Microelectronic Technology

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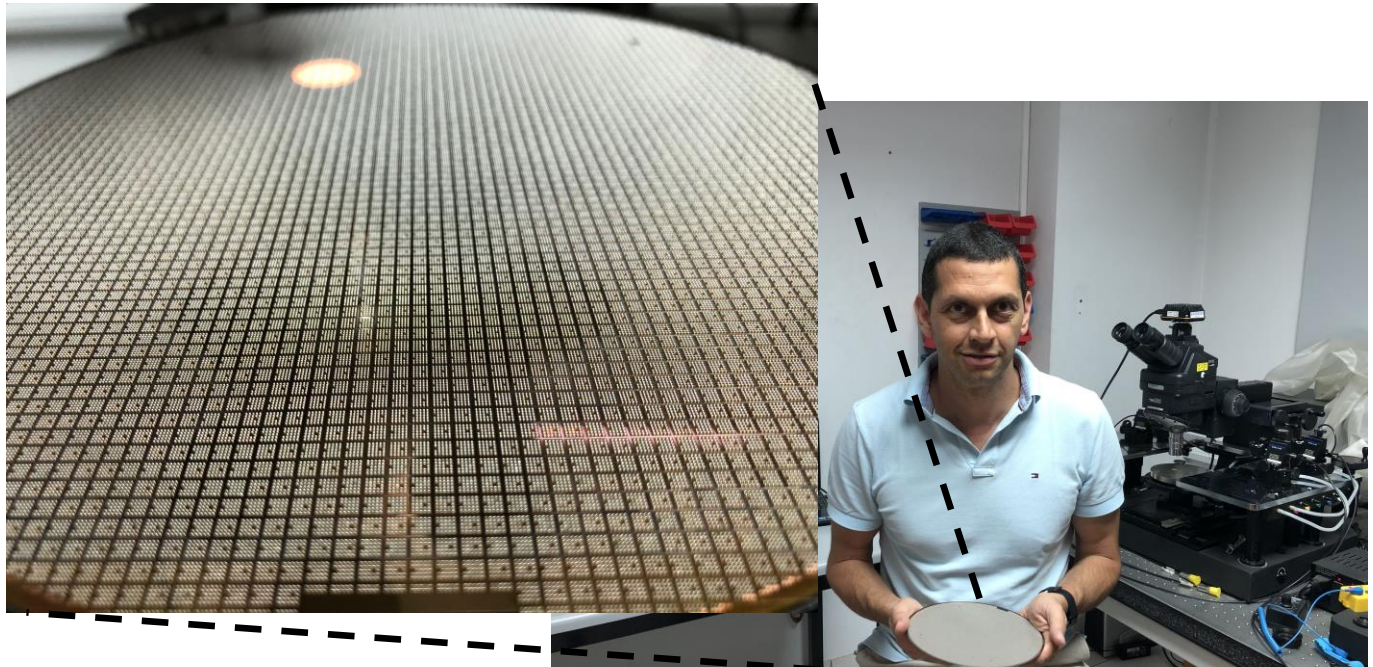
What are Microelectronics?

"The Design, Manufacture and use of Microchips and Microcircuits"



Are Microelectronics Important?

The New York Times

September 9th 2022

STRATEGIES

How Silicon Chips Rule the World

Maintaining the flow of oil is still crucial for the world economy. But now the supply of semiconductors is also critical for commerce, and war and peace.

Finance & economics | Loading, please wait

The global chip shortage is here for some time

Microchips were a boom-and-bust industry even before covid-19

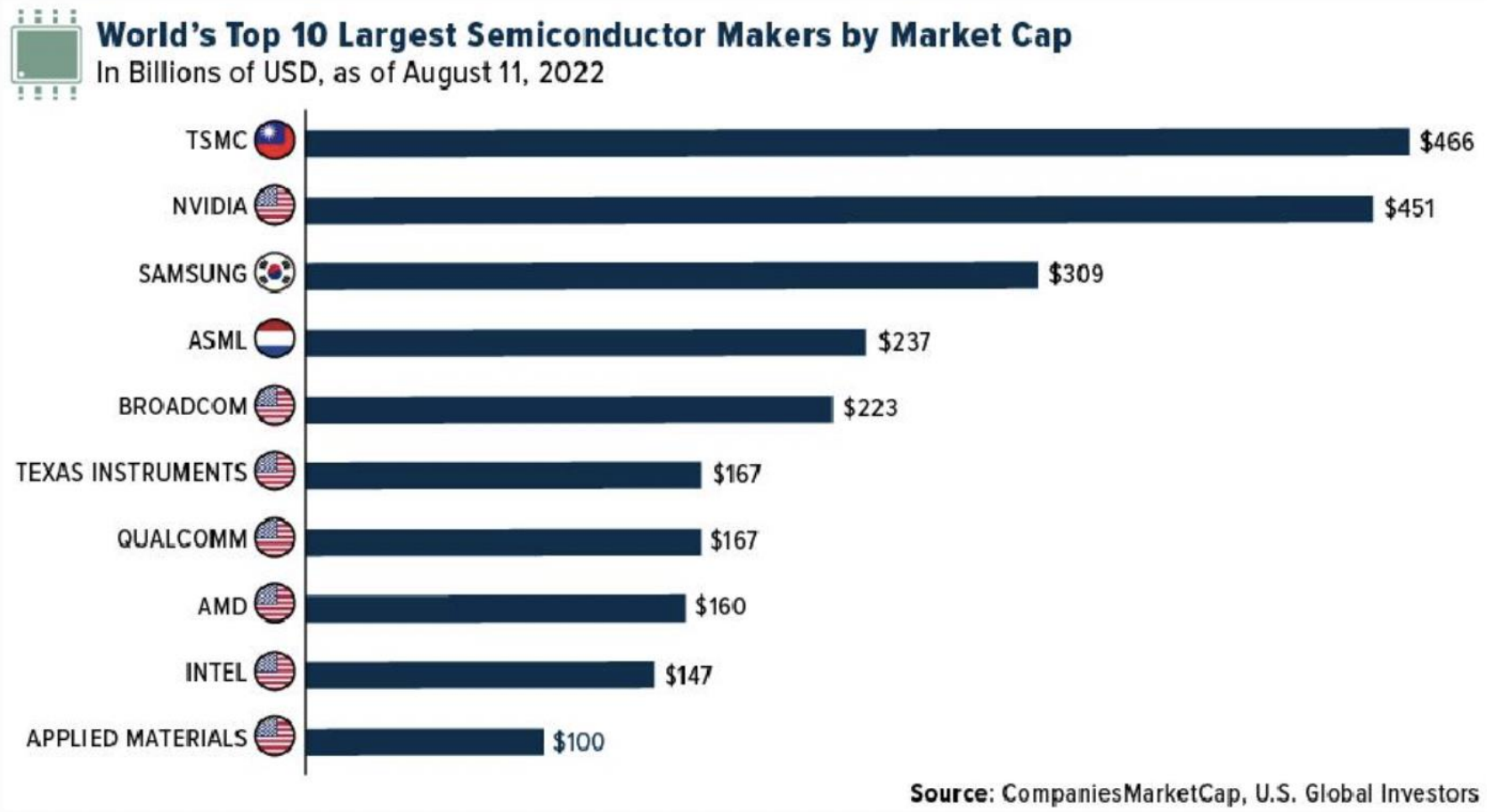
May 20th 2021

Share

FOR WANT of a chip, the factory was lost. On May 18th Toyota became the latest carmaker forced to cut production amid a global shortage of microchips, announcing it would suspend work at two of its plants in Japan. Firms including Ford, General Motors and Jaguar Land Rover have also had to send workers home.

The pain is not confined to the car industry, for the shortage spans all sorts of chips, from the expensive, high-tech devices that power smartphones and data centres to the simple sensors and microcontrollers that have become a

Worlds top Semiconductor Makers



U.S today accounts for only 12% of global semiconductor manufacturing capacity, whilst the **EU accounts for 10%**

How did Taiwan Get to the top?

- Morris Chang:Foundry Father (91y)
  - Born in China
  - MIT Eng., Texas Instruments, Stanford PhD
- President of Industrial Technology Research Institute (ITRI) 1985
- Founded TSMC in 1987 with $220M
  - 3μm process whilst everyone else was 1.5μm
  - introduced “Fabless” Semiconductor Industry or “Pure Play” Foundry

TSMC's impact

Jen-Hsun Huang, cofounder, president, and CEO of Nvidia, said

"TSMC's birth enabled all sorts of creative ideas—in areas like networking, consumer electronics, computers, and automotive technology—to be turned into successful companies, because the barriers to getting your chips built, to realizing your imagination, disappeared."

- 2022 TSMC
  - 3nm production (Intel is still at 7nm)
  - $57 Billion Revenue
  - **53% of global chip production!!!**

How are Governments Responding?

USA

What Is The Semiconductor CHIPS Act, And Why Does The U.S. Need It?

Aug. 16, 2022 9:33 AM ET | SOX, SOXX, SMH... | 6 Comments | 7 Likes

Summary

- The bipartisan CHIPS Act was signed into law last week, setting aside $52 billion to boost domestic semiconductor research and production.
- The worldwide semiconductor market is forecast to increase 16.3% this year, which would be the second straight year of double-digit growth.
- Today, the U.S. represents only 12% of global semiconductor manufacturing capacity, despite the technology being invented in the U.S.

$52 billion

How are Governments Responding?

