Website: terahertz.tudelft.nl

MASTER THESIS PROJECTS

TeraHertz Sensing Group

2023-2024

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

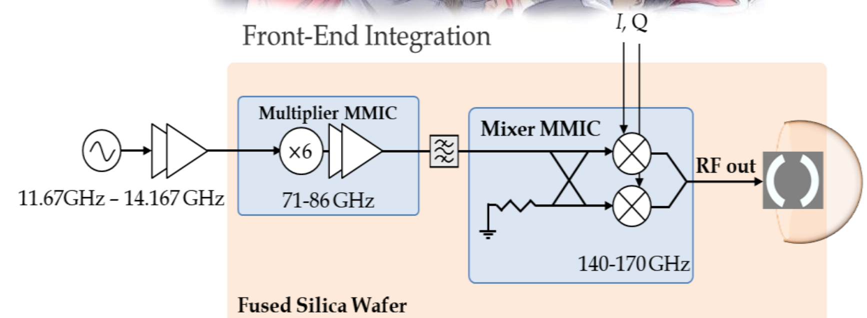
XG Communications: Fly's Eye Concept

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

HUAWEI

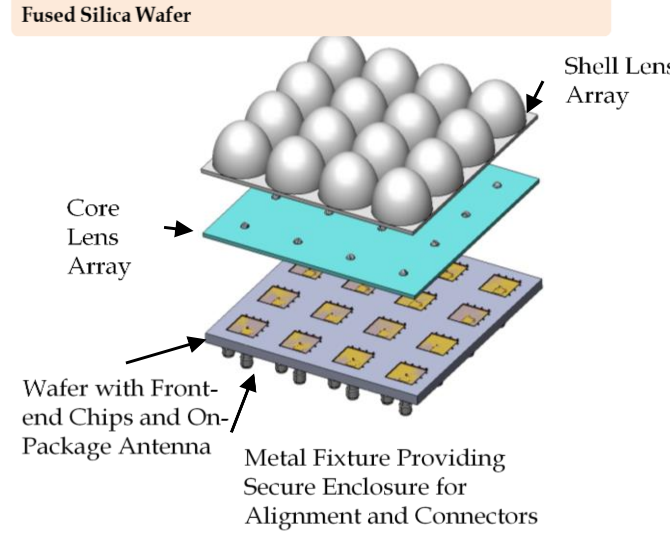
Internship Project:

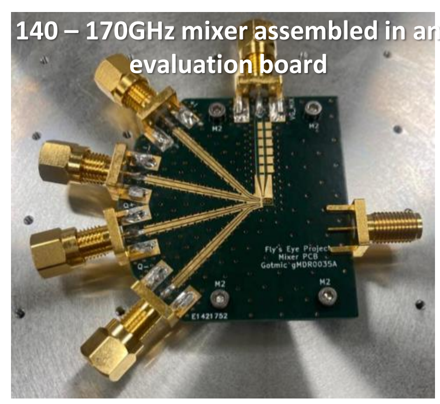
State of the art of of Silicon technology receiver front-ends and characterization techniques. Design a measurement setup at 140-170 GHz for a differential I/Q mixer



Master Project:

Characterization of a mixer of the Fly's Eye system front end in the 140-170GHz band. Apply high frequency mixer modelling and characterization techniques to extract the figures of merit for the Fly's Eye communication scenario



