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Metasurfaces for future wireless communications

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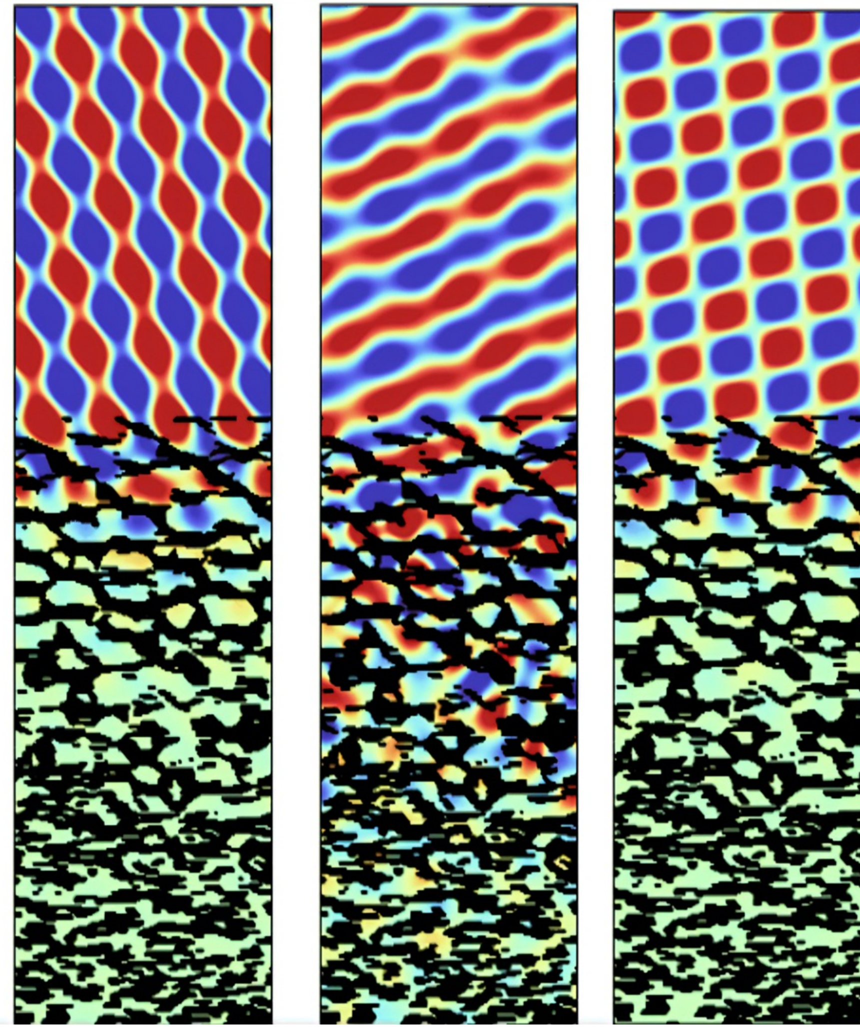
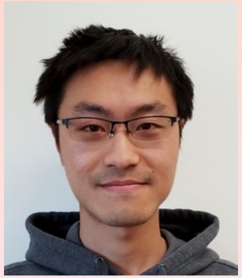


Acknowledgement

M.M. Asgari

Aalto University, Finland

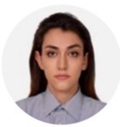


P.B. Catrysse H. Wang S. Fan

Stanford University, USA

Also my other colleagues: S.A. Tretyakov, A. Diaz-Rubio, S. Tcvetkova, F. Cuesta, M. Albooyeh, A. Elsakka, M. Movahediqomi

Designer Materials and Devices group



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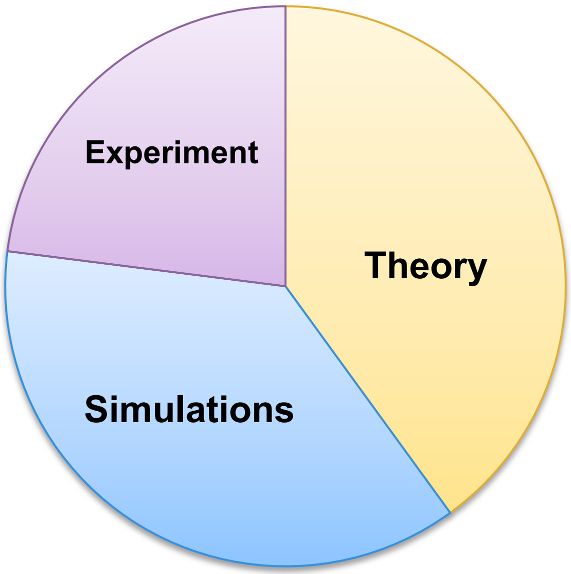
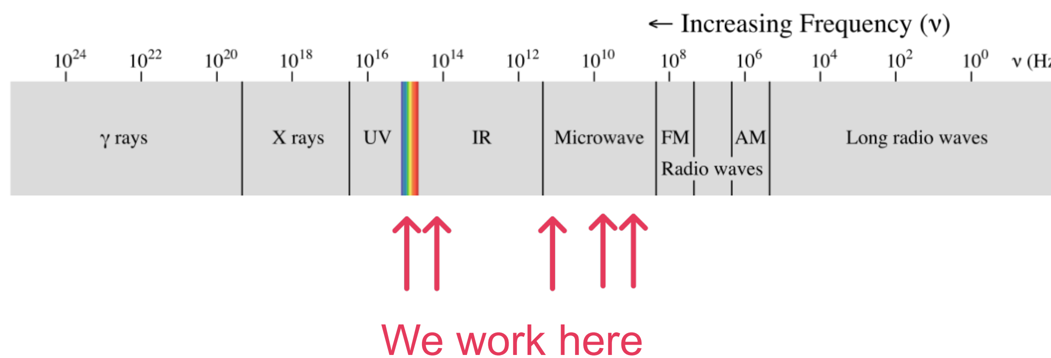
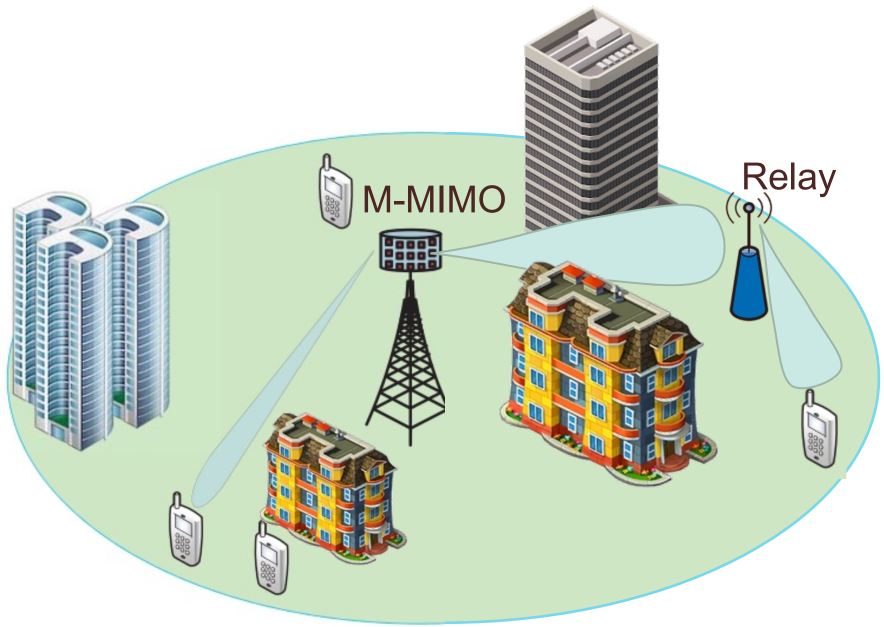
Our expertise





