guerrero (UC3M)** – *Photonic-enabled Broadband Phase Array Antennas Operating in the Millimeter-Wave Range* (Tera6G)
- **Ronan Sauleau (IETR / Université de Rennes)** – *Compact Sub-Terahertz Antennas Using Folded Flat Optics*
- **Guillaume Ducournau (IEMN)** – *Measurements for THz Communications: Active Devices and RIS* (FUNTERA / SYSTERA / TIMES)
- **Nuria Llombart (TU Delft)** – *Towards High Capacity and Efficient Communication Links at 300 GHz* (TeraGreen)
- **M. Sajjad Ahmad (Barkhausen Institut)** – *ISAC/JCAS, Antenna and Beamforming Challenges, Solutions, and Performance Trade-offs* (6G-SENSES / HiCONNECTS)

For TERRAMETA, the workshop provided an excellent opportunity to disseminate project results to the wider European antenna and propagation community, while strengthening links with other SNS and Horizon Europe projects working on enabling technologies for future 6G systems.

Workshop Picture at EuCAP 2026 with the organisers and presenters.

TERRAMETA at EuCNC & 6G Summit 2026 Workshop on 6G Hardware Technologies

TERRAMETA will contribute to the EuCNC & 6G Summit 2026 workshop *“Microelectronics and Photonics Hardware Challenges and Solutions towards 6G”*, taking place on 2 June 2026. The workshop is organised by Luís Pessoa (INESC TEC / Univ. Porto), Eric Klumperink (Univ. Twente), Alexios Birbas (Univ. Patras), and Ioannis Tomkos (Univ. Patras), in the context of the SNS JU Hardware Technologies Working Group (HT-WG).

The event will bring together leading experts from industry, academia, and European research projects to discuss the key hardware challenges shaping future 6G systems, including RF front-ends, heterogeneous integration, photonics-electronics co-design, advanced packaging, and energy-efficient communication platforms.

TERRAMETA will be represented by Antonio Clemente (CEA-Leti), presenting the talk *“Novel bonding strategies and on-chip metasurfaces for D-band antenna arrays”*. The presentation will highlight recent advances from the project on innovative integration approaches and metasurface-enabled antenna technologies targeting high-frequency 6G communications.

The workshop also features a keynote by Ericsson on the role of microelectronics in unlocking the potential of 6G systems, alongside a strategic panel discussion addressing European hardware sovereignty and the alignment between SNS JU, Chips JU, and pilot lines. Through this participation, TERRAMETA contributes to the broader European effort towards next-generation 6G hardware ecosystems and the convergence of communications, sensing, microelectronics, and photonics technologies.

Workshop Agenda:

Keynote: How microelectronics unleashes the potential of 6G systems
Fredrik Tillman – Ericsson

Session I – Enabling Hardware Technologies and Integration

- Time-modulated arrays for multi-beam MIMO – 6G-REFERENCE / ETH Zurich
- Low-power 60 GHz RF front-ends for ISAC – 6G-SENSES / IHP
- Novel bonding strategies and on-chip metasurfaces for D-band arrays – TERRAMETA / CEA-Leti
- Heterogeneous integration and packaging enabled by EM simulations – X-TREME6G / Fraunhofer IZM
- Design of ultrabroadband MMICs using III–V technologies – UCL

Session II – Microelectronics and Photonics Platforms for 6G

- Active devices: photonics and electronics characterizations – TIMES / Univ. Lille
- Photonic technologies for 6G fronthaul and optical wireless – 6G-EWOC / AIT
- Integrated frontend for optical communications towards 200 Gbaud – X-TREME6G / KIT
- Photonic-enabled 2D antenna arrays for 6G transceivers – TERA6G / UC3M
- Merging photonics & electronics ICs for ultra-high data rate transceivers – FLEX-SCALE & PROTEUS / PICADVANCED

Panel Discussion – Moderator Oana Radu (SNS-JU)

Focus on:

- Hardware bottlenecks for 6G systems
- Electronics-photonics co-design challenges
- Alignment between SNS JU, Chips JU, and pilot lines

TERRAMETA Releases Open Datasets for sub-THz RIS and Metasurface Research

As part of its commitment to Open Science and FAIR data principles, the TERRAMETA project has released a first set of open-access datasets supporting research on sub-THz communications, Reconfigurable Intelligent Surfaces (RIS), and advanced metasurface technologies for future 6G systems. The datasets are publicly available through the **TERRAMETA Zenodo Community** and are also registered in the SNS-JU Metadata Registry System (MRS).

The published datasets provide experimental measurements, simulation data, and processing tools covering several of the key hardware technologies developed within the project. These datasets are intended to support reproducibility, benchmarking, and further research by the wider scientific community.

The currently released datasets include:

- **Sub-THz Multifunctional Metasurface Dataset for Transmission and Reflection Phase Manipulation:** Experimental and simulation data for a dual-band metasurface capable of independently controlling transmission and reflection phases, supporting both transmitarray and reflectarray operation.
- **Passive Reflective Metasurface for D-band (140 GHz): Simulation and Measurement Results:** Measured and simulated characterization data for highly efficient passive reflective metasurfaces operating at 140 GHz with wide steering angles.
- **300 GHz Passive 1-/2-/3-Bit RIS Characterization Dataset:** Experimental angular scattering measurements and electromagnetic simulations for passive RIS implementations with different phase quantization levels at ~300 GHz.
- **Memristor RF Characterization Dataset:** Broadband S-parameter measurements (up to 160 GHz) of memristive switching devices operating in Low Resistance State (LRS) and High Resistance State (HRS), targeting future reconfigurable RIS implementations.
- **Calibrated Azimuth-Resolved Channel Impulse Responses at 300 GHz in an Industrial-Like Environment:** Calibrated channel sounding measurements for RIS-assisted propagation scenarios.

Several datasets also include MATLAB processing and visualization scripts to facilitate reuse and reproducibility of the published results.

These open datasets represent an important contribution of TERRAMETA to the European research ecosystem on THz communications and RIS technologies, while supporting transparency, validation, and accelerated innovation toward future 6G wireless systems.