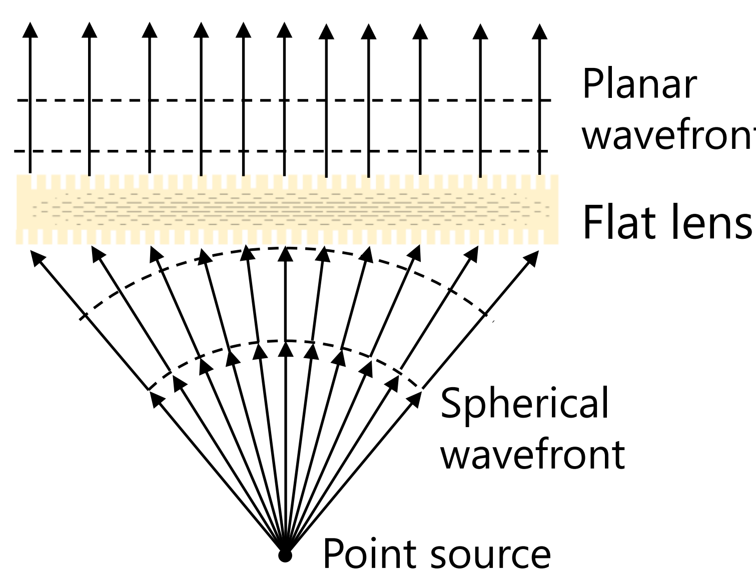


Supervision Team:

Maria Alonso, Nuria Llombart, Marco Spirito
PhD: Nick van Rooijen

Wideband lens feed design

Research line: *mmWave artificial dielectric flat lenses*

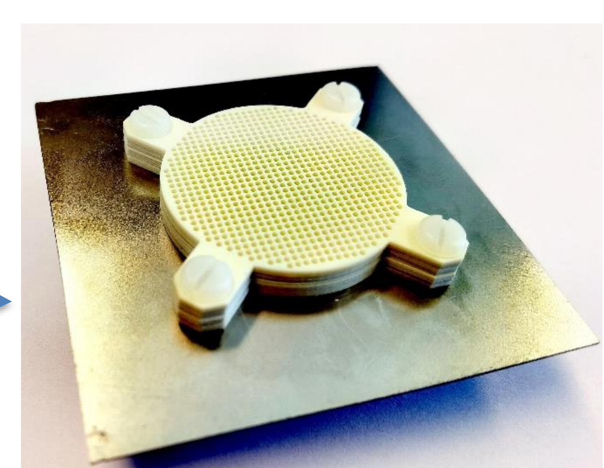


Extra Project:

Review of the current solutions for wideband mmWave feeds for lens antennas; comparative analysis of different feeds over wide bandwidth in terms of aperture efficiency and Ohmic losses

Master Thesis Project:

Design of wideband feed for illumination of artificial dielectric lens for mmWave applications (30 to 60 GHz). Manufacturing and testing of the feed together with a flat lens prototype

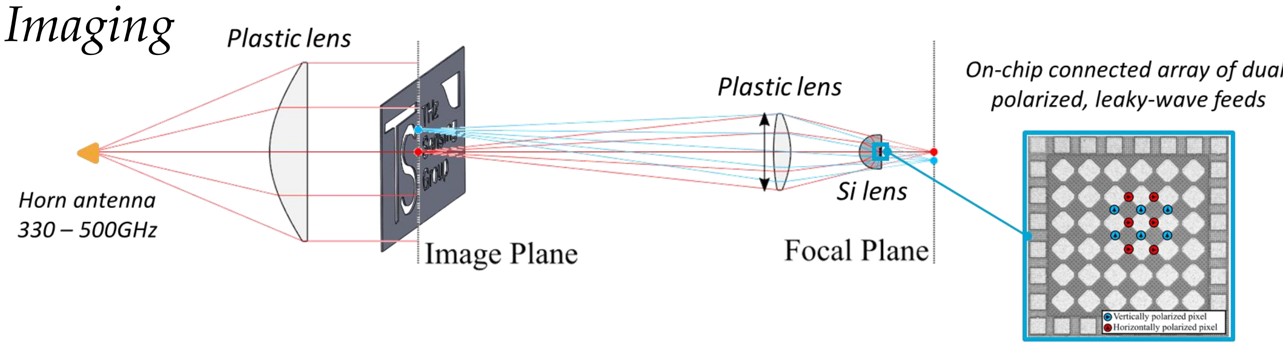


Supervision Team:

Daniele Cavallo
Caspar Coco Martin (PhD)

THz Imaging Cameras

Research line: *Direct-Detection Imaging for Future Passive THz Cameras*



Extra Project:

Model of a QO imaging system for demonstrating diffraction-limited THz images using active, coherent illumination

Master Project:

Fabrication and characterization of the QO imaging system. Compare measured and simulated images. Study the dynamic range of the images including 1/f noise

