TU Delft

THz Sensing Group

Website: terahertz.tudelft.nl

MASTER THESIS PROJECTS
TeraHertz Sensing Group

2025-2026

Faculty EECSM, Building 36, **Floor 18**, Delft University of Technology
Address: Mekelweg 4, 2628 CD, Delft, The Netherlands

Master thesis projects on the “THz Catastrophe”

Two possible master thesis projects are offered. The candidate is expected to very self-motivated to work on the fundamental aspects of electromagnetic theory, numerical modelling, but also present practical and collaborative mentality to contribute to the characterization campaign.

Supervision team: Andrea Neto, Laurens Beijnen (PhD), Riccardo Ozzola (Postdoc)

Background

Unexpected thermal radiation from silicon wafers has been recently observed in a dedicated measurement campaign performed at TU Delft. The thermal radiation presents a frequency decay response that is a direct function of the electron doping in a way that cannot be explained resorting to Planck's law and corresponding emissivity (see Fig. 1).

A classic model for thermal radiation has been recently introduced to explain the dominant physical mechanism responsible for the unexpected observations. The new model describes the field by means of a modal expansion. For the sake of simplicity the first modal expansion identified, was derived assuming the radiating body to be infinitely extended, and the finiteness of the actual geometry was introduced only “a posteriori”.

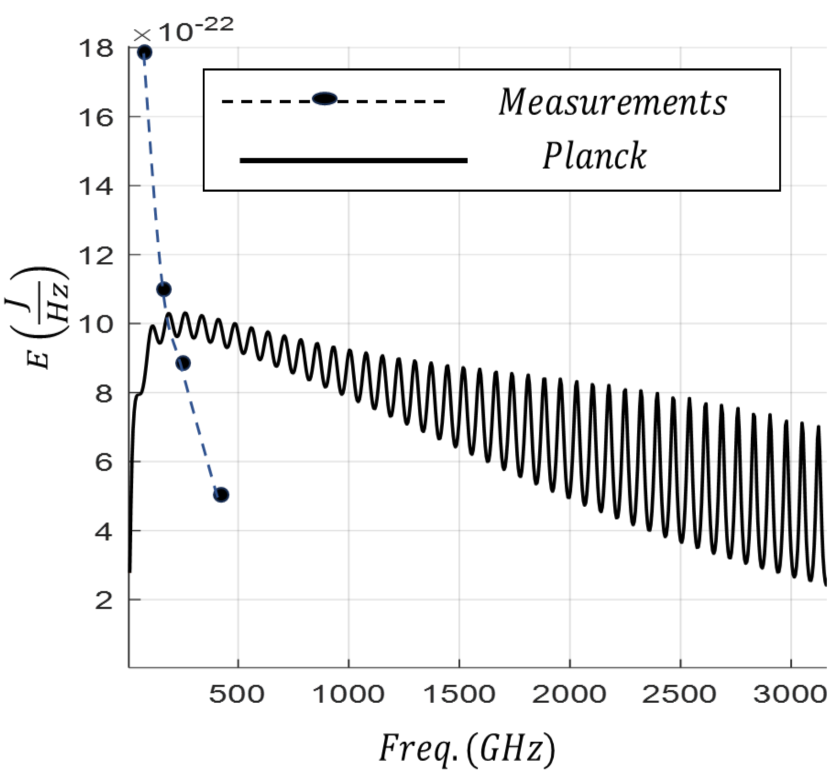


Fig.1. Measured Spectral Energy Densities vs predictions from Planck’s law corrected with estimated emissivity for the estimated phosphorus doping of $n=5{\cdot}10^{21}$. Temperature of the silicon T_{si}=425 K and temperature of the detector T_{det}=315K.

Theoretical work

In the first thesis work it is proposed that the newly developed model be fine-tuned to include the specific information of the thermally radiating geometries. The candidate will learn how to use a 3D Method of Moments tool developed within the group, he will use it to derive the eigenvalues and eigen vectors of the solutions pertinent to a specific geometry considered and will move on to identify the modal functions that can be used to represent the thermally excited fields accounting for the finiteness of the structures.

The identified structures will be the characteristic modes of the thermal radiator and are expected to provide a very accurate estimation of the radiated thermal energy bypassing the accuracy of the present state of the art model. The daily supervisor for this candidate will be Dr. Riccardo Ozzola

Experimental work

The scope of the second candidate work will be to help with a renewed experimental characterization of the thermal radiation properties of the considered geometries (Fig. 2).

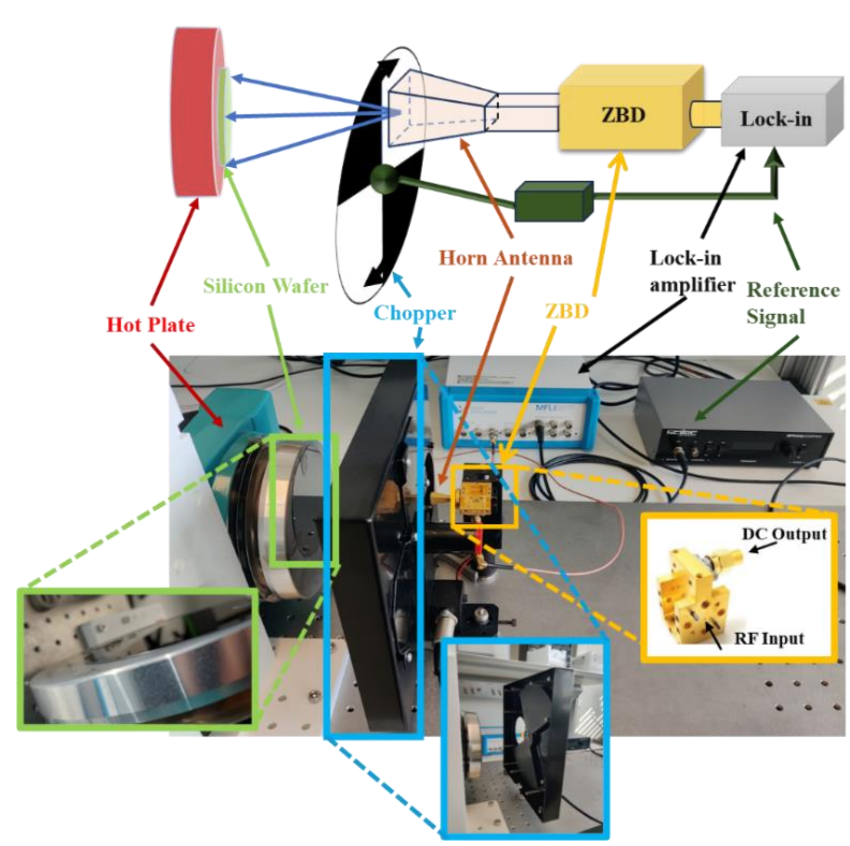
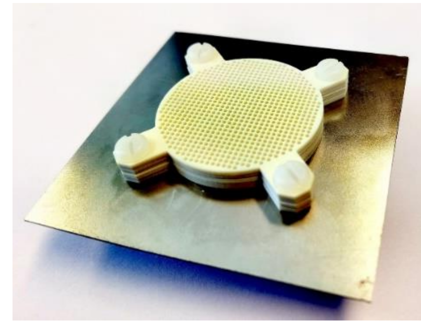