Current wireless communications



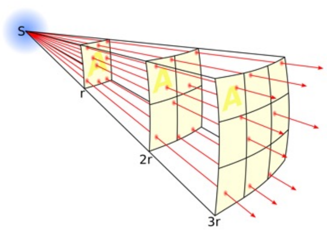
Going to higher frequencies means:

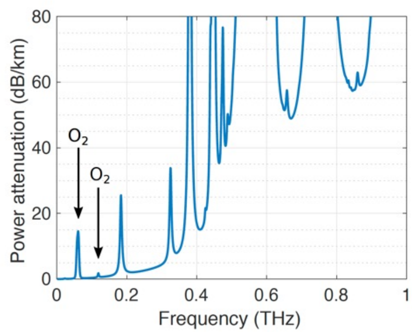
- Higher price
- Higher complexity
- More interference issues
- Higher energy consumption
- Less multipath propagation

Reconfigurable **transmitters and receivers**

Critical aspects in mmWave communications

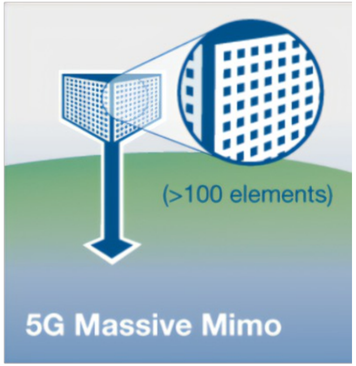
High free-space path loss and sensitivity to obstacles





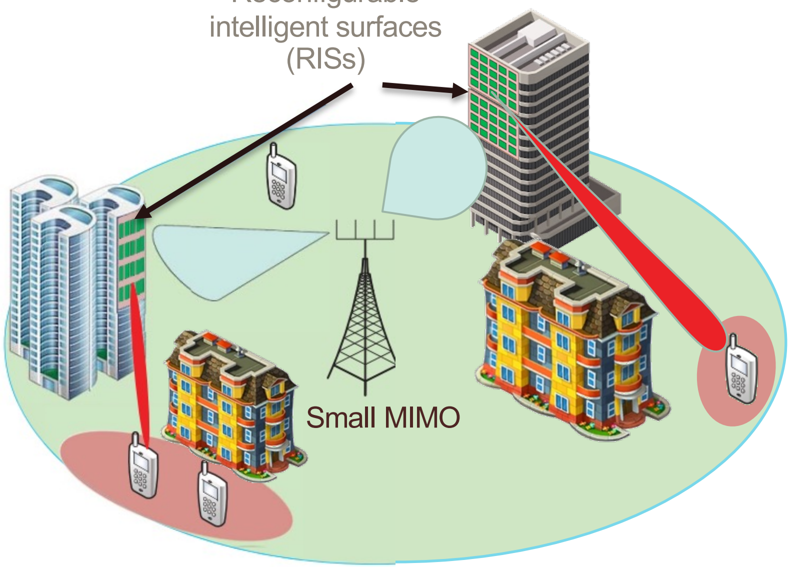
Terahertz wave atmospheric power attenuation for temperature T = 20°C

Denser antenna arrays with smaller elements



- O'Hara et al, A Perspective on Terahertz Next-Generation Wireless Communications, Technologies 7, 43, 2019.
- R. Flamini et al, Toward a Heterogeneous Smart Electromagnetic Environment for Millimeter-Wave Communications: An Industrial Viewpoint, IEEE TAP 70, 10, 2022.

Future wireless communications

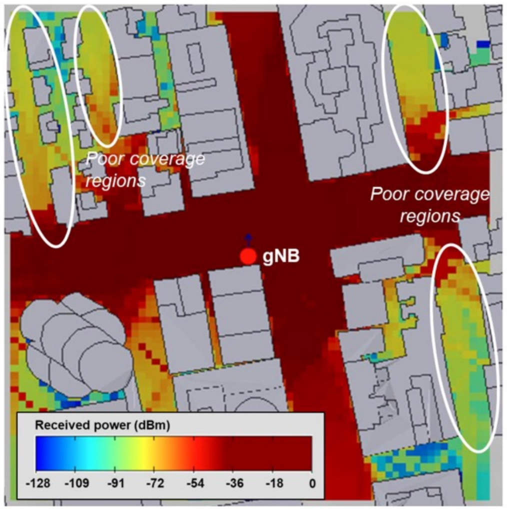


Reconfigurable transmitters and receivers
and Smart Environment

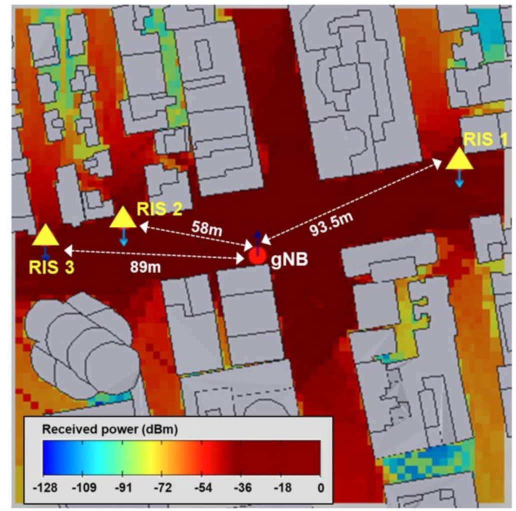
Reconfigurable intelligent surfaces:

- Passive or almost passive (inexpensive)
- No interference
- Low maintenance cost

Example of RIS deployment in Hong Kong city



60% coverage



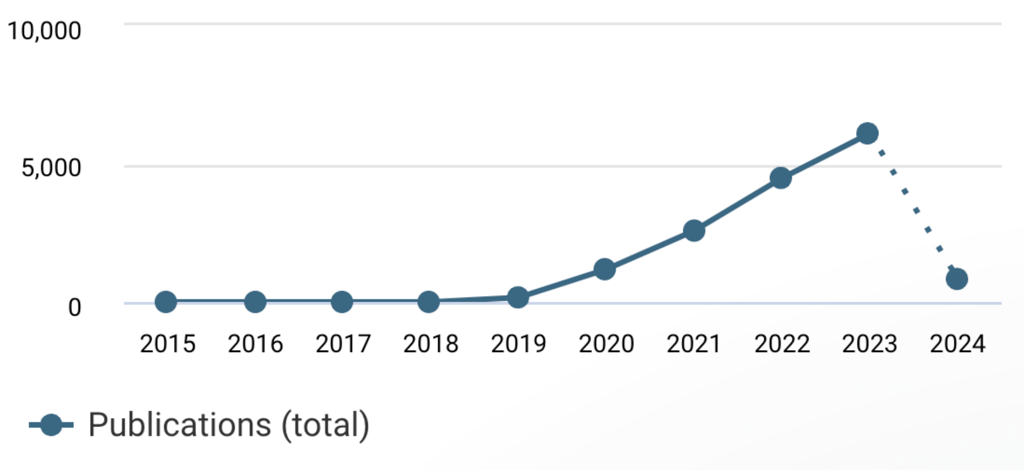
80% coverage

R. Flamini et al, Toward a Heterogeneous Smart Electromagnetic Environment for Millimeter-Wave Communications: An Industrial Viewpoint, IEEE TAP 70, 10, 2022.