Supervision Team:

Maria Alonso, Nuria Llombart
PhD: Martijn Hoogelander

XG Communications: Fly's Eye Concept

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

HUAWEI

Extra Project:

State of the art study in lens antennas. Matlab code to model the near field of leaky wave dual lens antenna

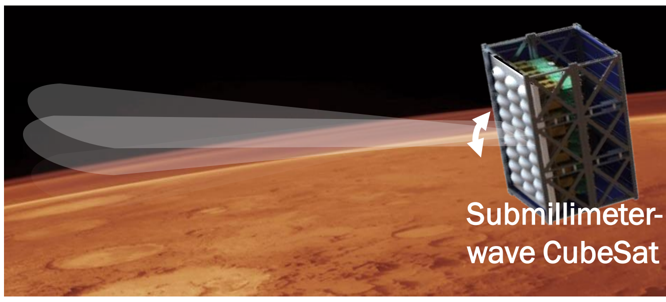
Master Project:

Design a Fly's eye antenna system to generate 200 directive beams in a field of view of 50degrees. For the design, Matlab codes based on high frequency techniques will be developed to shape an array of core-shell lenses

Supervision Team:

Nuria Llombart, Maria Alonso, Shahab Dabironezare
PhD: Nick van Rooijen

Space: Scanning lens phased arrays

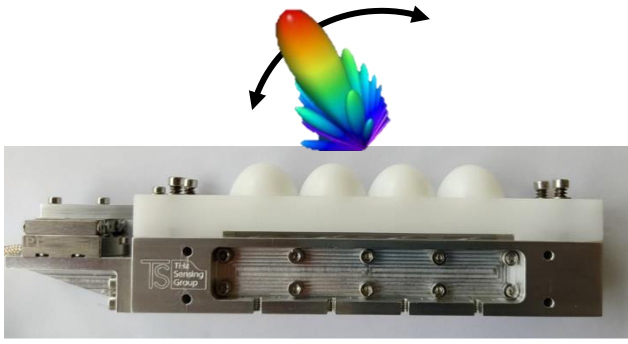


Research line: *Development of lens phased arrays for heterodyne space instruments at submillimeter-wave frequencies*

Internship Project:

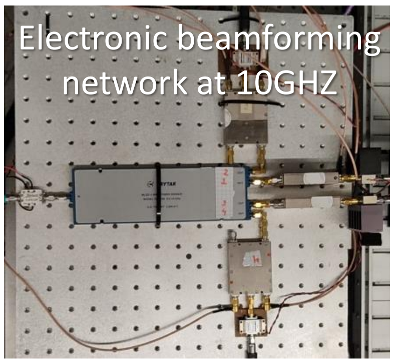
State of the art of electronic beam-steering architectures.
Model different electronic beam-steering architectures for submillimeter-wave frequencies.

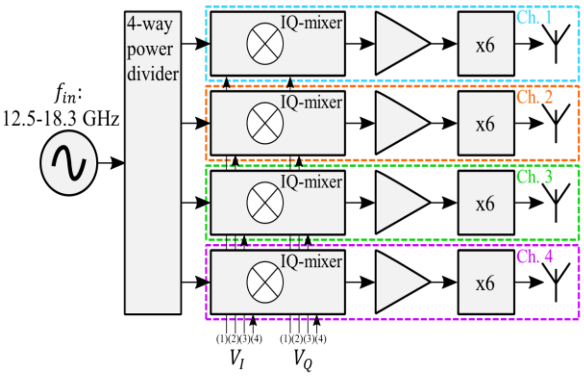
Lens phased array at 100GHz with electro-mechanical beam-scanning



Master Project:

Develop a measurement setup to characterize different electro-mechanical beam-forming network architectures at 100GHz frequencies





Supervision Team:

Maria Alonso, Nuria Llombart, Marco Spirito

M.Sc. Thesis Opportunity (July 2023)

Compact and multi-function in-package baluns for millimeter-wave automotive radars

High-performance millimeter-wave on-chip radar technology is enabled by differential amplifiers and receivers. However, many antennas and other devices have single-ended terminals. Thus, there exists a need for high-performance balanced-to-unbalanced converters (BALUNs). Such BALUNs are often implemented in the package of the mmWave IC. While there are a wide range of existing BALUN solutions, there is a desire for novel in-package balun topologies that show 1) wideband performance; 2) compactness; 3) compatibility with current and future packaging technologies (dimensions, tolerances ...); 4) scalability to higher frequencies (e.g. 140 GHz); and that 5) potentially combine multiple functions, for example package-layer transitions, solderball transitions and/or allow DC-passthroughs.