Fig.2 Sketch of the measurement setup including the silicon wafer, the hot plate, the chopper, the horn antenna, the zero bias detector (ZBD) and the lock-in amplifier.

After the original disclosure of the results the feedback from the theoretical scientific community have been enthusiastic, however some experimentalist colleagues have manifested scepticism. The results are considered so revolutionary that the reviewers have asked for additional work aimed at closing the loopholes that could give rise to doubts to readers from the physics community. At this time, the setup for the original measurements is being updated and rendered more rigorous than the TS group members originally thought necessary. Accordingly, a new campaign of measurements will be performed. The daily supervisor for this candidate will be Laurens Beijnen.

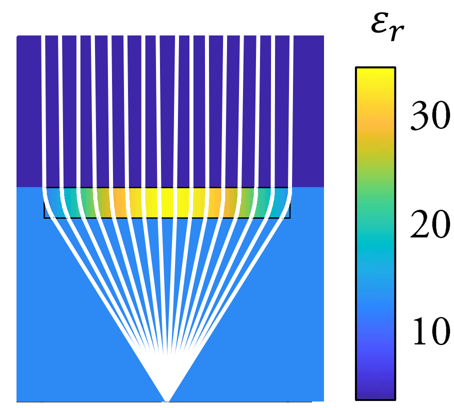
Artificial Flat Lenses for 140 GHz Automotive Radars

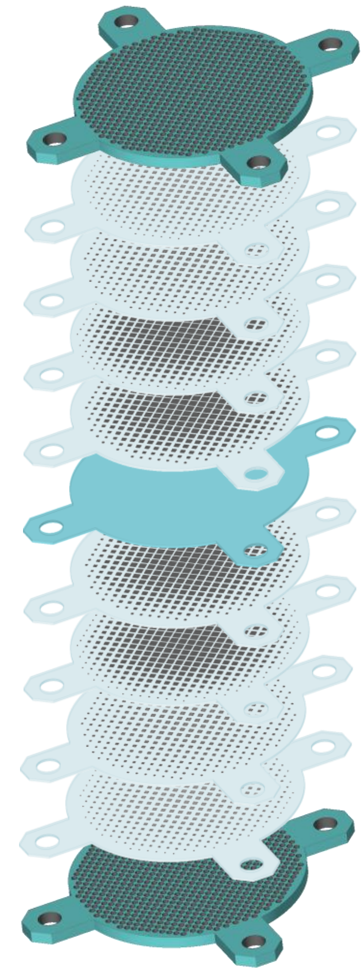
Research line: *mm-Wave integrated antenna design and artificial dielectrics*



Background:

Antenna arrays feeding elliptical dielectric lenses have emerged as suitable solutions for mmWave automotive radars because of their high gain and multi-beam capabilities. An alternative to curved lenses is constituted by flat lenses based on inhomogeneous artificial dielectrics. Such lenses can provide advantages in terms of compactness and integration, at the cost of reduced scan range.





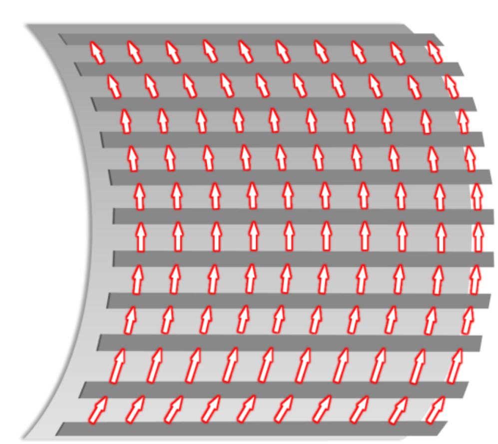
Master Thesis Project:

- Tradeoff analysis of artificial dielectric flat lenses for short-range automotive radars with wide field of view
- Design and in-package implementation of array-fed artificial dielectric flat lenses for compact 140 GHz automotive radar

Supervision Team: Daniele Cavallo, Jinglin Geng (PhD)

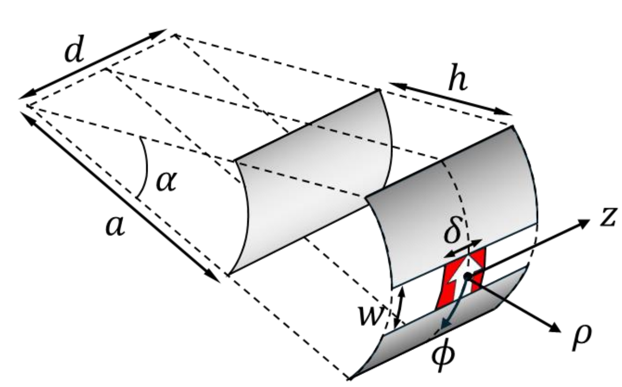
Analysis of conformal arrays

Research line: *Analysis and design of wideband phased arrays*



Background:

Wideband phased arrays are an essential part of multi-functional radar and communication systems. In the Terahertz Sensing Group we developed several models for planar arrays that we customarily use for the design. However, these model do not extend to the design of conformal arrays, which have several advantage in terms of scanning performance over planar arrays.