Indoor environments

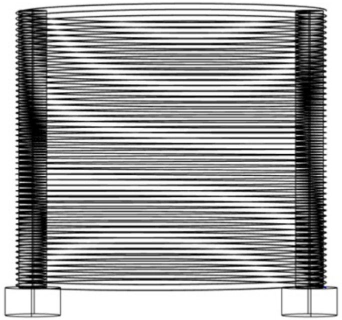
Research interest

Publications in each year. Keywords: “**reconfigurable intelligent surface**”.
Source: https://app.dimensions.ai



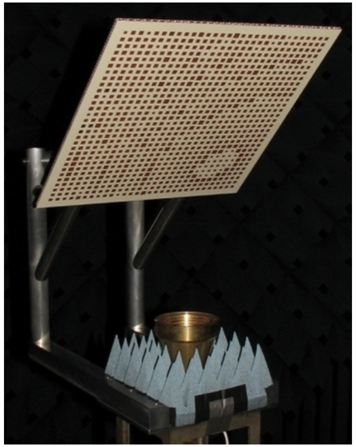
History of the field

Diffraction gratings



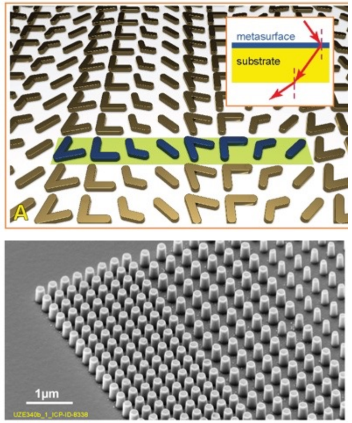
C. Palmer, E. Loewen, Diffraction Grating Handbook, 2005

Reflectarray antennas



N. Payam, F. Yang, and A.Z. Elsherbeni, Reflectarray antennas: theory, designs, and applications, 2018.

Metasurfaces



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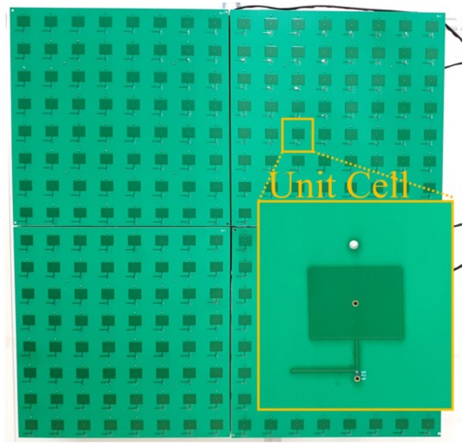
Reconfigurable intelligent surfaces (RISs)

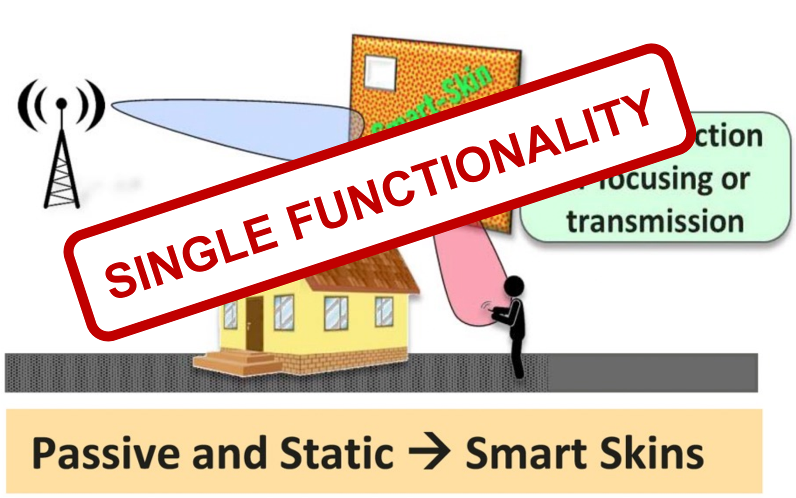


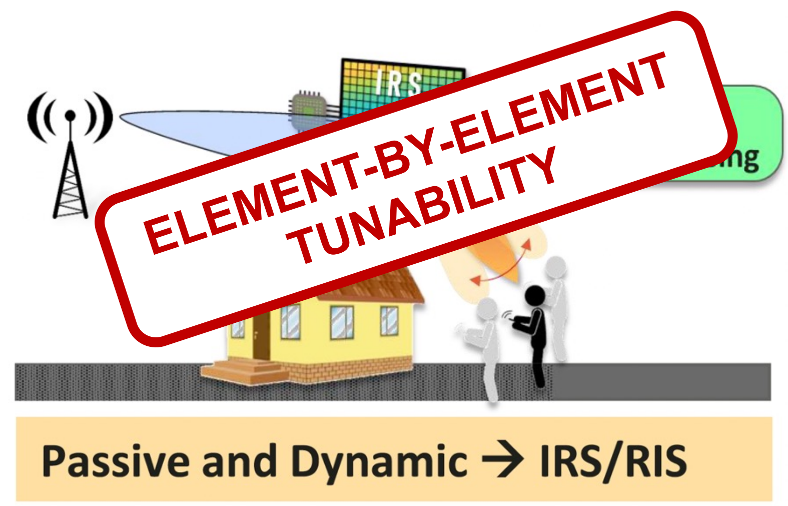
Y. Liu et al, Reconfigurable intelligent surfaces: Principles and opportunities, IEEE CST 23, 3, 2021.

Our metasurface experience

- Asadchy et al, Physical Review B 94, 7, 2016.
- Díaz-Rubio, Asadchy et al, Science Advances 3, 8, e1602714, 2017.