What you will be doing

In collaboration with and under supervision of NXP experts you will:

- Survey the literature to see the “state of the art” BALUNs in the literature (journals, conferences, patents and books)
- Compare their key-performance indicators and select several topologies for detailed studies
- Analyze these BALUNs with equations, equivalent circuits and full-wave computer simulations
- Investigate and model promising new BALUN topologies and/or multi-function modalities
- Work towards a potential “tape-out” of a test structure containing several existing and new BALUNs in an applicable technology such that they can be measured, post-processed, compared, evaluated and communicated to a wider audience

What you will get in return

- Opportunity to work and collaborate with an expert team of millimeter-wave package designers
- Potential to have a real-world impact on future radar products developed at NXP
- Close supervision and a desk in our Eindhoven office

What we ask of you

- M.Sc. student of electrical engineering at one of the Dutch Universities of Technology (Eindhoven, Delft or Enschede) with a specialization in electromagnetism, antennas, wireless systems or related field
- Interest in automotive radar systems
- Prerequisite knowledge: o B.Sc. in Electrical Engineering or similar field
    - o Working knowledge of linear circuits, transmission lines, impedance transformers, Smith charts and electromagnetic waves
    - o Programming experience in MATLAB or Python
    - o Bonus: Experience with full-wave numerical EM solvers and software such as Ansys HFSS, CST Microwave studio, ADS etc. (but you will learn it on-the-job regardless)
- Structured communication in English

How to apply

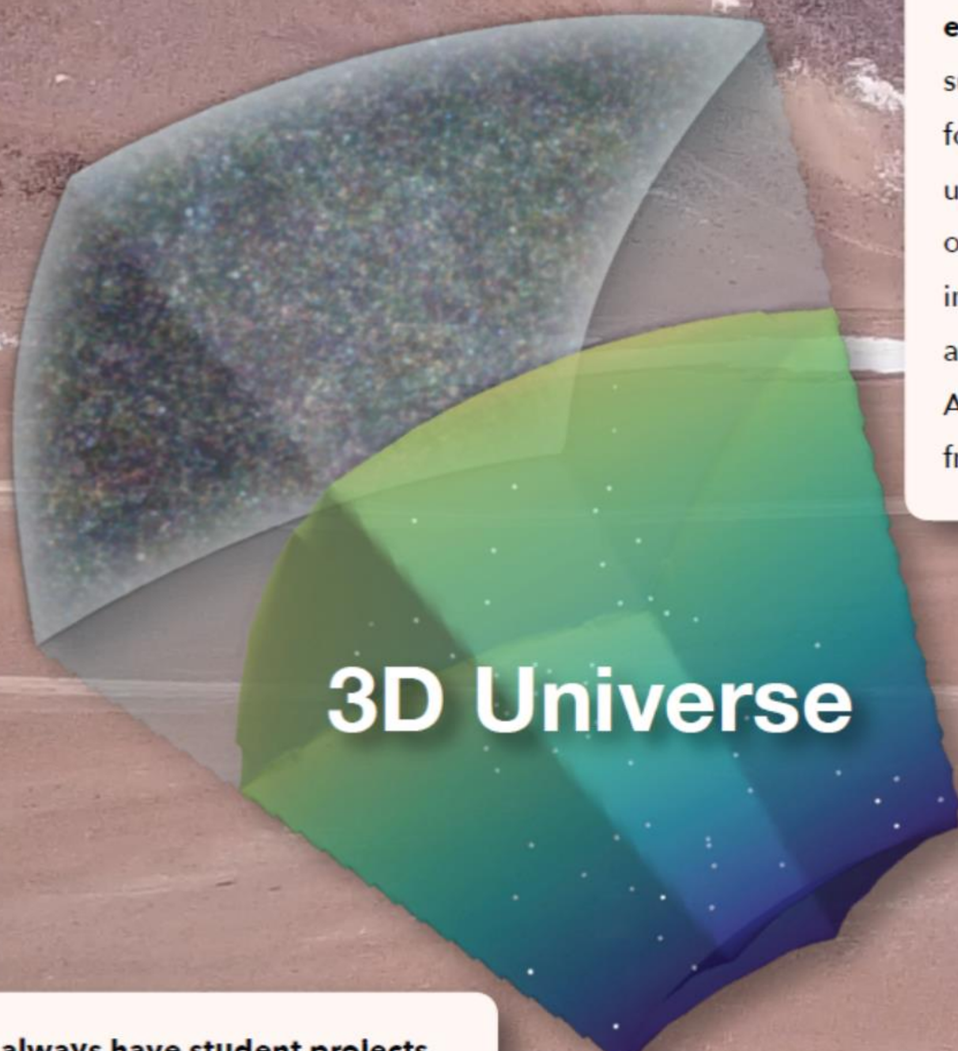
If you are interested in this opportunity, please address your application by email to dr. ir. Sjoerd Bosma (sjoerd.bosma@nxp.com) with the following information:

- Short résumé / CV
- List of completed Master-level courses with grades

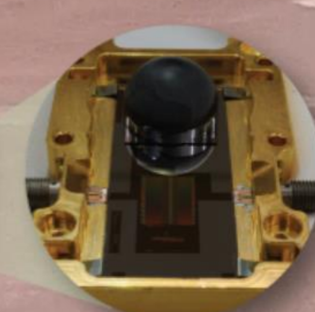
MSc Projects in

Cosmic 3D Mapping with On-chip Spectrometers

How did stars and galaxies form and evolve? In our group we develop superconducting detectors and instruments for mapping the evolution of matter the universe in space and time. We develop our own detectors in the cleanroom, test them in the Cryolab, and also conduct astronomical science observations at the ASTE telescope in Chile with astronomers from around the world.



The DESHIMA "Redshift Machine"



On-chip Spectrometer

ASTE telescope (4860 m altitude)

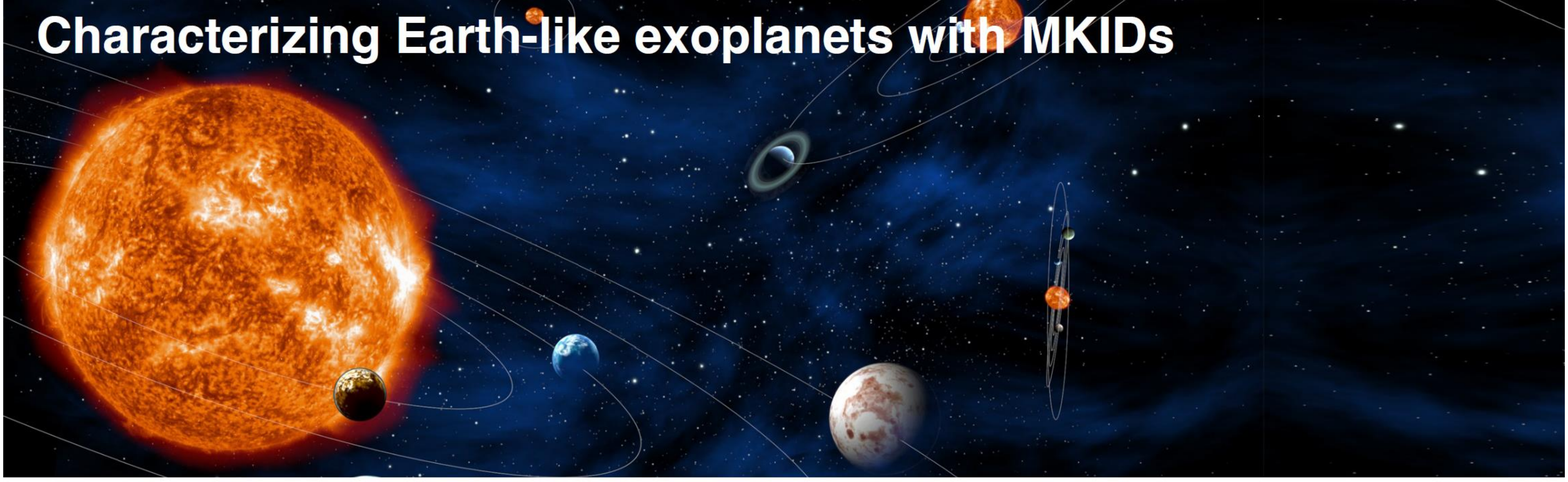
In our team we always have student projects in many facets of the multi-disciplinary R&D:

- Superconducting electronics
- Solid-state physics
- Signal processing (with the CAS group)
- Observational astronomy and cosmology

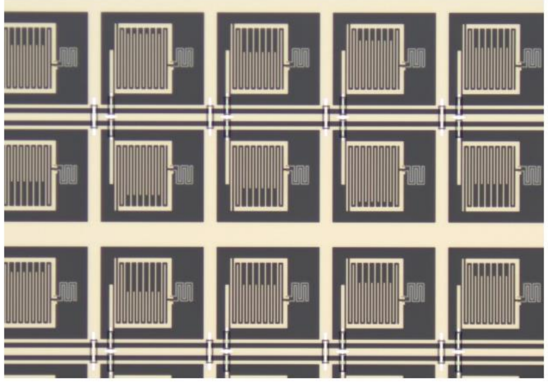
Regardless of your background, we are always open to discussing projects that fit your interest and current knowledge/skills.

Contact: Akira Endo (a.endo@tudelft.nl)

Characterizing Earth-like exoplanets with MKIDs

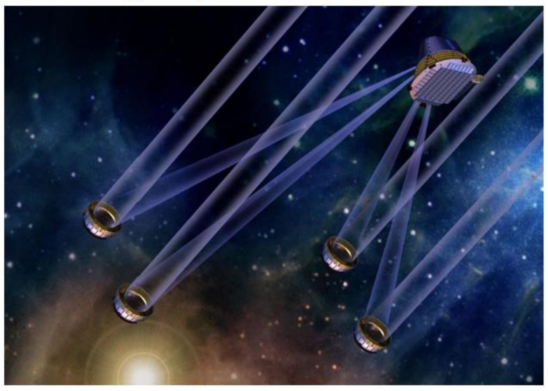


Integral Field Units



Single photon color resolution without dark counts or read noise

IR single photon detectors



Modular detector arrays for mid-IR interferometer outputs (LIFE)

Chromatic wavefront sensors

Real time photon counting with microsecond arrival timing and color information

Projects 1: Electro-dynamics of disordered superconductors (theory, data-analysis, experiments)

Normally, MKIDs are made with aluminium. But, for optical MKIDs, the use of Al is very inefficient: it is practically a mirror and one can only achieve a few percent absorption. Disordered superconductors can solve this problem: they absorb much more light. However, the physics of disordered superconductors is not yet well understood, in contrast to 'standard' superconductors such as Al.

- Dive into the physics of quasiparticles in disordered superconductors
- Data-analysis and experiments to probe the recombination in these superconductors in various ways

Projects 2: Kilopixel array of photon-counting MKIDs (microwave design, fabrication, experiments)

Compared to other superconducting detectors, MKIDs are easy to use in large arrays. Currently one of the bottlenecks is the pixel yield. In this project we want to take the step from small test arrays (of 10's of pixels) to a 1000 pixel array.

- Design a kilopixel array of MKIDs, based on the best design we currently have Simulate cross-coupling and how fabrication tolerances affect the yield of large arrays.
- Develop and test practical solution for frequency-scatter (i.e. yield) together with our cleanroom engineers
- Experimentally demonstrate a >1000 pixel array with high yield and sensitivity

Projects 3: Quantum efficiency of MKIDs (optical setup, experiments)

We know how to make good MKIDs and how to make them efficient, but do not yet have a setup to measure the absolute efficiency.