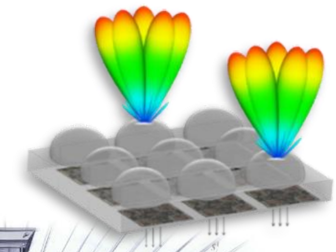
Master Thesis Project:

- Analysis of conformal connected array unit cells with cylindrical stratified media
- Design of cylindrical array and assessment of the performance

Supervision Team: Daniele Cavallo, Roderick Tapia Barroso (PhD)

XG Communications: Fly's Eye Concept

Research line: *Development of antenna systems based on Fly's Eye Lens Arrays at 150GHz to address future XG communication scenarios*



Background:

Future 6G communications will require the realization of multiple wireless links with extreme data rate capacities. At the THz Sensing group, we are exploring the use of the 150GHz frequency band to realize antenna systems that can give coverage to thousands of users. The antenna system is based on integrated lens arrays. Several initial prototypes have been already realized. Now, the scope is to experimentally demonstrate the capacity of these antenna systems.

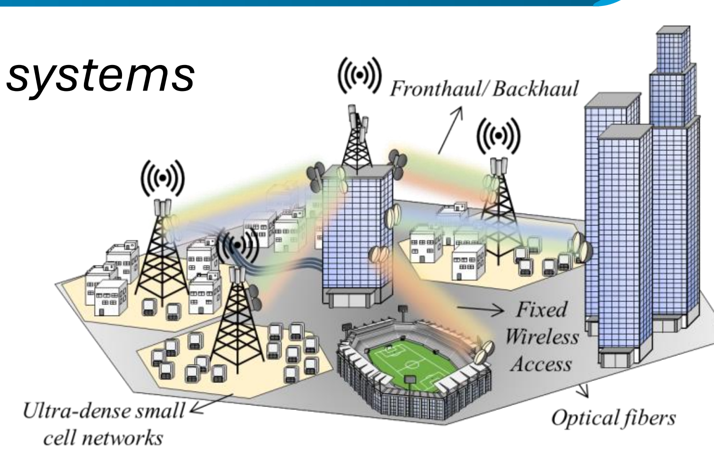
Master Thesis Project:

- Capacity analysis based on Line of Sigth links and development to use cases
- Experimental validation in the lab
- Derive trends on antenna systems requirements and architectures for future 6G networks

Supervision Team: Maria Alonso-Del Pino, Nuria Llombart

XG Communications: QO MIMO Links

Research line: *Development of Lens Arrays for MIMO systems operating in the Radiative Near Field at 300GHz*



Background:

Future 6G communications will benefit from having wirless links reaching Tbps to substitute current fiber optics. At the THz Sesning Group, we are leading a EU project to realize such links at 300GHz. We want to exploit the possibility of transmitting multiple data streams in parallel between two base stations to achieve Tbps

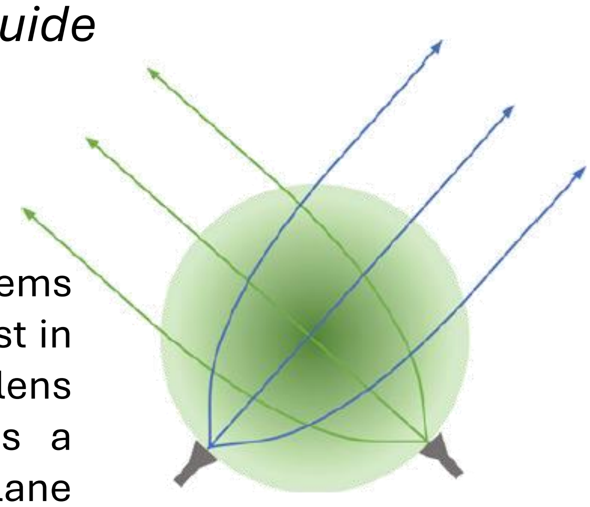
Master Thesis Project:

- Capacity study in lens arrays for links in the order of 100m
- Development of an array prototype at 300GHz in BiCMOS

Supervision Team: Maria Alonso-Del Pino, Nuria Llombart, Alexandros Bechrakis Triantafyllos

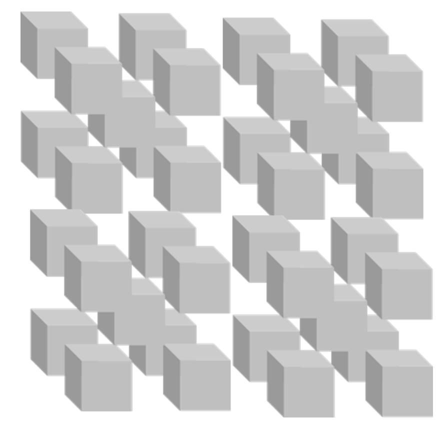
Parallel-plate waveguide Luneburg lens

Research line: *Analysis and design of a parallel-plate waveguide Luneburg lens*



Background:

With the development of the new generation of communication systems operating at millimeter-wave frequencies, there has been renewed interest in architectures providing multibeam wide-angle scanning, in particularly lens antennas. A lens geometry that intrinsically offers wide-scanning is a Luneburg lens, often realized in 2D configuration offering single-plane scanning. Within this project, we aim to design a parallel-plate waveguide (PPW) Luneburg lens implemented in printed circuit board (PCB) technology, whose inhomogeneous permittivity is synthesized with the usage of metallic inclusions.