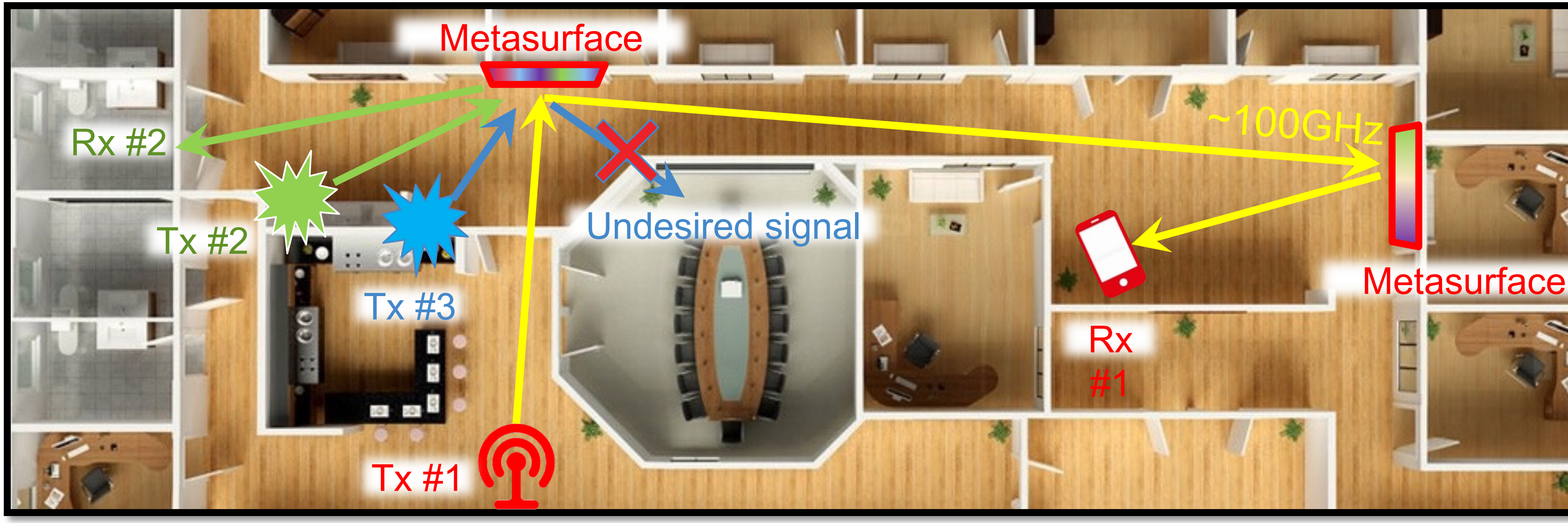
Passive vs reconfigurable



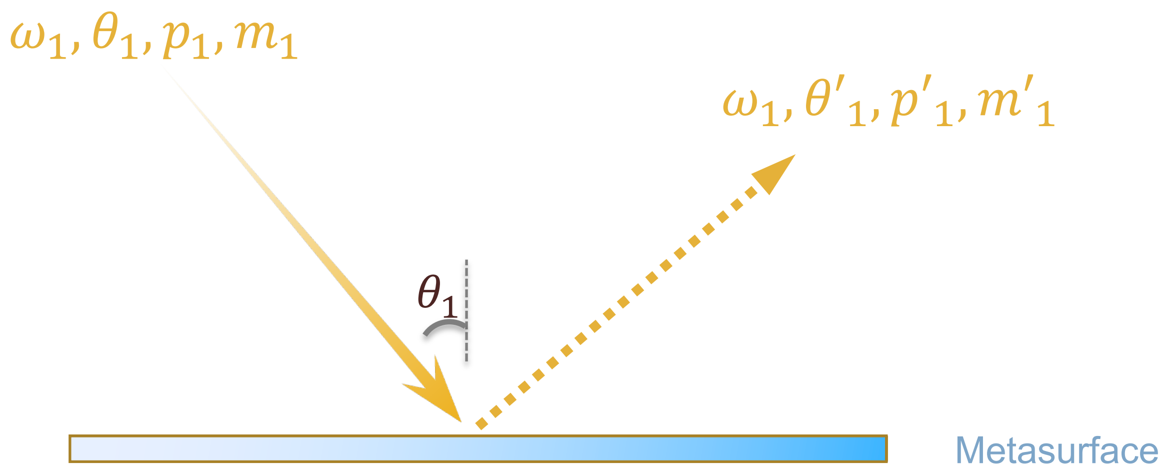


R. Flamini et al, Toward a Heterogeneous Smart Electromagnetic Environment for Millimeter-Wave Communications: An Industrial Viewpoint, IEEE TAP 70, 10, 2022.