- Design and verify a quantum-efficiency measurement setup in the lab
- Characterize setup optical components
- Measure the efficiency of the current MKIDs

SRON

Contact: Pieter de Visser, p.j.de.visser@sron.nl

Project

Multiplexing of Detector Arrays for Future Ground- and Space-Based Instruments: Solving the Frequency-Scatter in MKID Devices

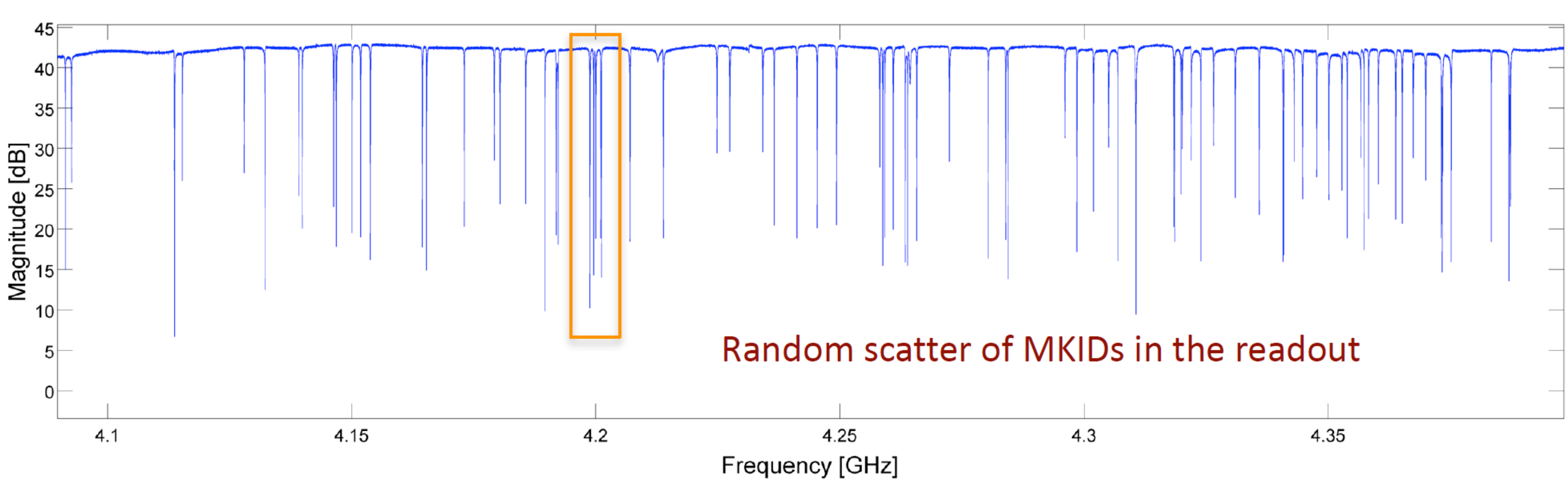
One of the most significant advantages that MKIDs have is that they are easy to multiplex. Currently, we have been able to have a single readout with up to 1000 MKIDs. The next goal will be to scale to even larger arrays of up to 10.000 MKIDs and we would like to minimize the number of readouts needed. We are collaborating with JPL and NASA to develop detector arrays for future space-based systems and our ground-based TIFUUN project aims to develop a number of detector arrays in the coming years.

MKIDs are microwave resonators, where each detector corresponds to a single dip in the graph below. Key in making large arrays is being able to go from ~1000 to >3000 detectors in 2 GHz of readout bandwidth. In practice this is not yet possible, because the resonant frequency shows a random scatter, causing the resonance dips to have a randomized center frequency, and they might overlap, as shown below. This is one of the biggest hurdles that **all** the in-development instruments in our group face. By working on this project with us, you are able to have a significant contribution to the development of these instruments.