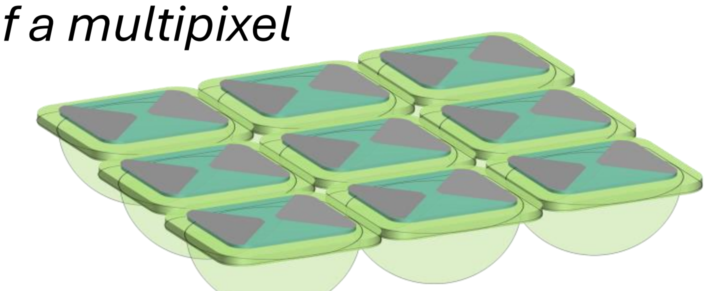
Master Thesis Project:

- Analysis and design of a PPW Luneburg lens synthesized with metallic inclusions
- Development of the lens prototype and measurement campaign

Supervision Team: Nuria Llombart, Dunja Lončarević (PhD)

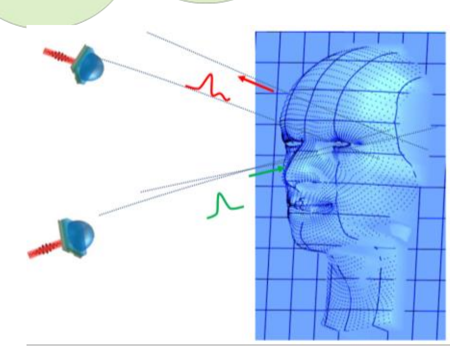
THz Imaging Radar – Receiver Array

Research line: *Design, fabrication and characterization of a multipixel leaky-wave photoconductive receiver array for imaging*

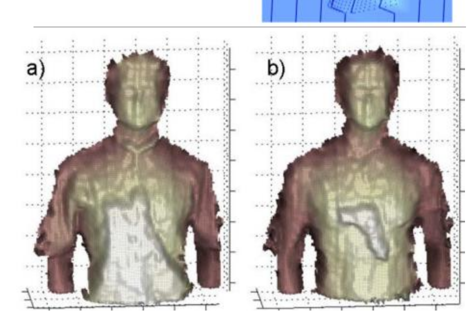


Background:

Terahertz imaging radars have the potential to revolutionize the security sector. Photoconductive antennas are a key enabling technology for this, as we can achieve over 1THz of bandwidth with this technology, allowing for sub-millimetric depth resolution. We have made significant advancements in THz sources based on this concept over the past years.



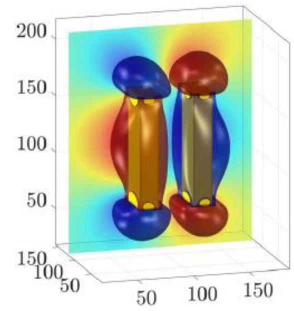
The key thing still missing for a working THz radar is a <u>multi-pixel</u> receiver array. The goal of this project is to design a multi-pixel photoconductive receiver array based on leaky-wave bow-ties. Apart from design and simulations, you potentially also have the chance to measure your device in the THz lab.

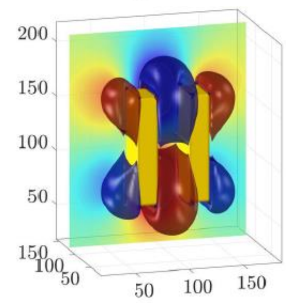


Supervision Team: Andrea Neto, Juan Bueno, Paolo Sberna, Martijn Huiskes (PhD)

Wavefield Imaging and Inversion

- **Forward wavefield problems:**
  Determine the (acoustic, electromagnetic) wavefield in a known configuration, Applications: nano-optics, bio-engineering
- **Inverse wavefield problems:**
  Determine medium parameters based on field measurements
  Applications: geophysics, biomedical applications





- Interested in one of these or related topics?
- Please contact
  - Dr. Rob Remis
  - Terahertz Sensing Group
  - Room: 18.060
  - Email: R.F.Remis@TUDelft.NL

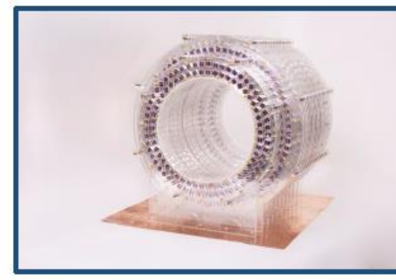
To talk about the possibilities and/or to setup an MSc graduation project

- **Recommended background/courses:**
  Analysis, linear algebra, Laplace/Fourier transforms
  Advanced electromagnetics
  Introduction to wavefield and magnetic resonance imaging

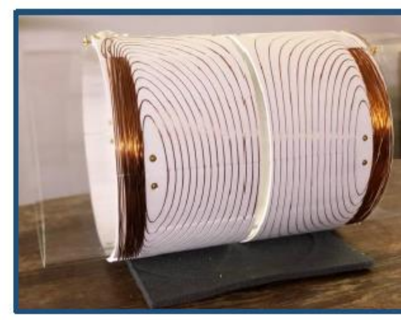
Magnetic Resonance Imaging

- **Contribute to the development of low-field MR scanners**
  Portable, low-cost, easy to maintain, perfect for rural areas, ...
  Background field is produced by permanent magnets!
  - *Contribute to **magnet design**, **gradient** and **radiofrequency** coil design*
  - *Develop **advanced image processing** methodologies and algorithms for low-field MRI*

  In cooperation with the Leiden University Medical Center

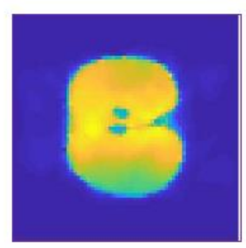


Scanner

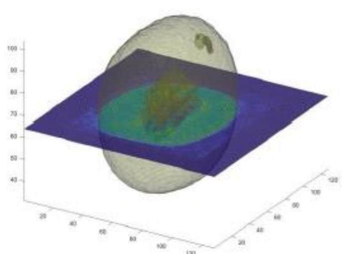


Gradient coil
Developed by TU Delft MSc student

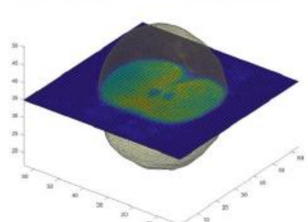
Advanced Imaging Algorithms
MSc/PhD projects