European Union

Commission President **Ursula von der Leyen** said: "The European Chips Act will be a game changer for the global competitiveness of Europe's single market. In the short term, it will increase our resilience to future crises, but enabling us to anticipate and avoid supply chain disruptions. And in the mid-term, it will help make Europe an industrial leader in this strategic branch. With the European Chips Act, we are putting out the investments and strategy. By the key to our success lies in Europe's innovators, our world-class researchers, in the people who have made our continent prosper through the decades."

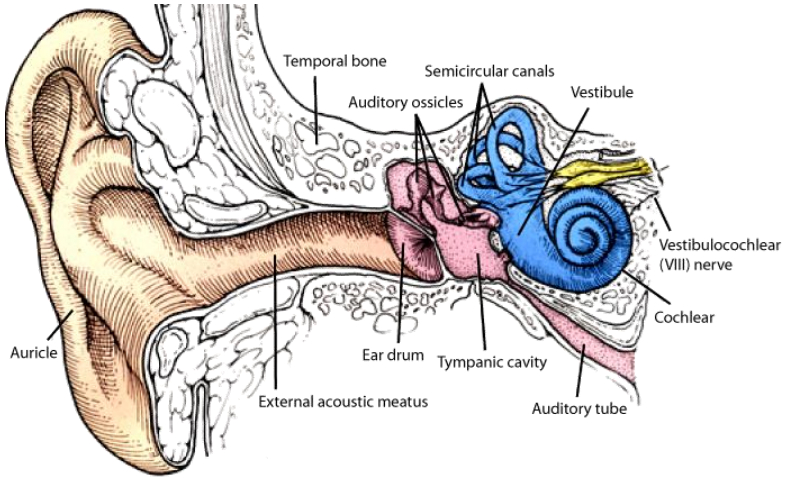
The EU Chips Act will build on Europe's strengths – **world-leading research and technology organisations** and networks as well as host of **pioneering equipment manufacturers** – and address outstanding weaknesses. It will bring about a thriving semiconductor sector **from research to production** and a resilient supply chain. It will **mobilise more than €43 billion euros of public and private investments** and set measures to prevent, prepare, anticipate and swiftly respond to any future supply chains disruption, together with Member States and our international partners. It will enable the EU to reach its ambition to double its current market share to 20% in 2030.

What is required to design chips?

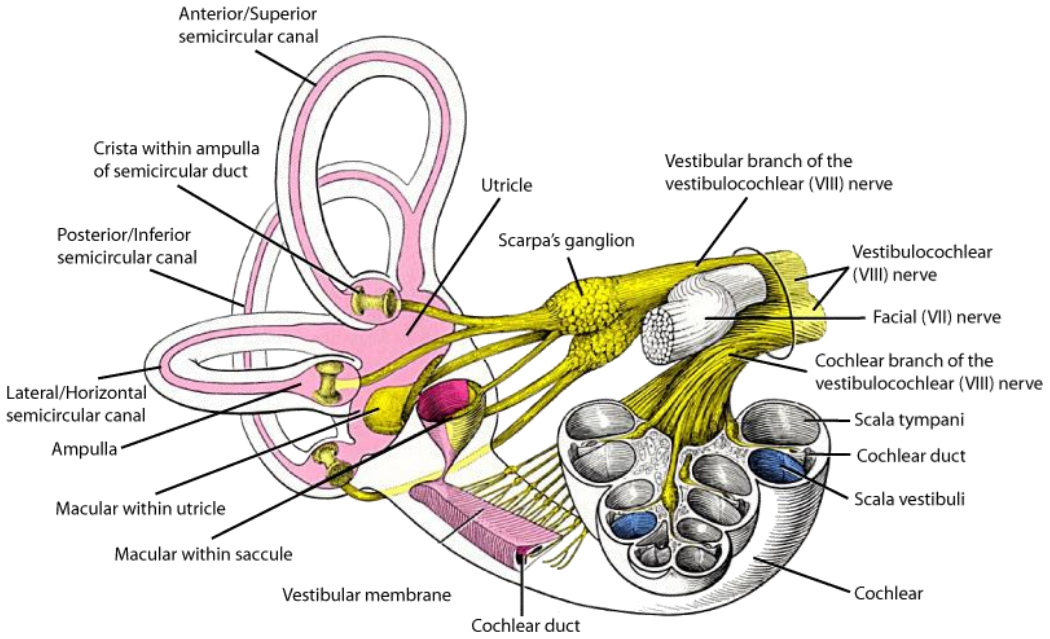
- A customer to buy the chips
- Chip design software and foundry Process Design Kit
- A good workstation
- **Well-trained personel in circuit / chip design**
- **Well-trained personel to test chips**

Huge shortage of such personel!!

The Vestibular System



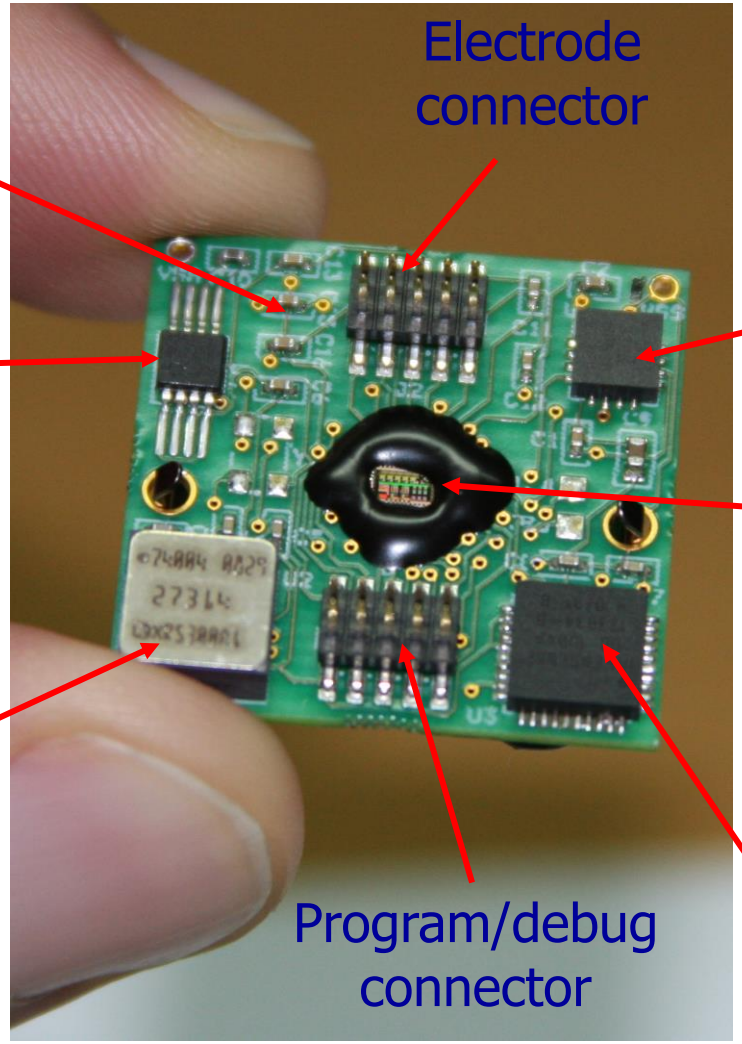
Inner Ear



Problem - EU and US has 15 million people suffering from incapacitating balance-related disorders resulting in vertigo, dizziness, nausea and blurred vision.

Solution – Vestibular Implant

A Prototype Vestibular Implant

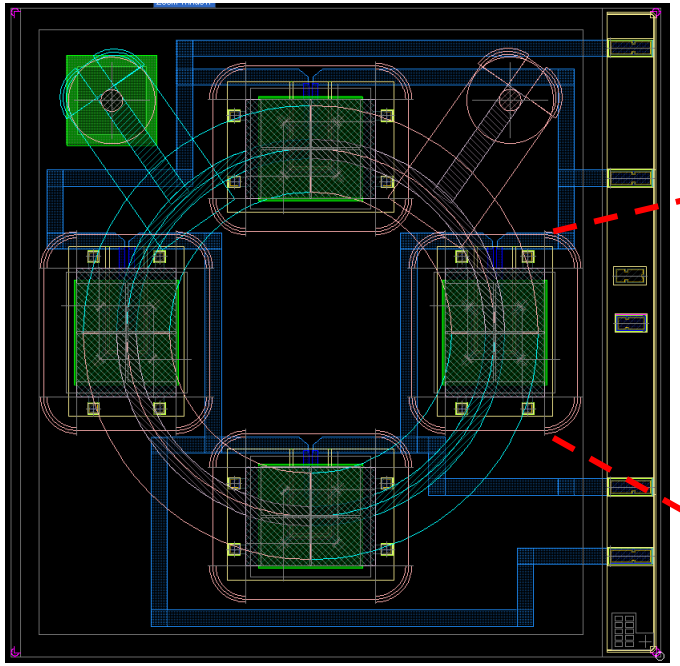


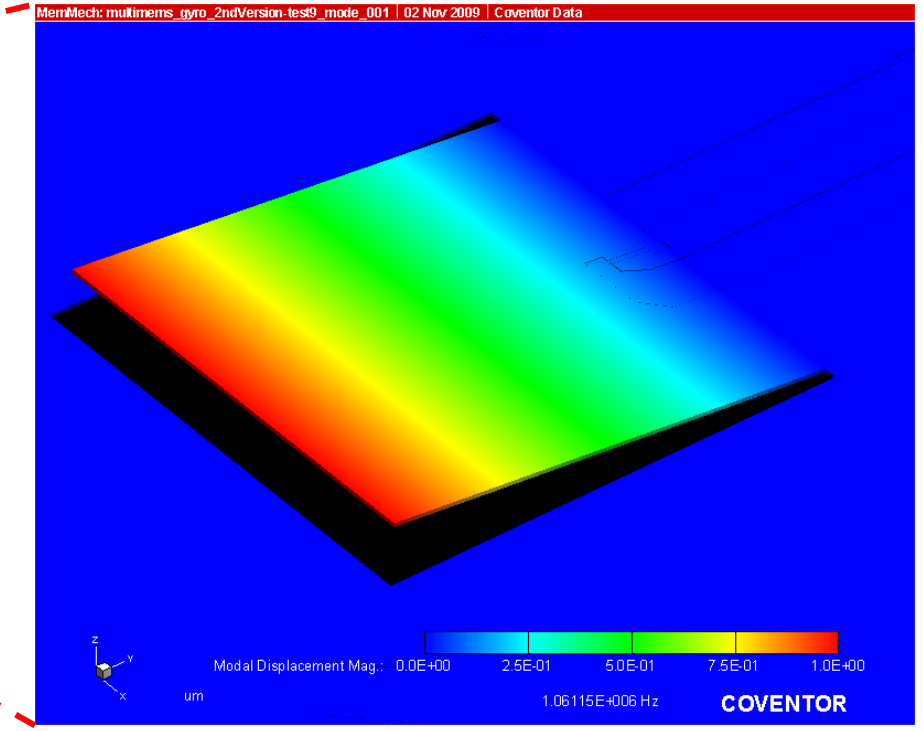
Problem: Vibrating MEMs gyroscopes are too power hungry ~7mW/axis