Multifunctional metasurfaces for 6G

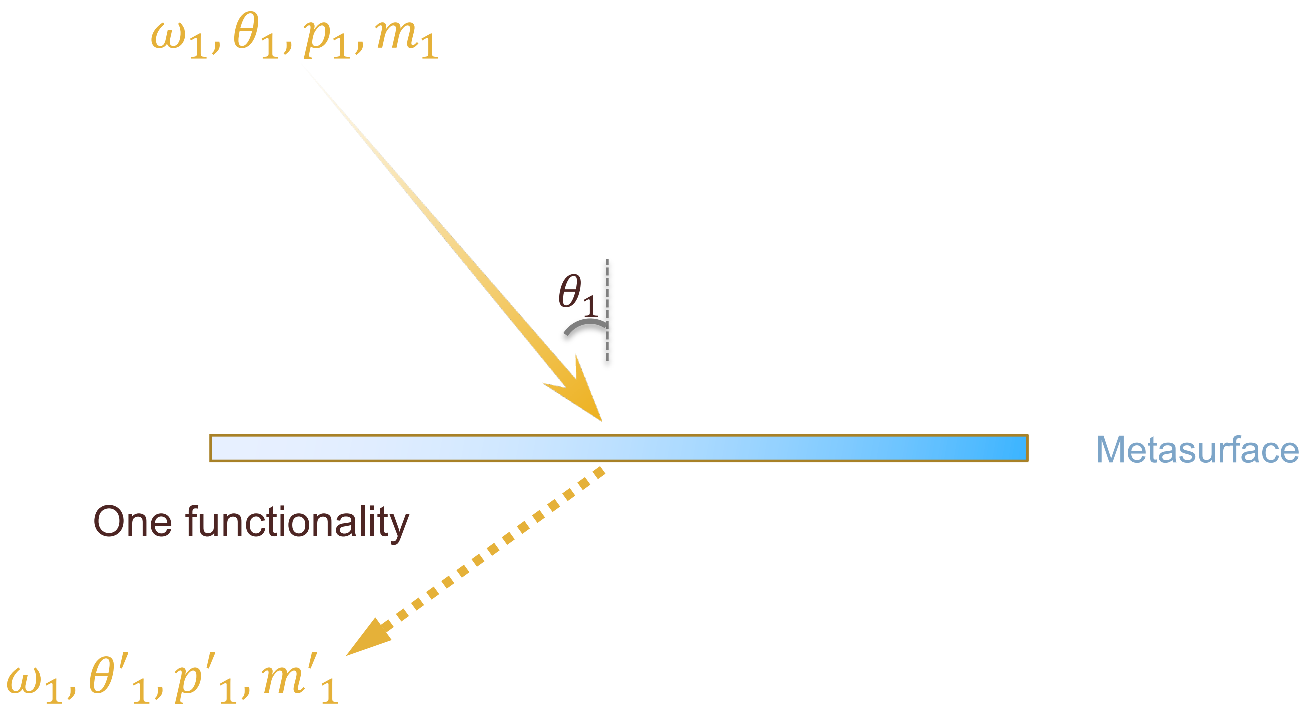


Arbitrary scattering of EM waves

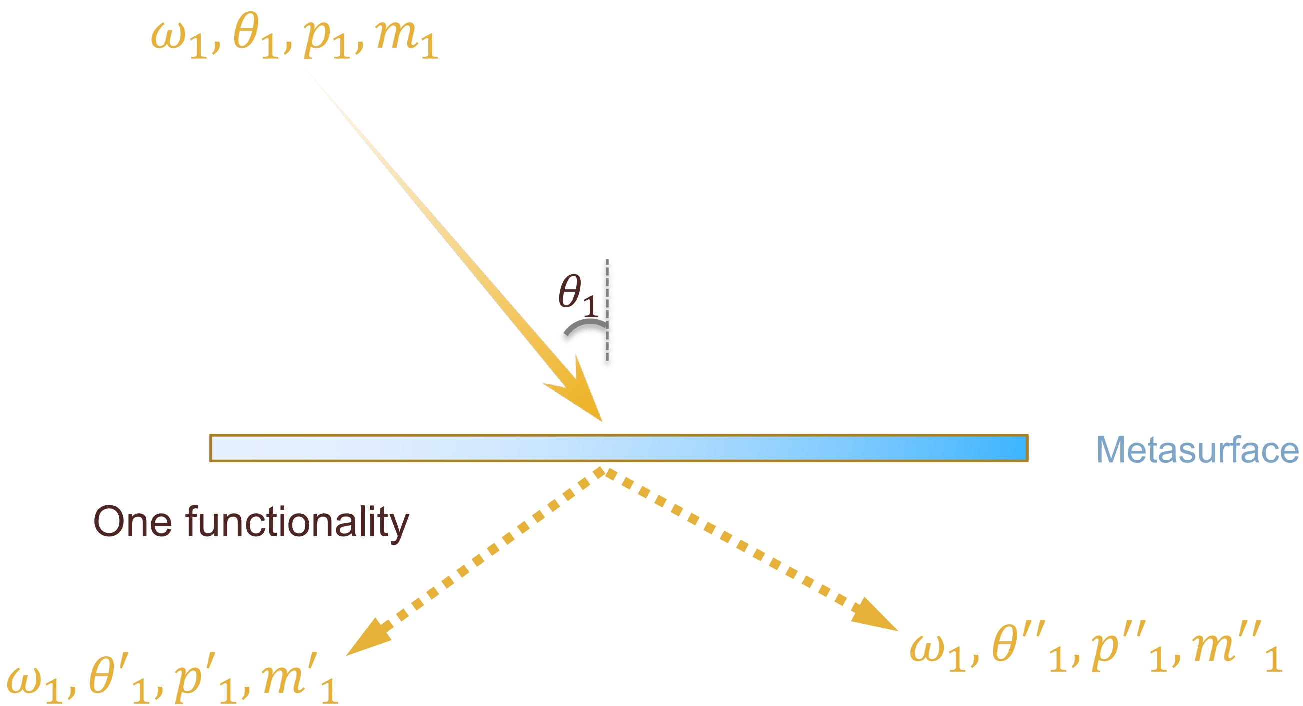


One functionality

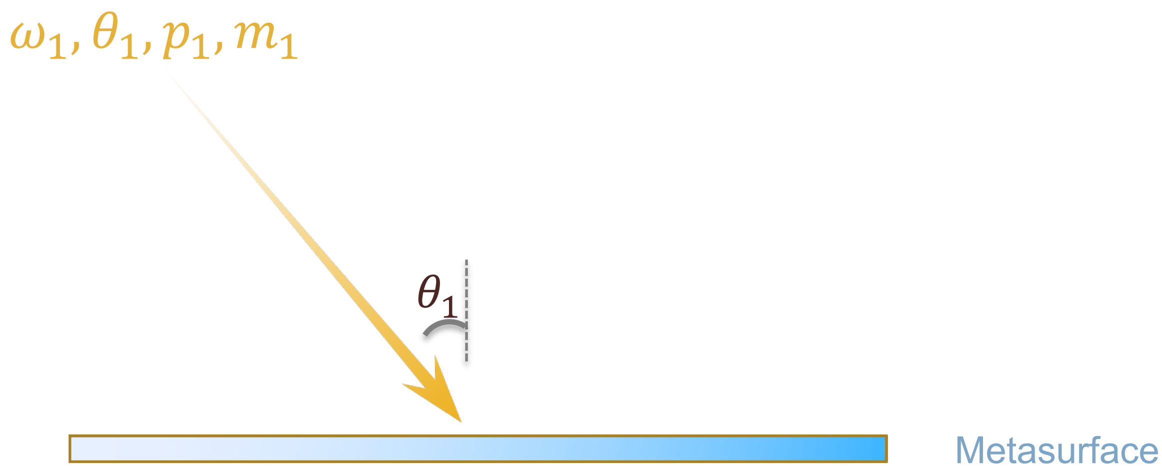
Arbitrary scattering of EM waves



Arbitrary scattering of EM waves

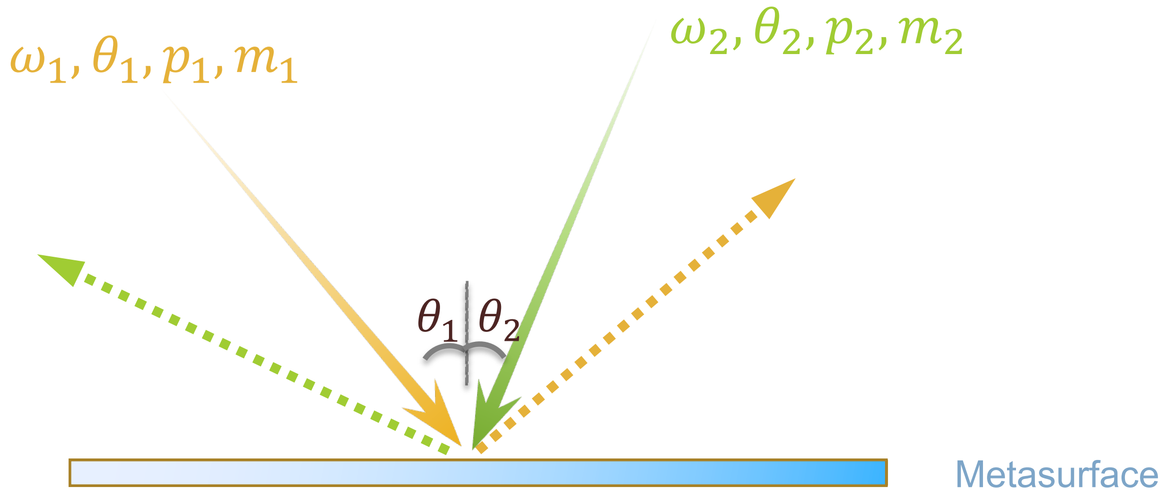


Arbitrary scattering of EM waves