2D slice



3D reconstruction



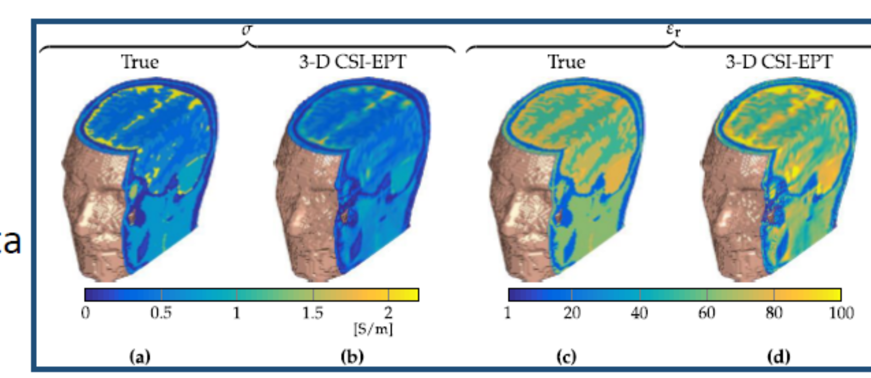
3D reconstruction

Low-field brain image

Low-field knee image

- **Electrical Properties Tomography – EPT**
  The dielectric parameters of tissue – the conductivity and permittivity – can serve as important biomarkers.
  Also important for heat prediction inside the body.
  EPT: retrieve the tissue parameters from standard MR data

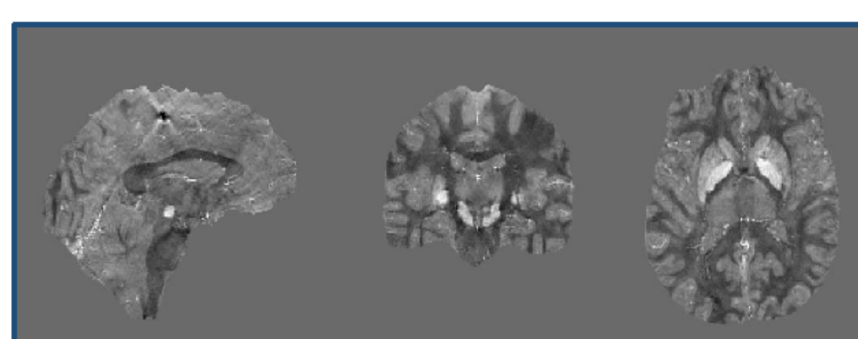
  Contribute to the development of efficient and accurate EPT reconstruction techniques
  In cooperation with the University Medical Center Utrecht and the Leiden University Medical Center



True and reconstructed conductivity (left) and permittivity (right) tissue profiles of a male head model

- **Quantitative Susceptibility Mapping – QSM**
  The magnetic susceptibility of tissue can be used to characterize e.g. diseased tissue
  QSM: retrieve the susceptibility of tissue from field disturbances in the background field of the MR scanner

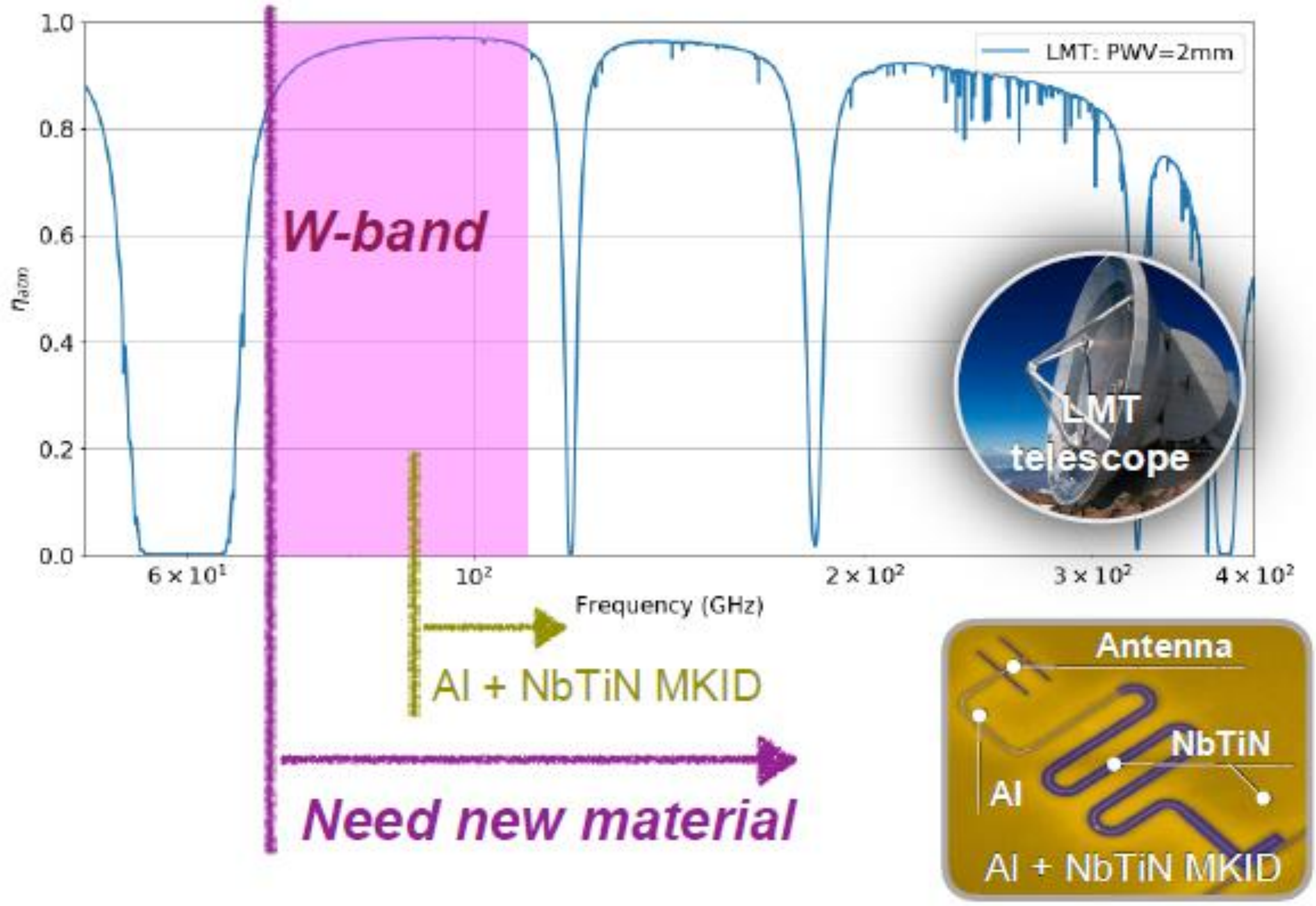
  Contribute to the development of efficient and accurate QSM reconstruction techniques
  In cooperation with the University Medical Center Utrecht and the Leiden University Medical Center