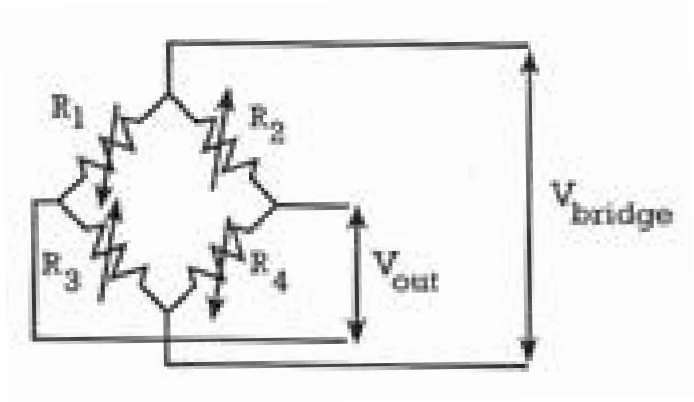
Requirement: <1mW/axis

Solution: Bioinspired gyroscope

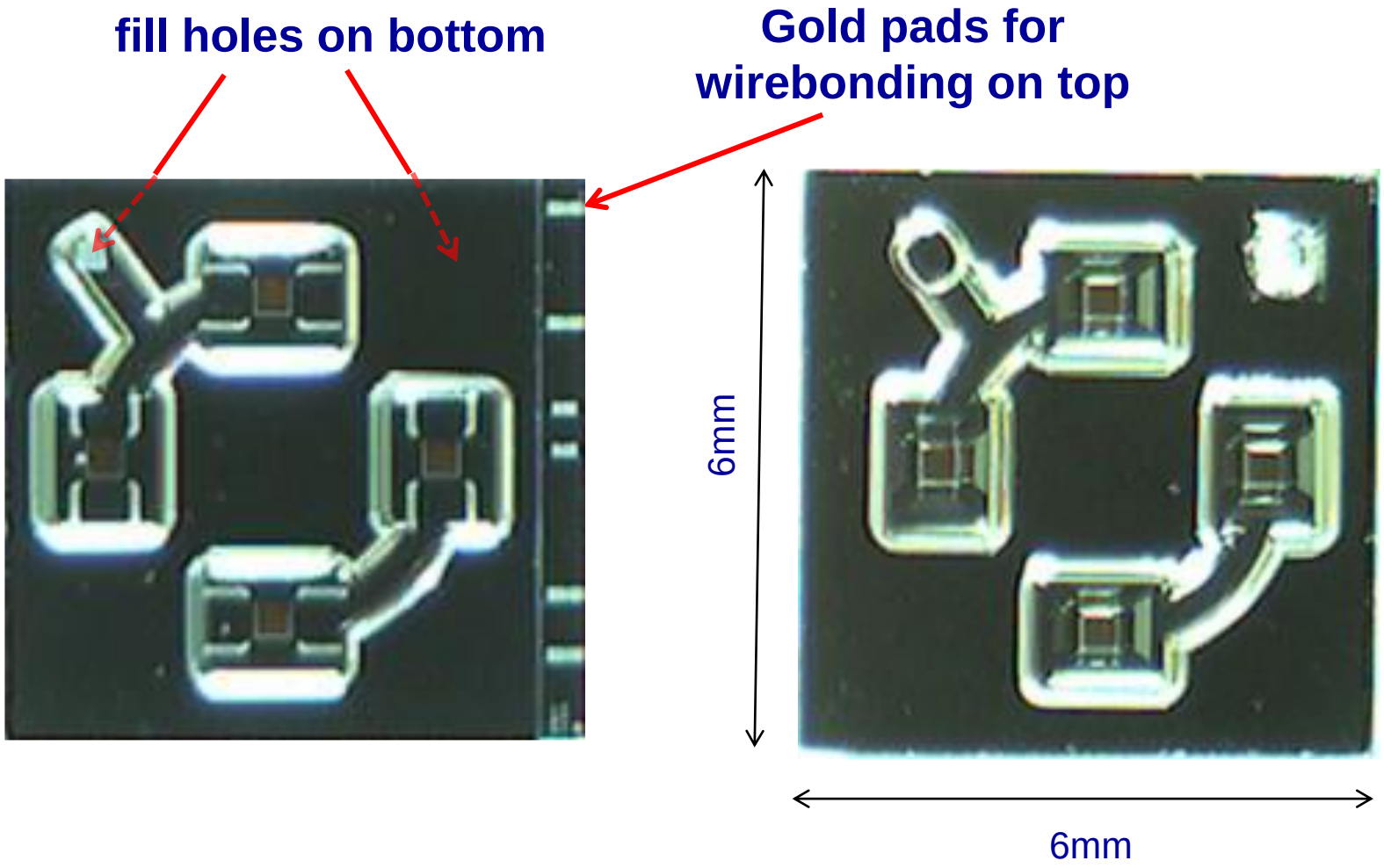
Micro-fluidic Ang. Accel.:







The Fabricated Device



Patents:

J. Georgiou and C. Andreou, "Hybrid MEMS microfluidic gyroscope", 10,563,982 B2 , 18-02-2020

J. Georgiou and C. Andreou, "Hybrid MEMS microfluidic gyroscope", US 9,759,562 B2 , 12-09-2017

J. Georgiou and C. Andreou, "Implant Vestibulaire Comprenant Un Gyroscope MEMS Microfluidique Hybride", EP2893296B1, 15-07-2015

Device Performance

❑ Sensitivity	<1°/s	✔
❑ Supply Voltage	2V	✔
❑ Power Consumption	300μW	✔
❑ Chip size	6mm x 6mm	✔
❑ Technology	SensoNor's Bulk MM	

Multi-axis gyroscope **requirement of <1mW/axis** ✔

C. Andreou, Y. Pahitas and **J. Georgiou**, "Bio-inspired micro-fluidic angular-rate sensor for vestibular prostheses", Sensors 2014, 14, 13173-13185; July 2014, doi:10.3390/s140713173

Ultra-low-power Imager

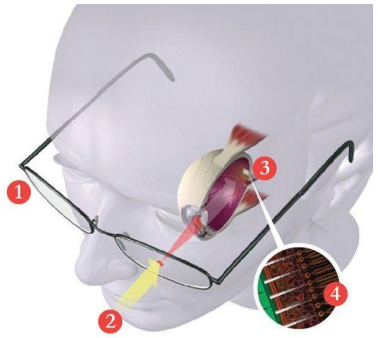
Bionic Vision Motivation

- **Problem:** It is estimated that globally 120 million are suffering from Age related Macular Degeneration and that 140 million suffer from diabetic retinopathy

- **Solution:** *artificial electrical stimulation* of the optic nerve.

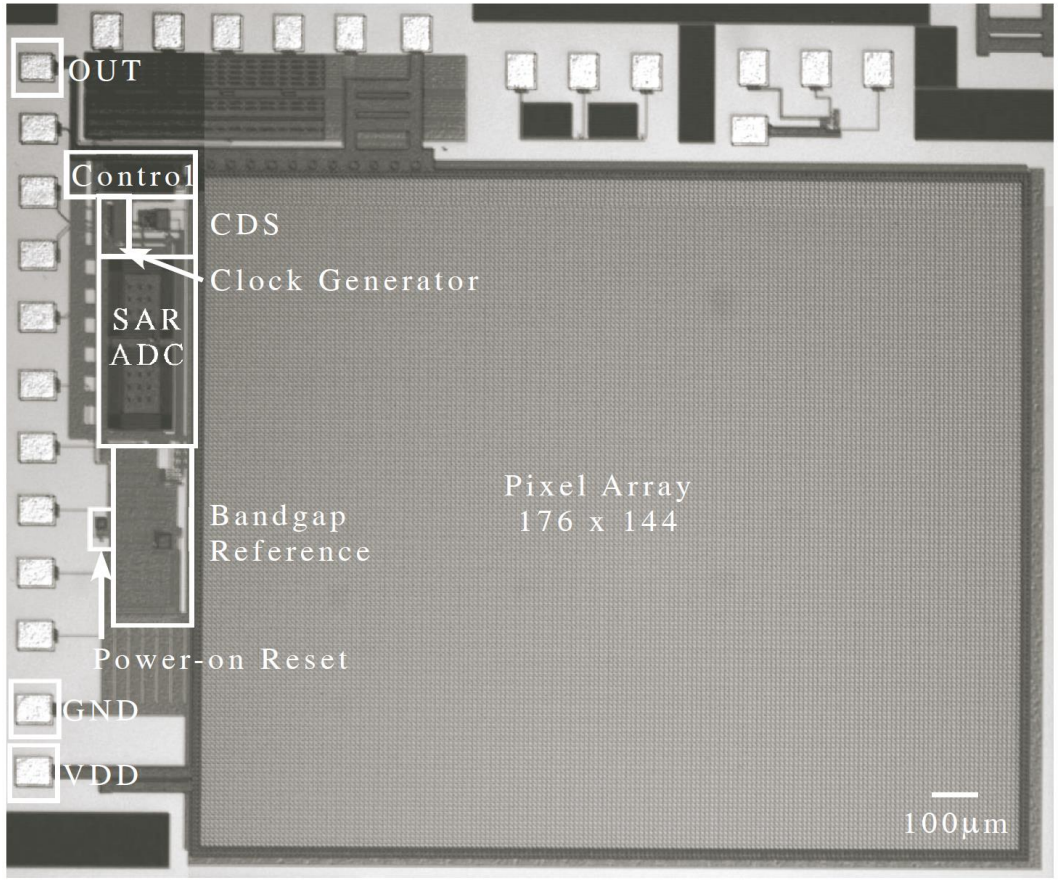
  Existing approaches:

  - external camera, relaying stimulation information wirelessly to internal implant (“60 pixels)
  - An external IR laser to power implanted chip that includes photodetectors (“ 500 pixel)



- **Proposed Solution:** A extreme low-power camera that can be powered via energy scavenging and has 25,344 pixels!

Fabricated Chip



- TSMC 0.18μm CMOS
- Chip: 2.2mm $\times$1.8mm
- Pixel: 9.85μm $\times$9.85μm
- 52% Fill Factor
- 176 $\times$144 Pixel Array
- 20-60 fps
- 45.8dB dynamic range
- 115μW at 1.0V 20fps

J. Lin, R. Ozgun, P.O. Pouliquen, A.G. Andreou, C. M. Andreou and **J. Georgiou**, "A 3-pin 1V 115µW 176x144 Autonomous Active Pixel Image Sensor in 0.18µm CMOS", 2011 IEEE International Symposium on Circuits and Systems (ISCAS 2011), pp.1568-1571, May 15th -18th, 2011, Rio de Janeiro, Brazil. (Sensory Systems BEST PAPER AWARD).

Bioinspired Acoustic Scene Analysis

Motivation for Acoustic Scene Analysis For Monitoring the Elderly

- Senses: *Sight*, *Hearing*, Touch, Taste, Smell (and Balance)
- Surveillance systems are mainly based on cameras which are intrusive

There are not many systems based on sound and yet there is so much information!

- Smart homes require non-intrusive monitoring of the elderly

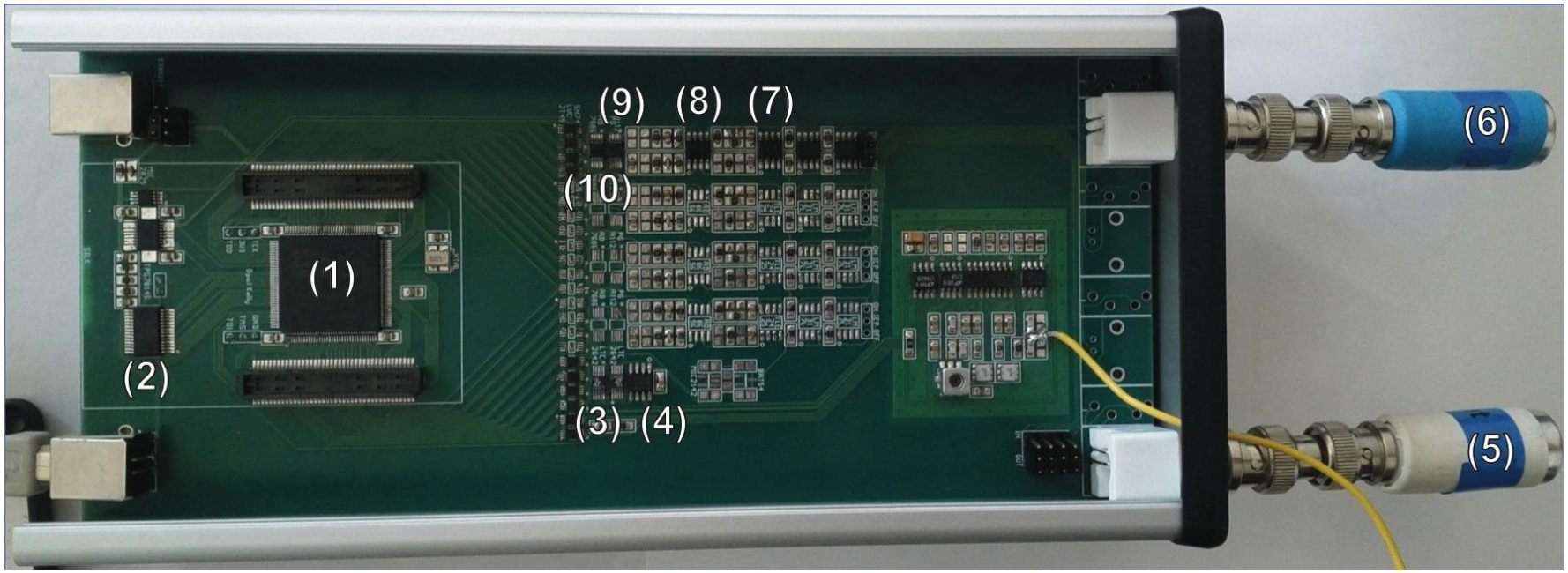
Inspiration from Biology
Bats

- Nocturnal to avoid being eaten by other predators
- Use ultrasound for obstacle avoidance
- Use ultrasound to identify, localise and track “food with wings

Ultrasound DAQC unit

- UFTRX : ultrasonic frequency transceiver
- Hardware consists of 1 PCB:

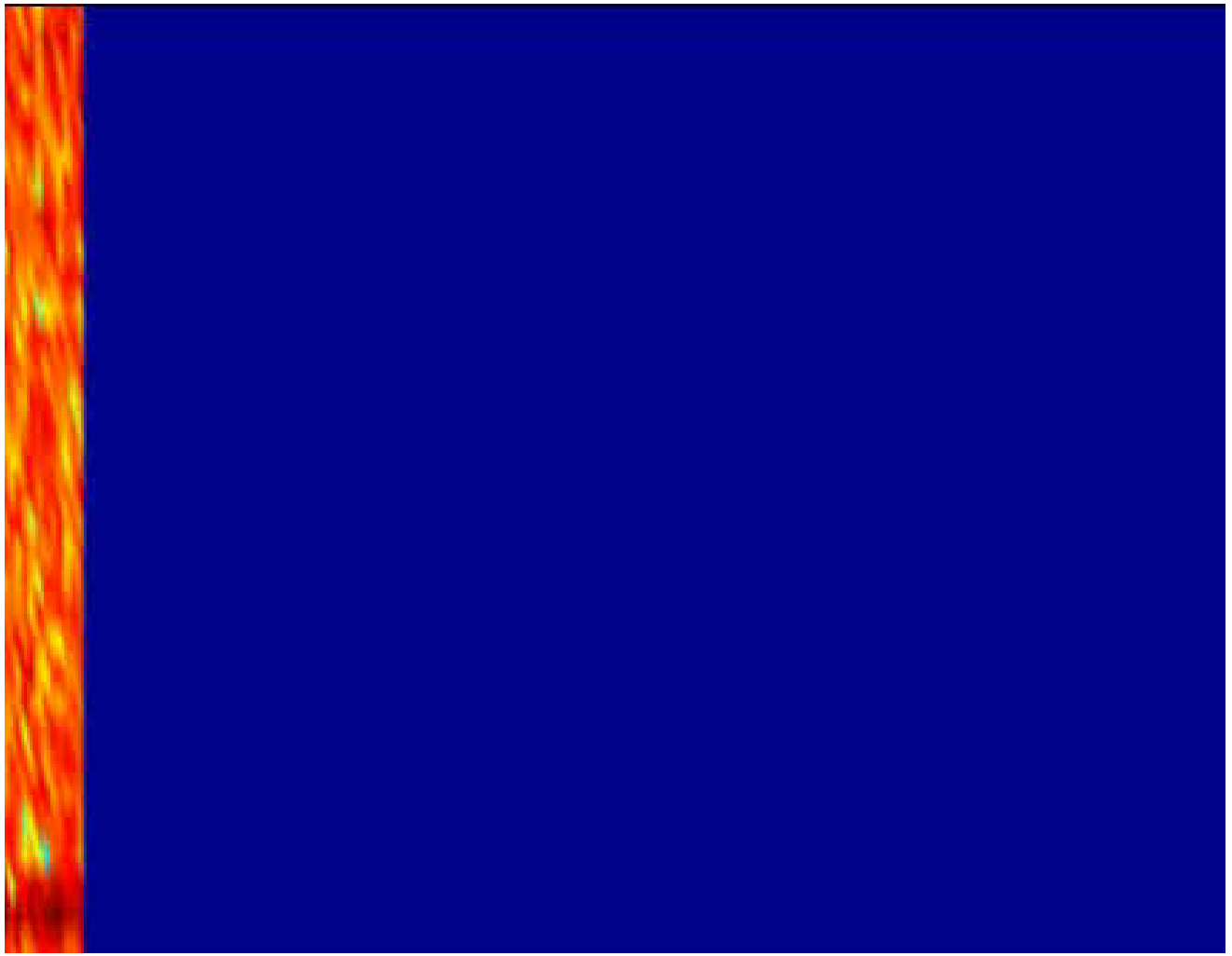
  - (1) FPGA XC3S50AN; (2) usb controller; (3) dac; (4-8) amplifier AD8656; (5) transmitter 400ET180; (6) receiver 400ER180; (7) virtual ground TLE2425; (9) PGA; (10) a 16 bit A/D converter at 500kSps AD7686;



G. Garreau, N. Nicolaou and **J. Georgiou**, "Individual Classification Through Autoregressive Modelling of Micro-Doppler Signatures", Proceedings of the IEEE Biomedical Circuits and Systems Conference (BioCAS'12), pp. 312-315, 28th -30th Nov 2012, Hsinchu, Taiwan.