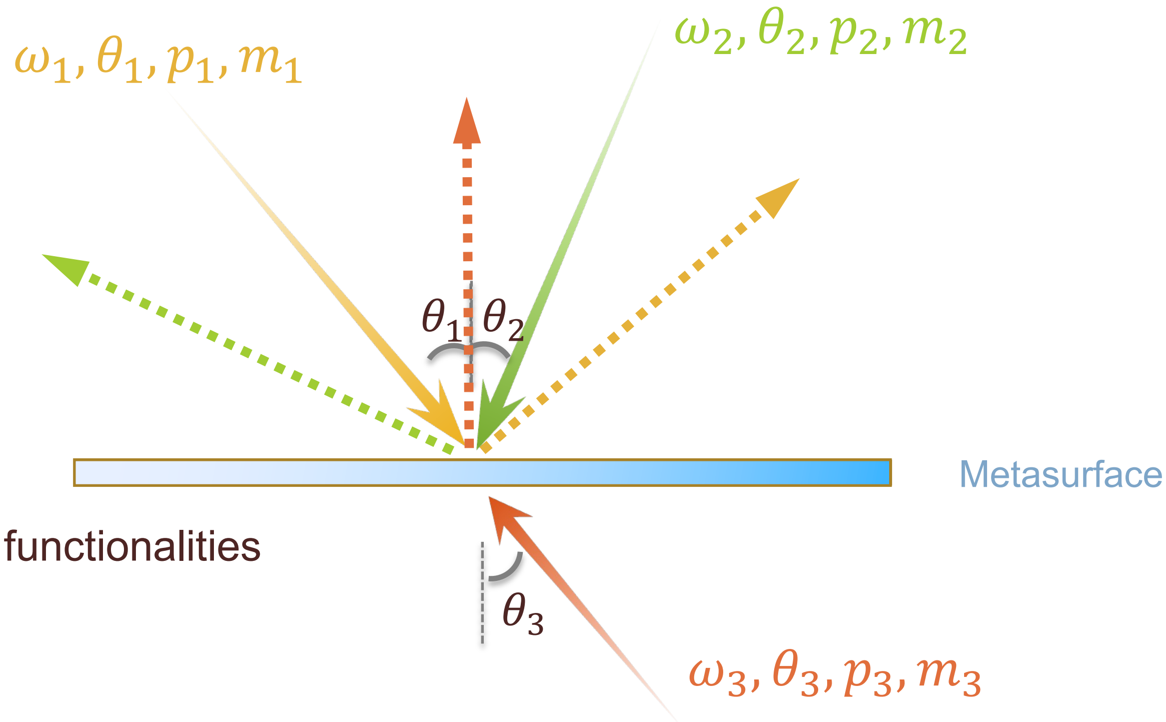
One functionality

Arbitrary scattering of EM waves



2 functionalities

Arbitrary scattering of EM waves



3 functionalities

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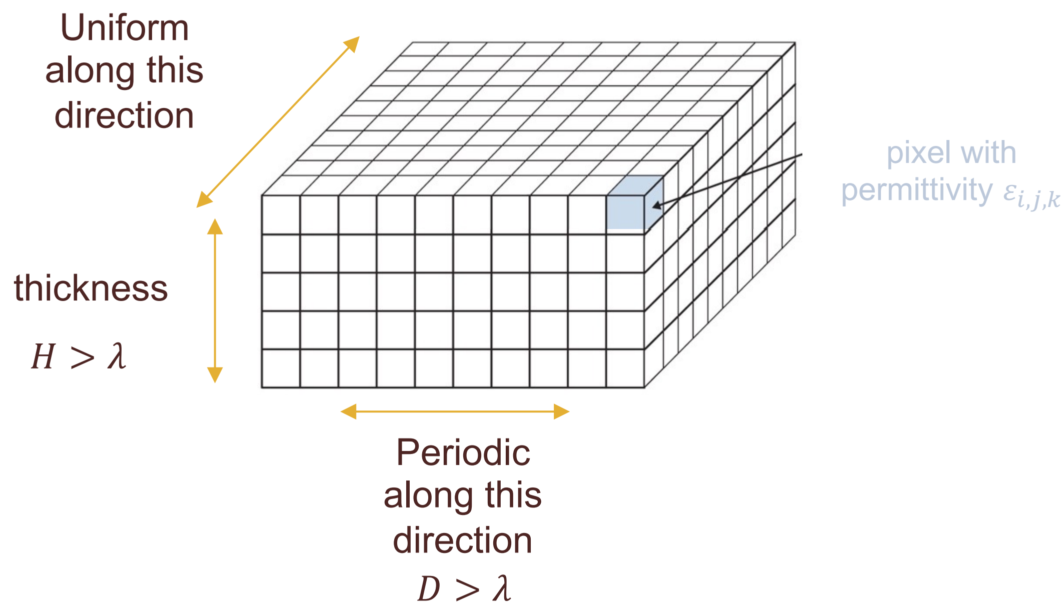
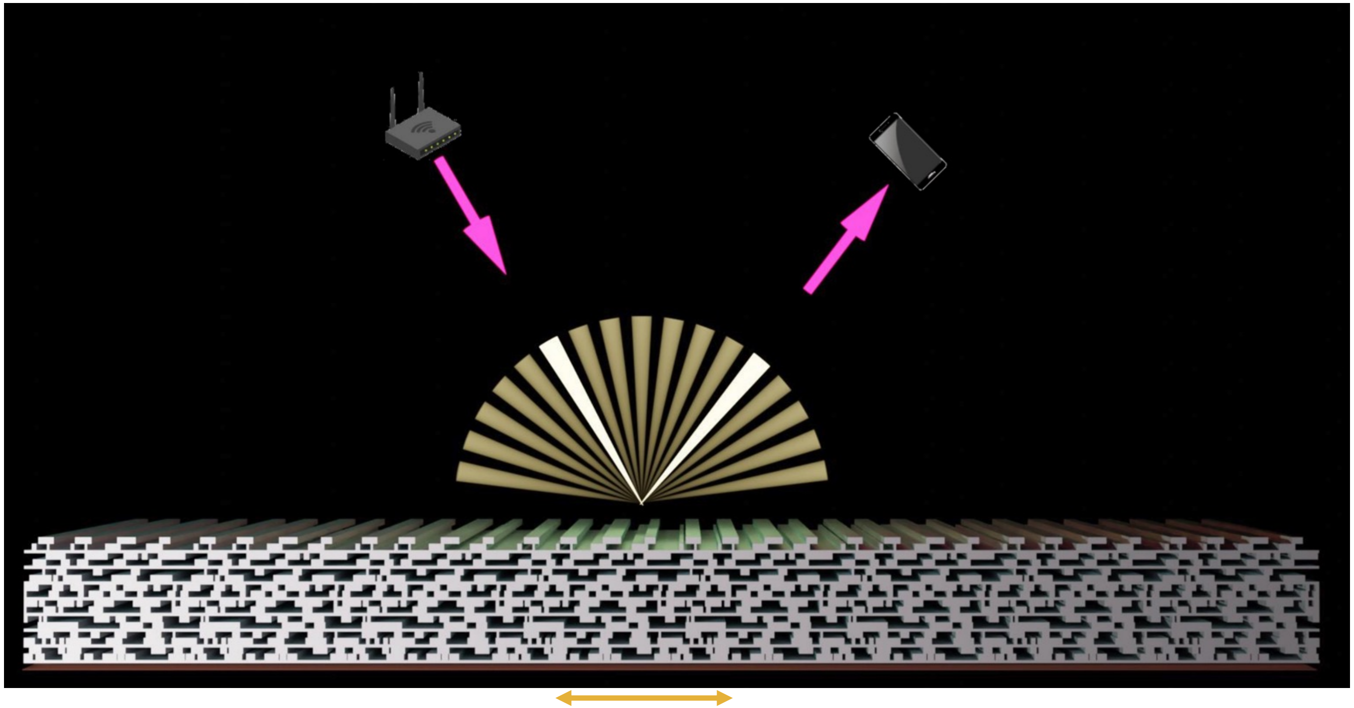
Towards highly multifunctional structures: metacrystals