Reconstructed susceptibility profiles of the brain using an imaging technique developed at the TU Delft

Project:
W-band superconducting detector

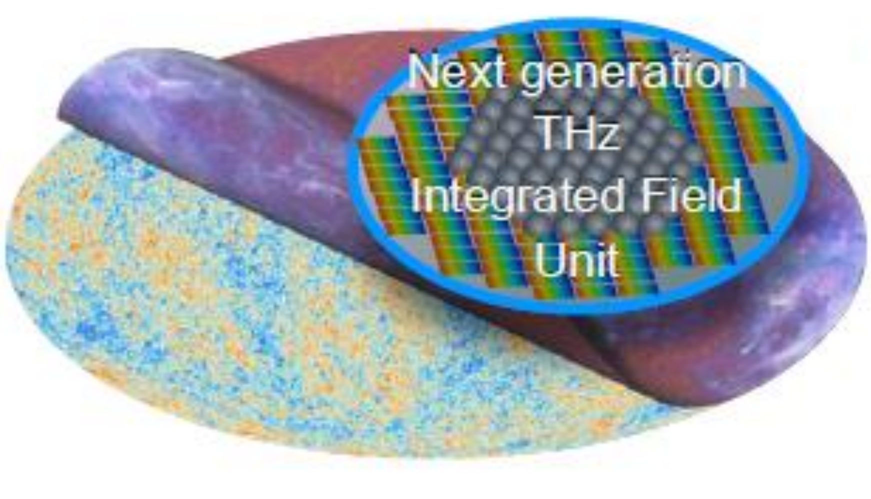
We have been developing a superconducting detector called MKID for astronomical instruments for years. Currently used material for MKID is aluminum (Al) that determines the lowest frequency threshold as 90 GHz.



Looking up the sky, there is an atmospherically transparent (high η_{atm}) window around 70-110 GHz, which is also known as W-band. As long as using Al MKID, we miss a part of this range.

In this project, you will try different materials than Al to **develop MKID that can fully use W-band for an astronomical observation.**

Possible astronomical application: Cosmic Microwave Background (CMB)



- Sunyaev Zel'dovich effect
  → galaxy cluster science
- CMB polarization
  → neutrino mass, cosmic inflation

For more information, please contact:
Kenichi Karatsu (k.karatsu@sron.nl)

Project

Advanced MKID coupler designs for large MKID arrays

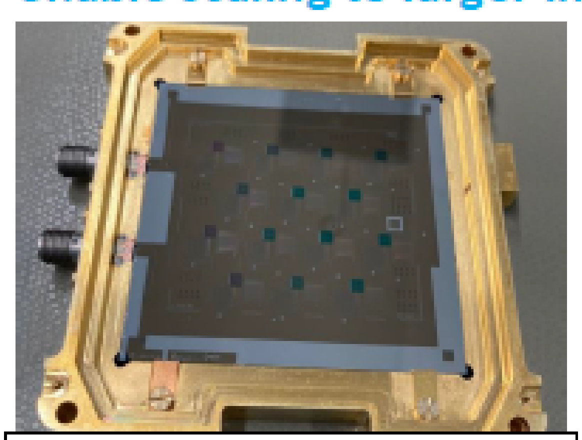
On-chip spectrometers, invented in our group, are revolutionary devices that allow us to measure the intensity and spectrum of the radiation of extra-galactic sources using a device orders of magnitude smaller than any other technology. This was pioneered in 2017 with the DESHIMA instrument on the ASTE telescope in Chile https://www.nature.com/articles/s41550-019-0850-8 . Currently, after successful campaigns of DESHIMA and DESHIMA 2.0, we are developing an imaging spectrometer, called TIFUUN, which we aim to bring to the telescope as well. This imaging spectrometer will vastly increase the number of pixels on one chip, with a spectrometer behind each pixel.

One challenge that we are facing is large variations in the coupling strength of the MKIDs to the readout line, even though they share the same design. These variations cause a limit on the number of MKIDs that we can fit into the readout line (~ 1000), because they get jumbled up in frequency. So, if we want to scale to 4000 MKIDs per readout line, we need a better design for our MKID couplers.

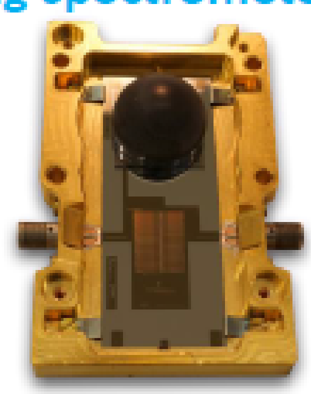
You will be working on is solving this problem. You will need to consider a complex electromagnetic environment in which these couplers exist. They are spaced close together and can mutually interfere with each other due to a common transmission line. You will create a detailed electromagnetic model of these couplers and use it to improve upon its design. We will fabricate a test chip to validate this new design against our existing couplers.