Gait, Body Movement and Ultrasonic Micro-doppler

Gait, Body Movement and Ultrasonic Microdoppler



So what can our bioinspired system do?

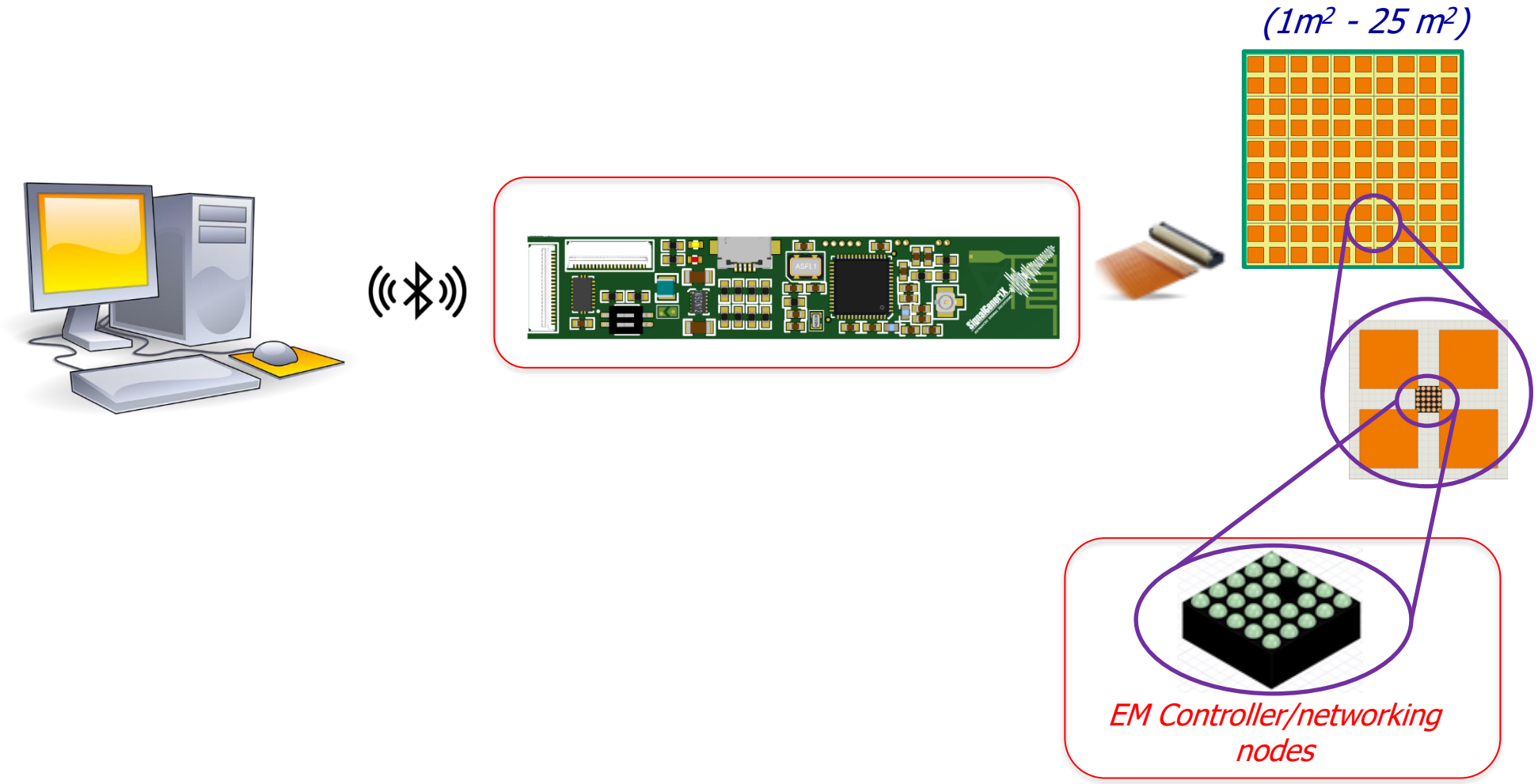
- Distinguish between walking, running, cycling, rollerblading [1]
  - Accuracy as high as 97%
- Distinguish individuals from gait [2]
  - Accuracy as high as 100%, average 87% (13 subjects)
- Distinguish sex from gait [2]
  - Accuracy as high as 92.4%, average 91% (13 subjects)
- Distinguish different human actions [3]
  - Accuracy as high as 100% with average 95%
- The system can be "trained " on fall signatures, changes of gait of elderly etc.

1. G. Garreau, N. Nicolaou, C. Andreou, C. D'Urbal, G. Stuarts and **J. Georgiou** "Computationally efficient classification of human transport mode using micro-Doppler signatures", 45th Annual Conference on Information Sciences and Systems (CISS 2011), DOI: 10.1109/CISS.2011.5766136, Mar 23rd -25th, 2011, Baltimore, USA.

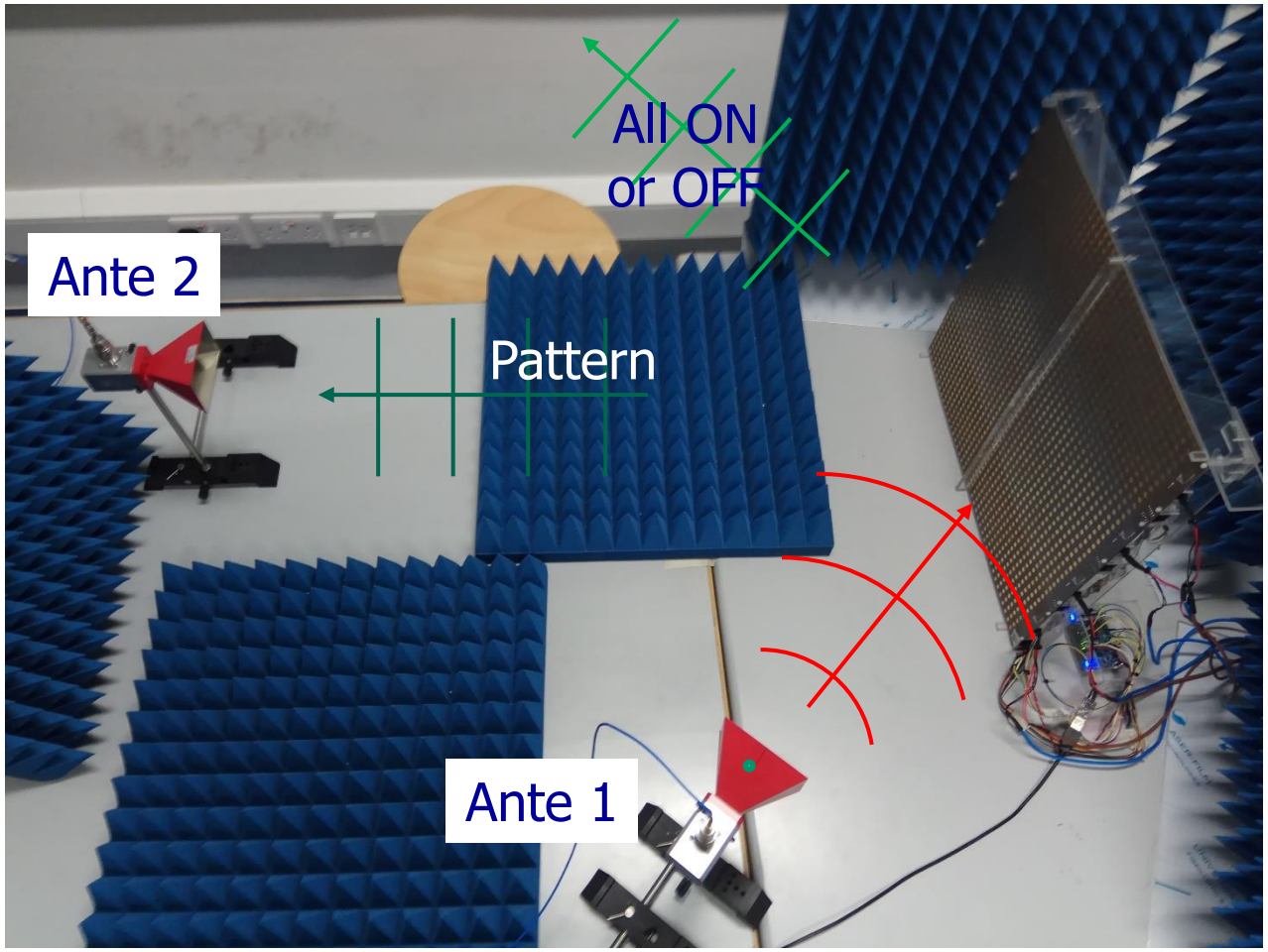
2. G. Garreau, C. M. Andreou, A. G. Andreou and **J. Georgiou** / S. Dura-Bernal, T. Wennekers and S. Denham, "Gait-Based Person and Gender Recognition Using Micro-Doppler Signatures" Proceedings of the IEEE Biomedical Circuits and Systems Conference (BioCAS' 11), 10th -12th Nov 2011, San Diego, USA

3. S. Dura-Bernal, G. Garreau, C. Andreou, A. Andreou, **J. Georgiou**, T. Wennekers and S. Denham, "Human action categorization using ultrasound micro-Doppler signatures", 2nd International Workshop on Human Behaviour Understanding, pp.18-29, 16th Nov, 2011, Amsterdam, Netherlands.