Groups of Jelena Vuckovic, Ole Sigmund, Andrei Faraon, Shanhui Fan, Jonathan Fan, Alejandro Rodriguez, Nader Engheta, and many others

Diffraction orders



$d = 4.2\lambda$

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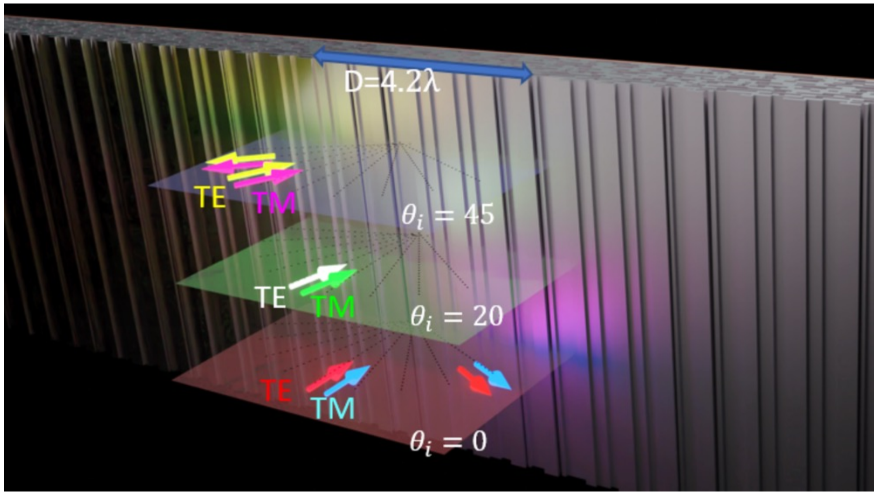
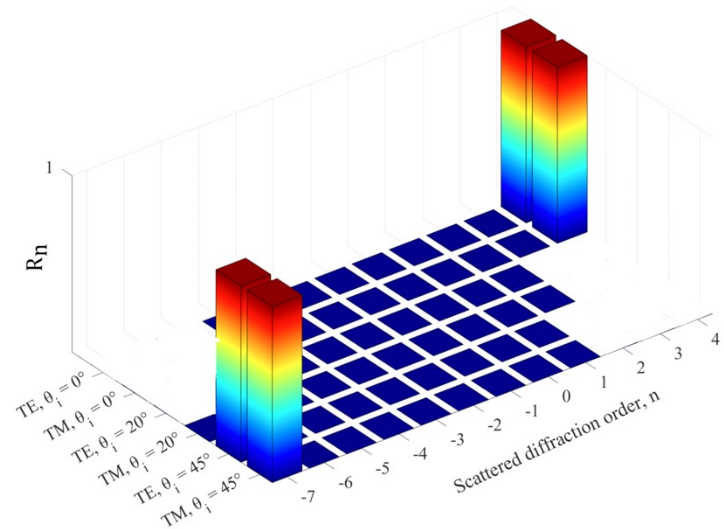
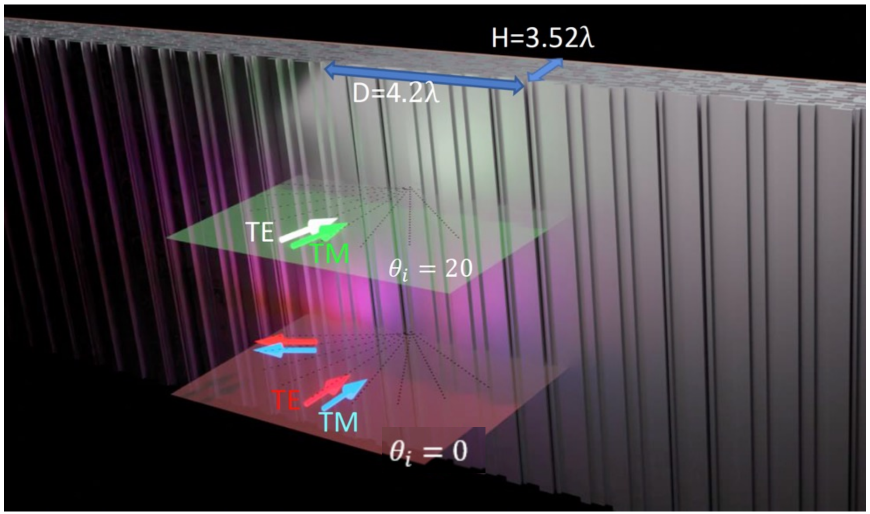
6 functionalities