Have we got you exited about studying, dissecting and designing in a challenging electromagnetic environment? Do you want to contribute to real instruments, going to real telescopes? Then we want you!

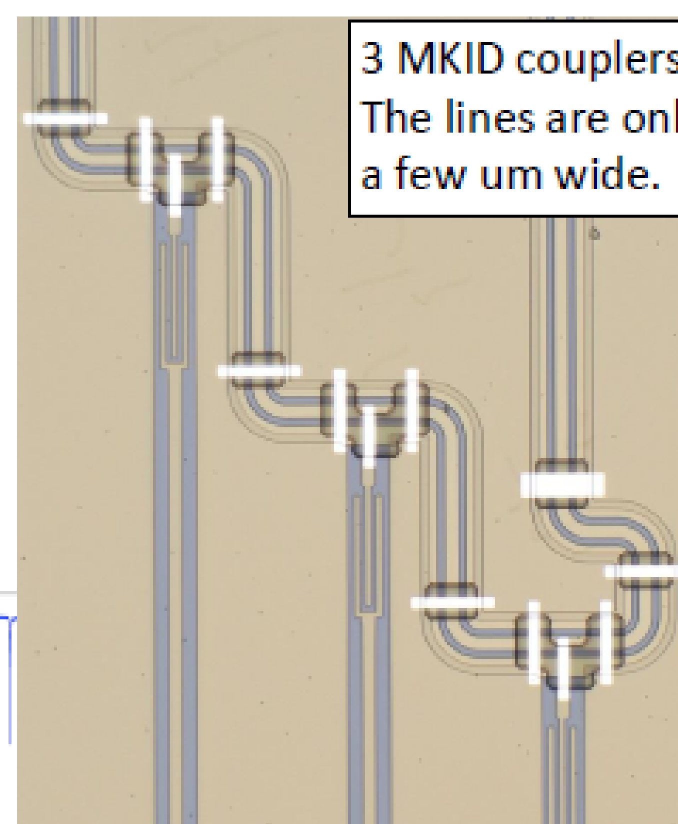
Challenge: Solve the problem of varying coupling strength in MKID readout lines to enable scaling to larger imaging spectrometers.



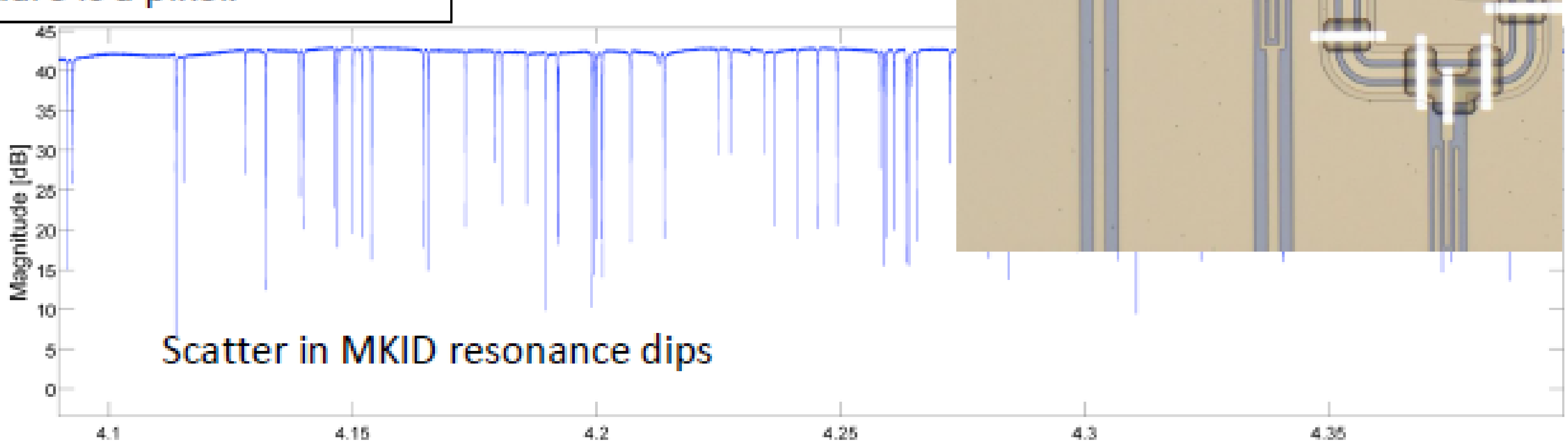
TIFUUN-like protype. Each square is a pixel.



DESHIMA 2.0



3 MKID couplers. The lines are only a few um wide.



Scatter in MKID resonance dips

For more information, contact: Prof. Jochem Baselmans (J.J.A.Baselmans-1@tudelft.nl)

SRON
Netherlands Institute for Space Research

Single photon counting and energy resolution with Kinetic Inductance Detectors (KIDs).

Linear Arrays for Exoplanet Spectroscopy

While kids are commonly used in square N by N pixel arrays, certain space missions and projects, such as the Large Interferometer for Exoplanets (LIFE), are interested in combining linear arrays of KIDs with the dispersive spectroscopic elements of their instruments. This project focuses on the design of linear or 1D arrays with all pixels in a single line, which will drastically change the design of the KIDs. You will design this new type of KID, study the possible improvements or limits in performance, and work with our cleanroom engineers to figure out how to fabricate these arrays.

Characterizing the dark current of kinetic inductance detectors

We need an exceptionally well-characterized measurement setup to measure the dark current of the incredibly sensitive KIDs. In this project, you will first have to characterize and understand the effects of cosmic rays, stray light, and readout effects on the photon count rate of a KID. Then, you will follow up this characterization with a thorough statistical analysis to determine the actual dark current for kinetic inductance detectors.