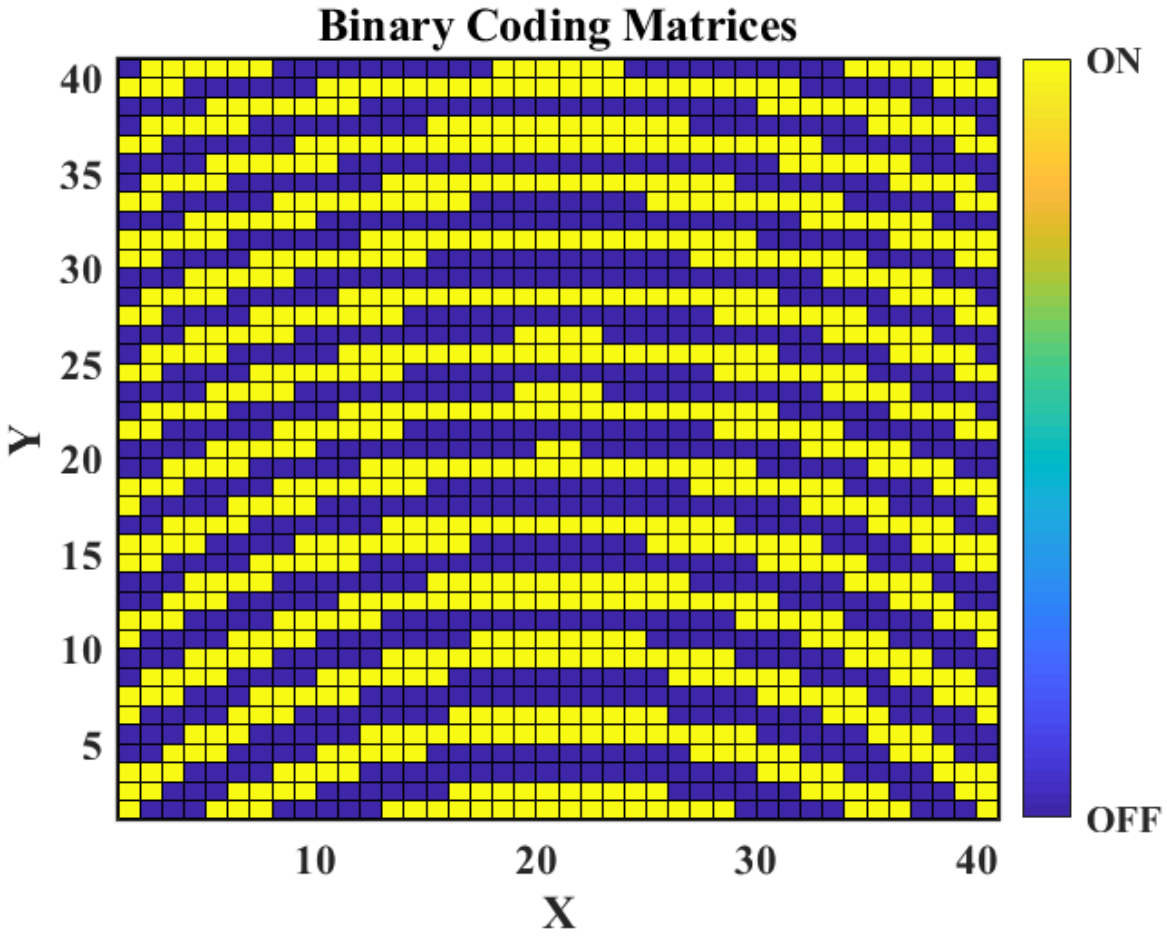
Programmable Metamaterials to Create HyperSurfaces