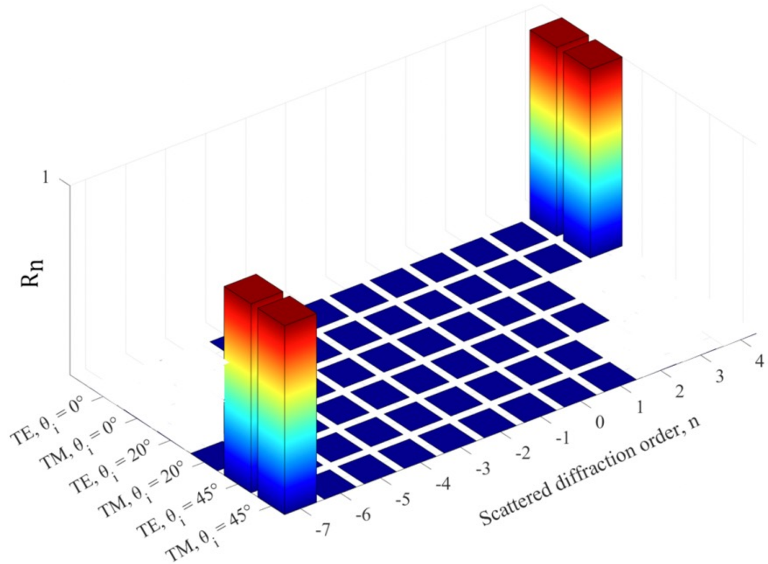




Average efficiency 92%

4 functionalities

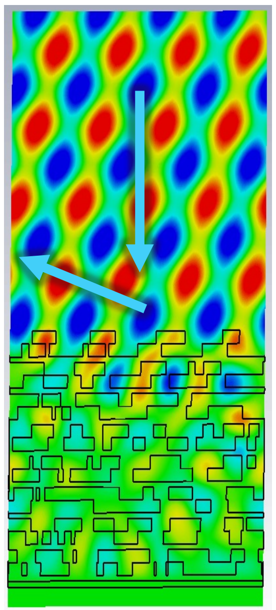




Average efficiency 87%

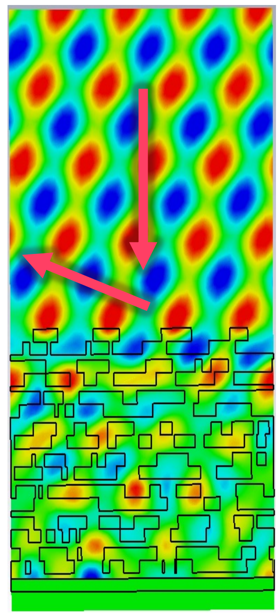
Full-wave simulations

TE, $\theta = 0°$



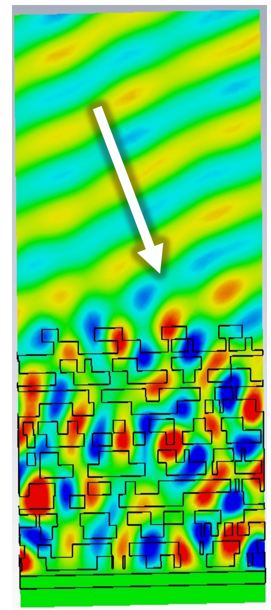
Anomalous reflection

TM, $\theta = 0°$



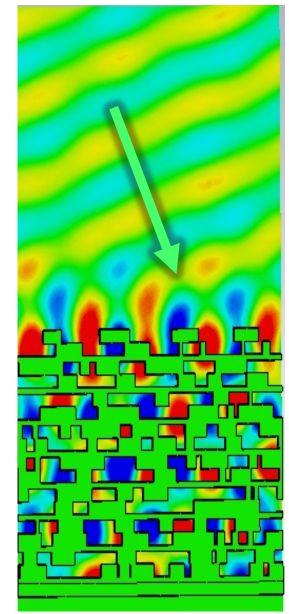
Anomalous reflection

TE, $\theta = 20°$



Absorption

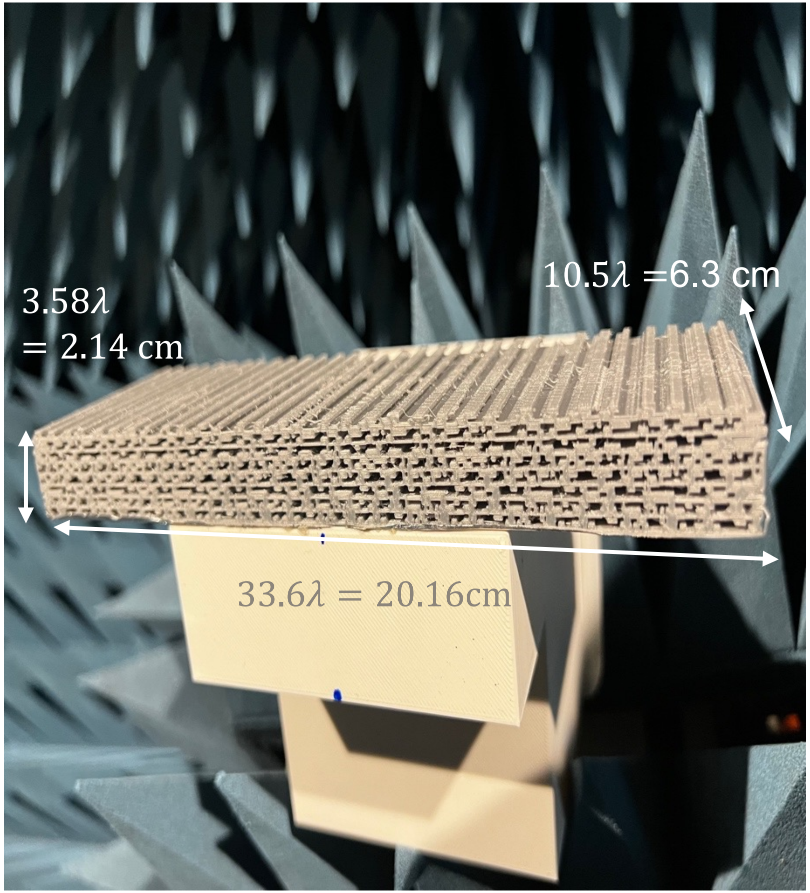
TM, $\theta = 20°$



Absorption

3D-printed sample

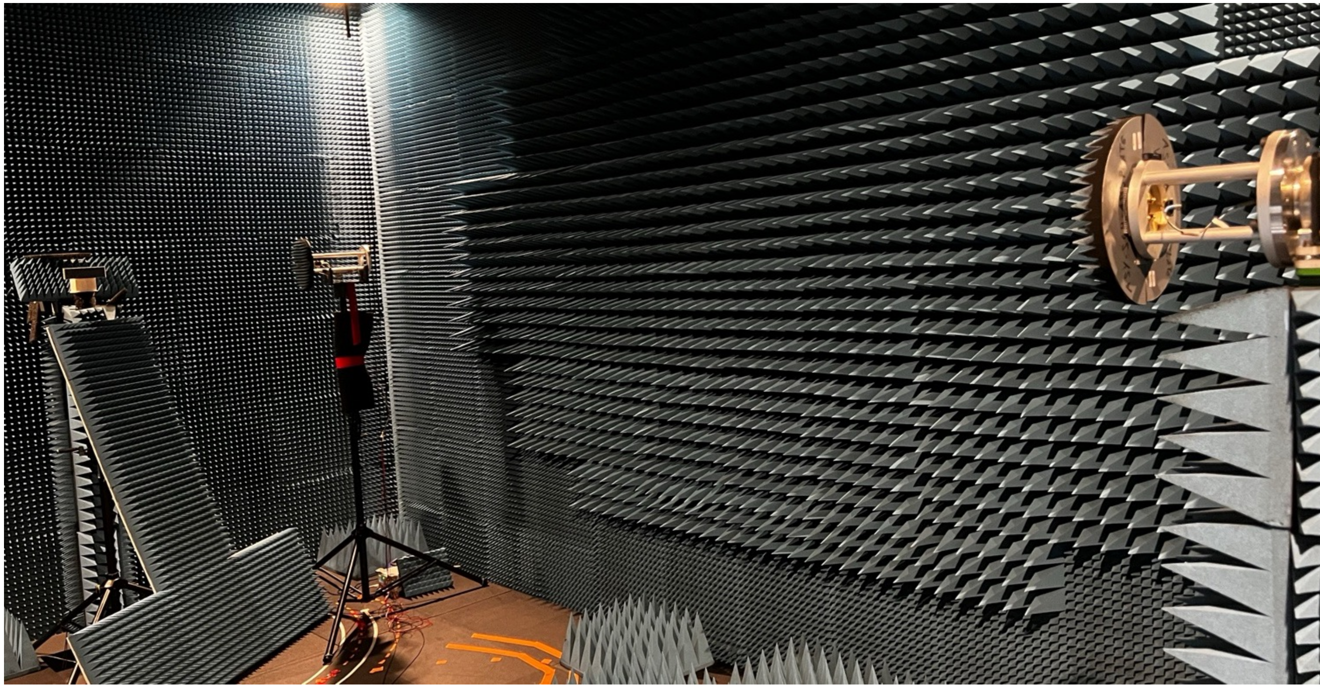
	In-plane resolution	Out-of-plane resolution
FDM	250 um	100 um
SLS	500 um	100 um
SLA	85 um	25 um



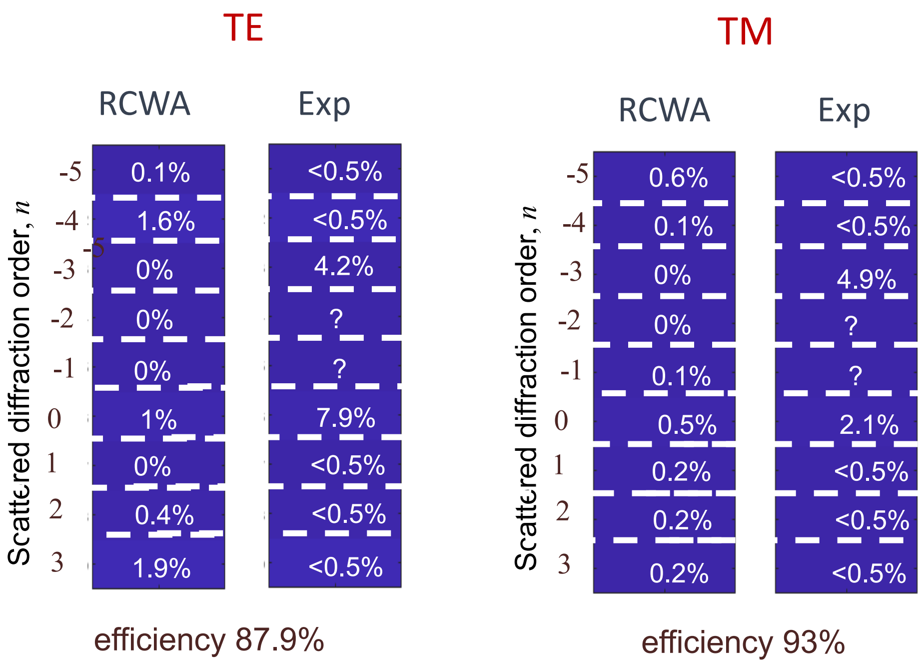
Fabricated structure operating at 50GHz

PLA permittivity measurements

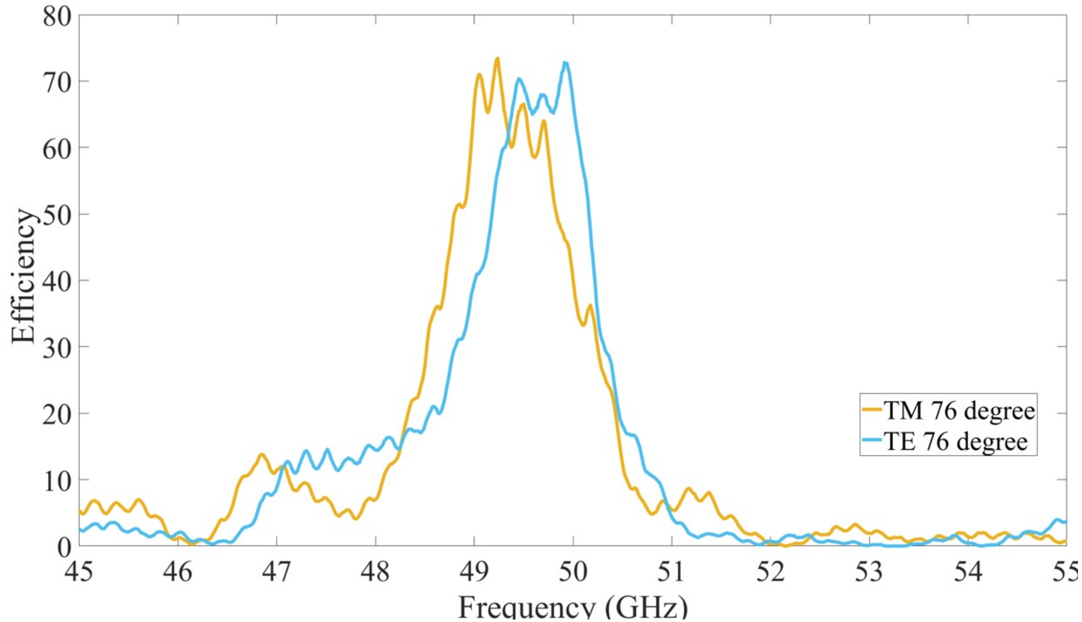
Measurement setup



Measurement results. Absorption



Measurement results. Anomalous reflection



Maximum average efficiency for 4 functionalities reaches 79.3% at 49.5 GHz

References

- M.M. Asgari, P.B. Catrysse, H. Wang, S. Fan, and V.S. Asadchy, Multifunctional Metacrystals for Advanced Wave Engineering, 17th International Congress on Artificial Materials for Novel Wave Phenomena (Metamaterials 2023), 2023.

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