Towards quantum-limited noise performance with kinetic inductance detectors

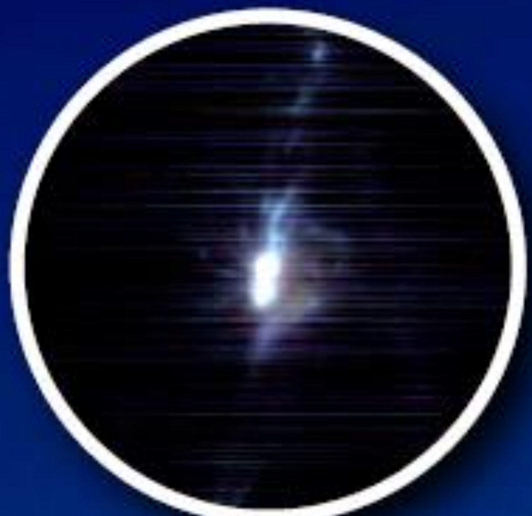
This project aims to implement a different type of amplifier into our cryogenic readout system: a parametric amplifier. You will need to implement the new amplifier in the cryogenic systems and characterize it to prove that it reduces the system noise. You can then work on an application that benefits from the reduced noise level. For example, measuring our KIDs at lower readout powers than before could reveal new insights into the effect of readout power on the superconducting properties of our detector.

Investigating the effect of current crowding in kinetic inductance detectors

KIDs are superconducting microwave resonators with photon-sensitive, high-inductance wires patterned into compact, meandering structures to save space. However, the gaps in these designs are larger than the wavelengths we want to absorb, allowing some photons to pass undetected. Reducing the gaps improves optical efficiency but risks breaking the superconducting state due to current crowding. For this project, we are looking for someone who wants to study the current crowding effects in compact superconducting structures and figure out a practical way to optimize the optical efficiency while keeping the current crowding

MSc Project:

Cosmological redshift measurement of distant star-forming galaxies using DESHIMA 2.0 data taken at the ASTE telescope



Orion KL region, measured with DESHIMA 2.0

Research Question:

How can you detect faint astronomical emission lines buried in various types of noise and systematics associated with the detector, instrument and the atmosphere?

Context:

DESHIMA 2.0 is an astronomical spectrometer with the widest bandwidth in the world in the millimeter-submillimeter wavelength range. It is the first instrument that utilizes the superconducting on-chip filterbank technology that was invented in Delft/SRON. Many students were involved in the development, simulation and operation of DESHIMA. In 2023-2024 we conducted observations on the ASTE telescope in Chile, with participation of TU Delft students, together with astronomers from around the world.

In the ASTE cabin with DESHIMA 2.0, 2024

At the ASTE Telescope, 2024

In this project, you will try to measure the cosmological redshift of a few dusty star-forming galaxies, to find out how many years after the Big Bang they existed. To this end, you will analyze data taken by DESHIMA 2.0, and try to distill the faint emission line signature of the galaxy, from the various types of noise. Whilst main area is signal processing, you will also need to develop a physical understanding of the working of the detectors, the telescope system, and the method of observations that were applied.

Contact

Akira Endo
a.endo@tudelft.nl (Room HB 18.270)

The project is flexible in the type of object you would like to analyze, and it can be tailored to your interest. I like to define projects with students. If you are interested, drop me an email or walk into my office.

MSc Project:

On the design of a superconducting on-chip Integral Field Unit for sub-mm astronomy

Context:

DESHIMA 2.0 is a superconducting on-chip spectrometer for sub-mm astronomy, developed here at TU Delft and at SRON in Leiden. During 2024 we have succesfully taken DESHIMA 2.0 to the ASTE telescope in Chile, were we carried out the commisioning and science verification campaign. The next step forward will be the upgrade of the spectrometer to a spectral imager, also called an Integral Field Unit or IFU for short.

Project Description:

In this project, you will investigate the design of TIFUUN, a planned IFU building on the DESHIMA 2.0 design. In particular, you will explore and quantify the design parameter space and investigate the trade-off between important quantities, such as field-of-view, spectral resolution, and spatial resolution. An important tool at your disposal will be TiEMPO2, a software package for simulating observations of arbitrary astronomical sources with superconducting detectors, taking into account realistic models of the atmosphere, telescope, instrument noise, etc.

You will then apply the design procedure to an astronomical science case of your interest, such as galaxy cluster science through the Sunyaev-Zel'dovich effect, or rapid redshift surveys of extremely distant galaxies. This allows for a range of research questions, and an example could be:

How can we optimise the TIFUUN design for tracking gas motions inside galaxy clusters?

The research question can of course be changed to suit your interests.

Interested?

If you are interested, want more information or literature, or want to get in contact for some other reason:
Arend Moerman
A.Moerman-1@tudelft.nl
Room HB 18.250

Master Thesis Supervision
TeraHertz Sensing Group

World-Leading Research Group on Applied EM, Antennas, Terahertz, Astronomical Instuments

Thesis supervisors:


Andrea Neto


Nuria Llombart


Jochem Baselmans


Daniele Cavallo


Akira Endo


Rob Remis


Maria Alonso-delPino


Shahab Dabironezare


Ioan Lager

What does it mean for you?

Very thorough supervision

- Master thesis related to research (often to PhD projects)
- Multiple supervisors: Professor + PhD / postdoc as daily supervisor
- Time availability: you can address supervisors on a daily basis
- All our master students graduate in time -> no extra tuition fee!

Strong cooperation with industries

- Directly financing our research
- Opportunities for paid internships
- Hiring our students

IMST SRON Viasat esa THALES HUAWEI ERICSSON NASA JPL TNO PHILIPS NXP HENSOLDT ASML

The courses we offer

- EE4C05 Electromagnetics
- EE4510 Advanced Electromagnetics
- EE4725 Quasi Optical Systems
- EE4620 Spectral Domain Methods in Electromagnetics
- EE4730 High Frequency Wireless Architectures
- EE4595 An Introduction to Wavefield and Magnetic Resonance Imaging
- EE4745 Superconducting Astronomical Instrumentation

Ask our ex-students