Programmable Metasurfaces



Pattern used
Collimation / Focusing



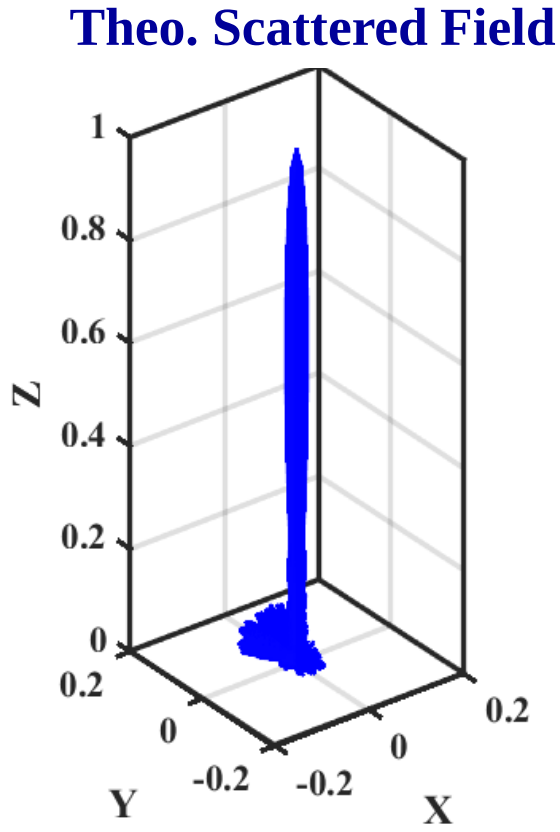
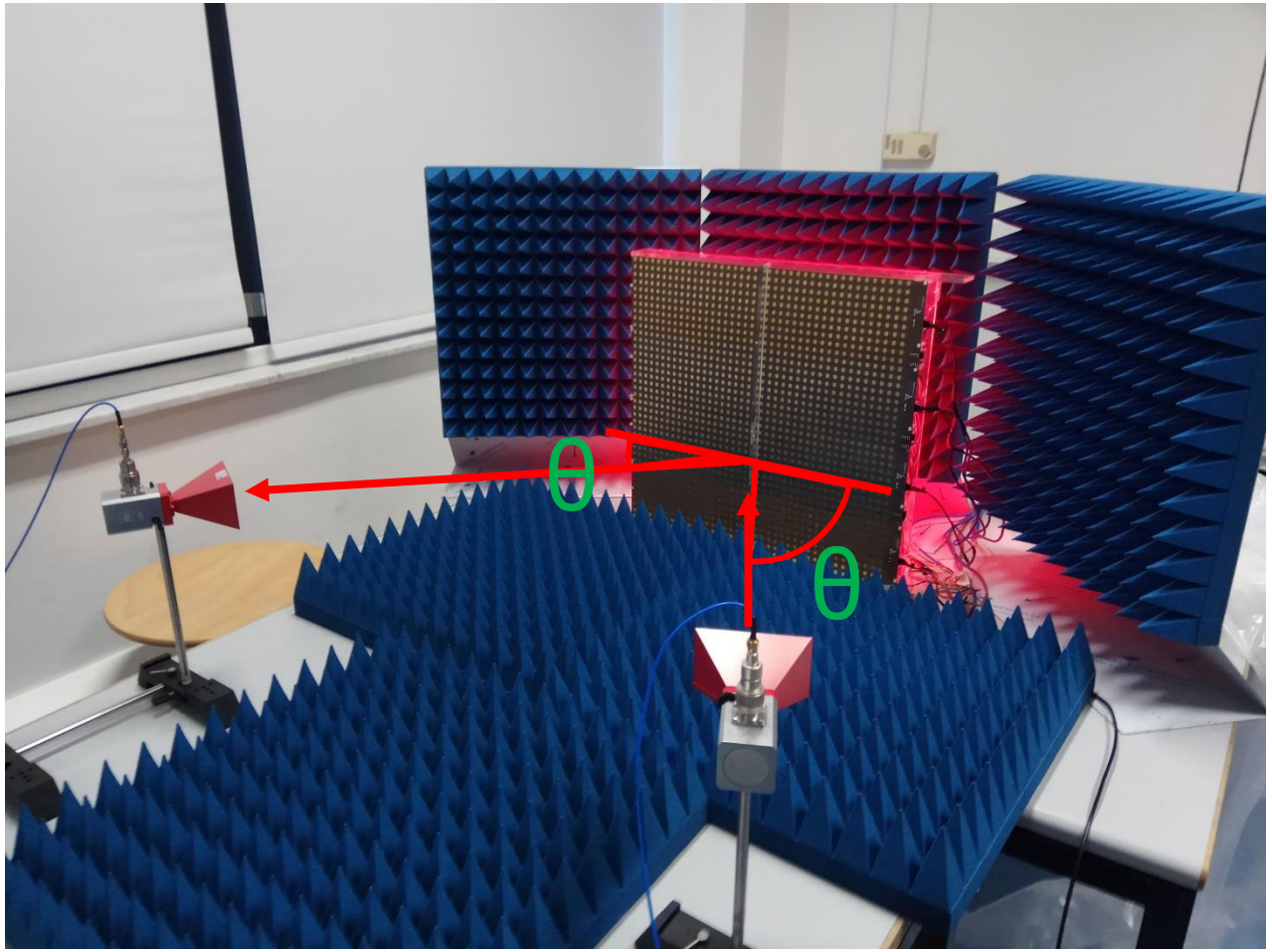
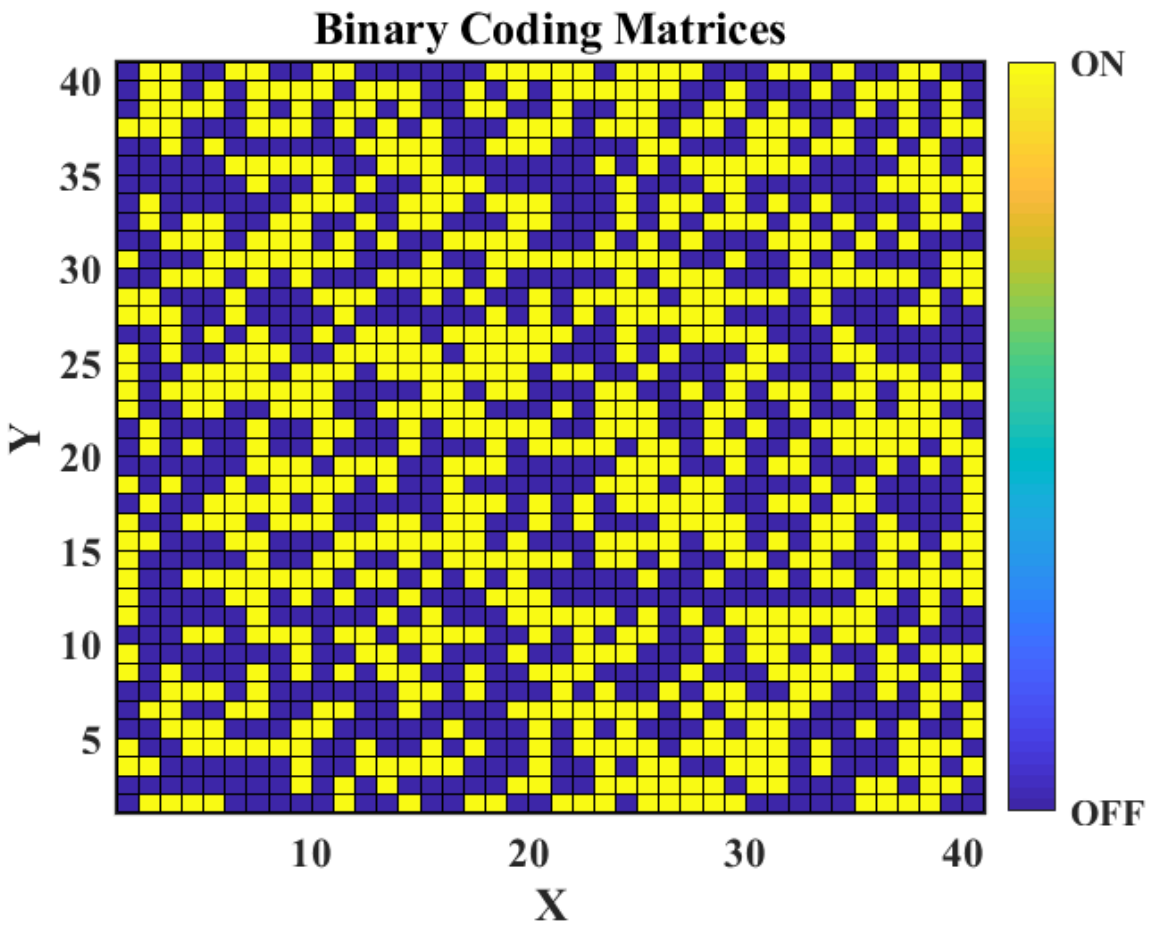
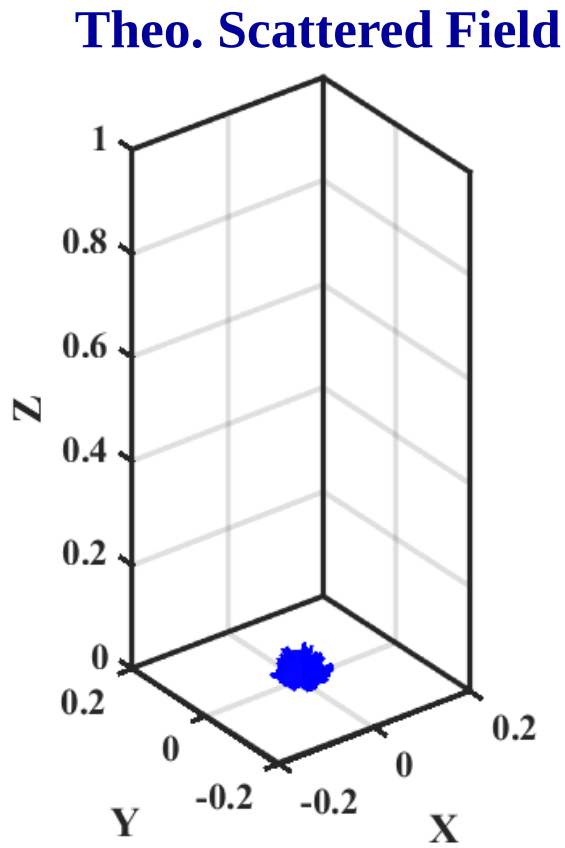


Table-Top Set Up for Scattering



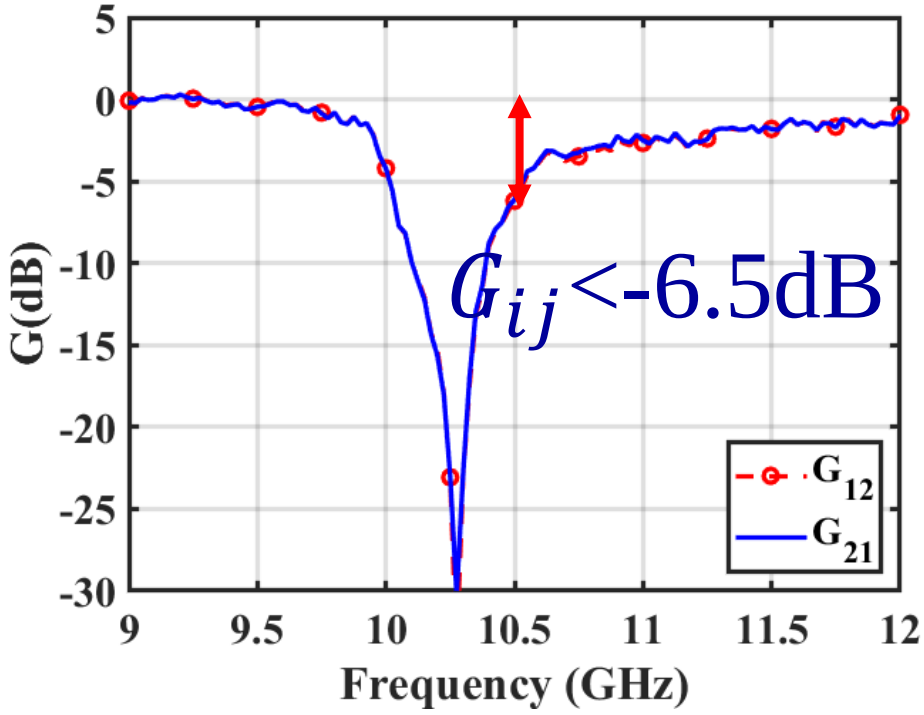
Pattern used Scattering



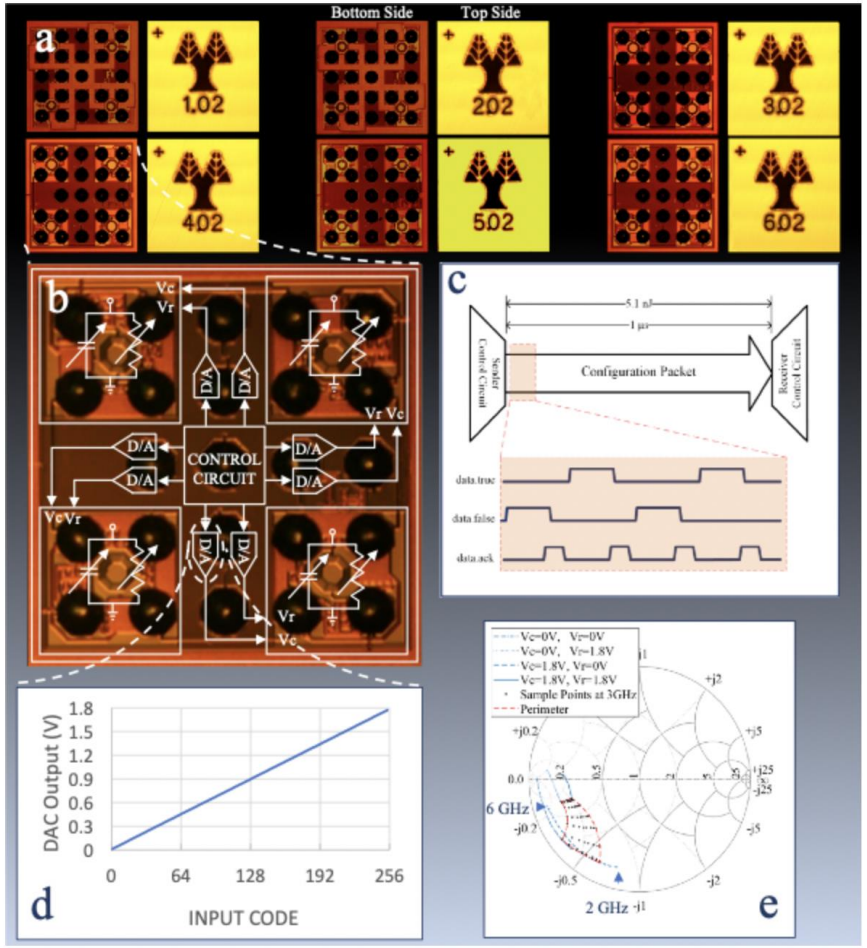


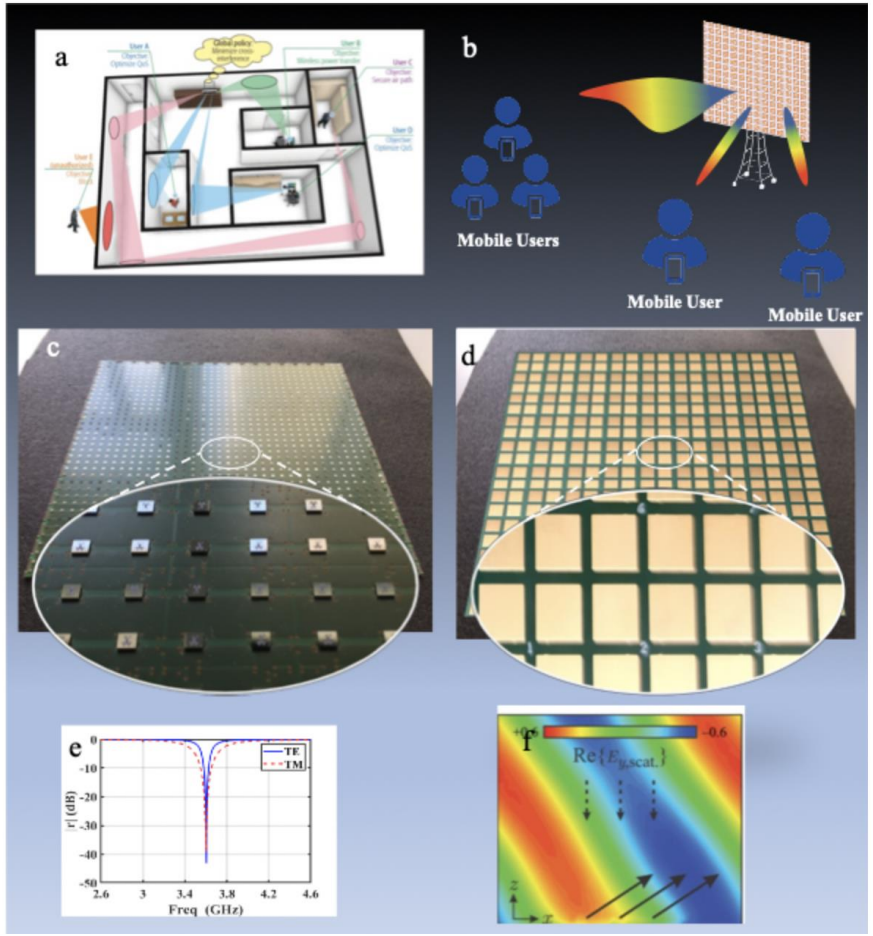
Measured Gain Scattering

- G_{ij} at 10.5GHz -6.5 dB
- Lower G_{ij} at 10.3 GHz



Custom Chips for Metasurfaces



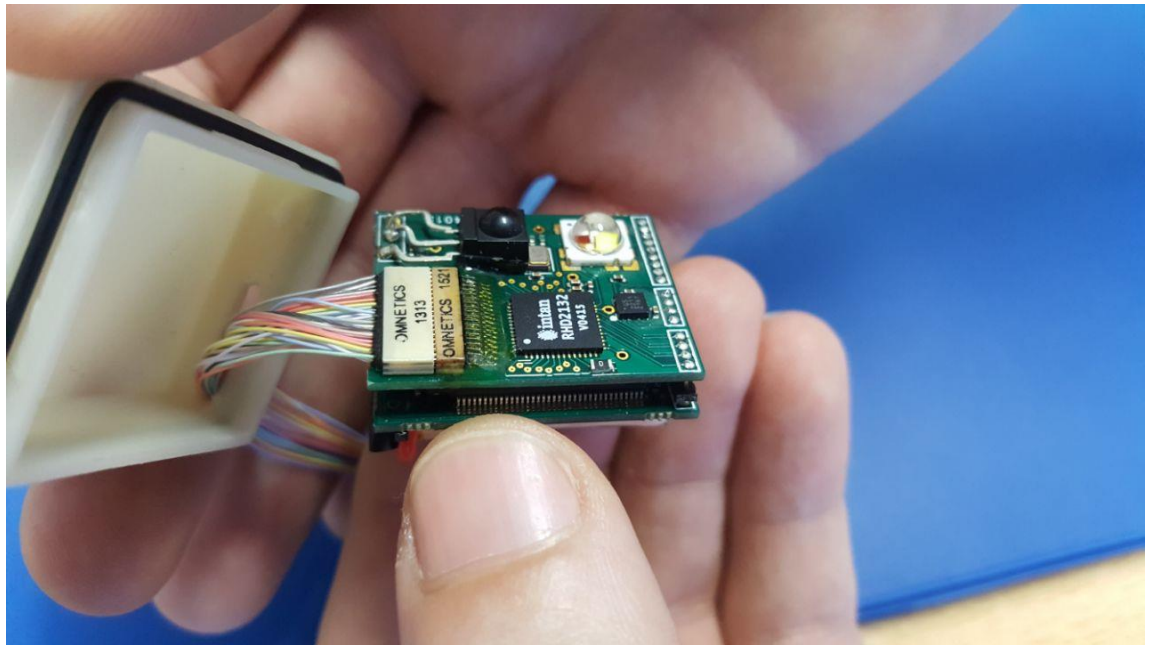


L. Petrou, K.M. Kossifos, , M. A. Antoniades and **J. Georgiou,** "The first family of application-specific integrated circuits for programmable and reconfigurable metasurfaces", *Accepted for publication*, Nature - Scientific Reports 2022

K. M. Kossifos, L. Petrou , G. Varnava , A. Pitilakis, O. Tsilipakos, F. Liu, P. Karousios, A. C. Tasolamprou, M. Seckel, D. Manessis, N. V. Kantartzis, D. Kwon, M. A. Antoniades and **J. Georgiou**, "Toward the Realization of a Programmable Metasurface Absorber Enabled by Custom Integrated Circuit Technology", IEEE Access, vol. 8, pp. 92986-92998, 2020, doi: 10.1109/ACCESS.2020.2994469

Miniature EEG System

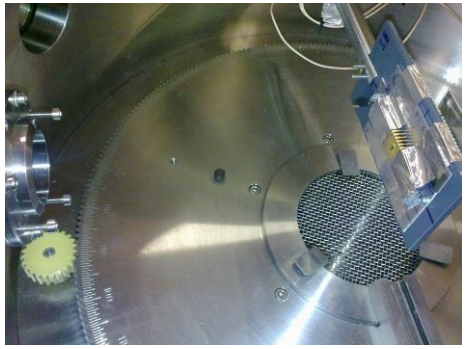
- 16 channels
- USB rechargeable
- MicroSD card (64GB)
- 12h battery life
- 25g total weight
- Remote controlled for
  - Start
  - Stop
  - Event Markers



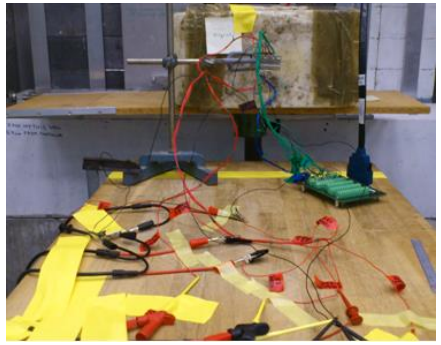
Rad-hard Circuit Design + Characterization

- **Subthreshold and Bandgap Reference circuits** for the space environment
- **Non-radiation** (Temperature, Supply Voltage, Noise).
- **TID** (γ-rays, x-rays, Protons).
- **Single Event Transients (SET)** Heavy Ions (Silicon, Krypton, Xenon).

γ-rays Tests USC
Irradiate up to 5153 Krad(Si)



X-rays (10-keV) Tests UPD
Irradiated up to 80 Mrad(Si)



Protons Tests TSL-Uppsala
Irradiated 170.5MeV protons

SET Tests UJY
Xe: E=1217.0MeV,
R=89.0 um,
LET=60.0MeV/(mg cm^2)

C. M. Andreou, D. M. González-Castaño, S. Gerardin, M. Bagatin, F. Gómez Rodriguez, A. Paccagnella, A. V. Prokofiev, A. Javanainen, A. Virtanen, V. Liberali, C. Calligaro, D. Nahmad, and **J. Georgiou**, "Low-Power, Subthreshold Reference Circuits for the Space Environment: Evaluated with γ-rays, X-rays, Protons and Heavy Ions," Electronics, vol. 8, no. 5, p. 562, May 2019.

C.M. Andreou, A. Javanainen, A. Rominski, A. Virtanen, V. Liberali, C. Calligaro, A.V. Prokofiev, S. Gerardin, M. Bagatin, A. Paccagnella, D.M. Gonzalez Castano, F. Gomez, D. Nahmad and **J. Georgiou**, "Single Event Transients and Pulse Quenching Effects in Bandgap Reference Topologies for Space Applications", IEEE Transactions on Nuclear Science, October 2016, DOI 10.1109/TNS.2016.2611639

Thank you for your attention!

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