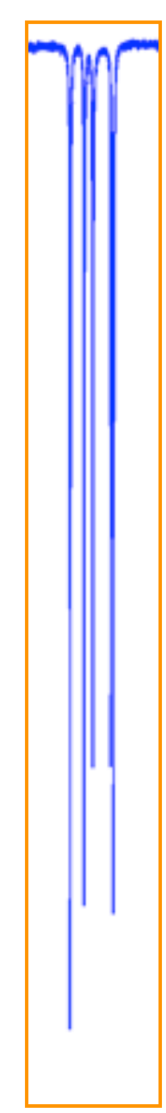
In this project, you will:

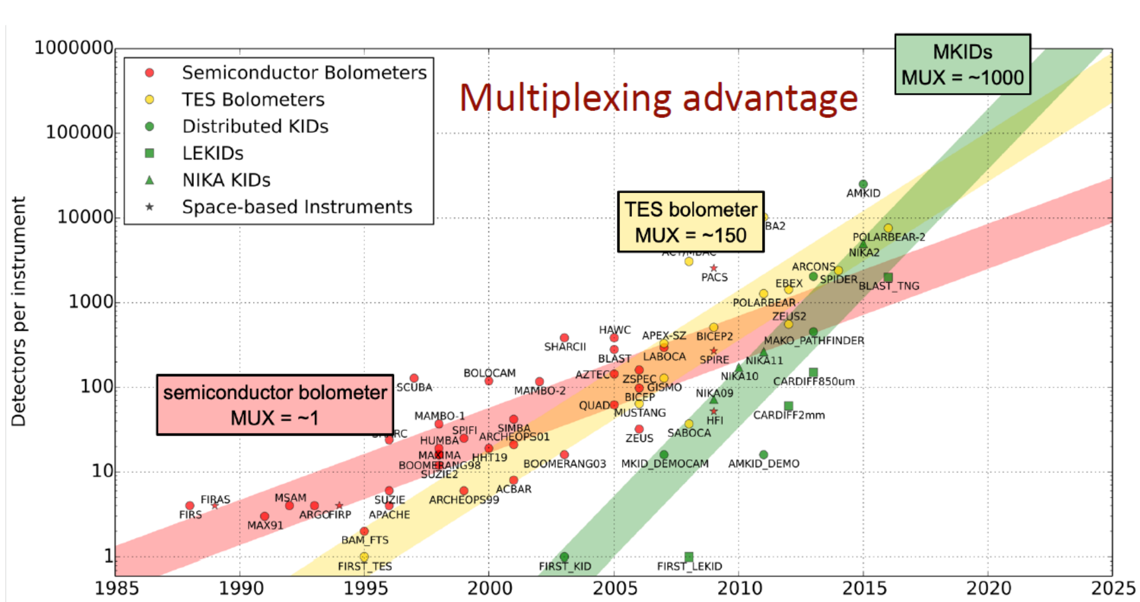
- Measure existing MKID arrays in our Cryolab in EWI and create an accurate model of the frequency scattering behaviour due to chip fabrication.
- Develop practical solutions for the frequency scatter by proposing changes in the chip design, the fabication methods and in post-processing steps.
- Design and measure a chip that uses your solutions.

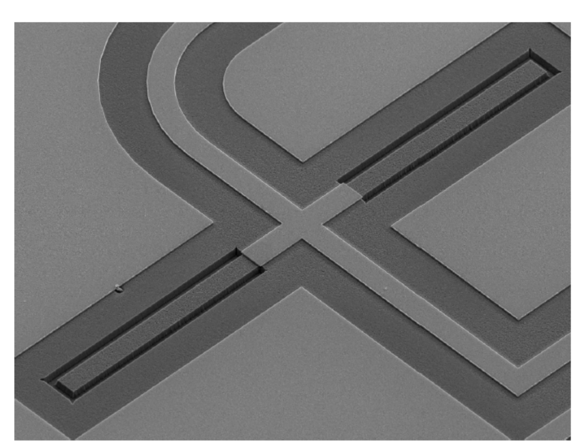
Challenge: Creating a robust solution by dealing with unforgiving margins, sensitive devices and many variables that can be tuned.



Overlap







Example of a post-processing step on a resonator (nibbling)

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

Project:
Development of lens based detector arrays for far infra-red (FIR) astronomy

Problem statement:

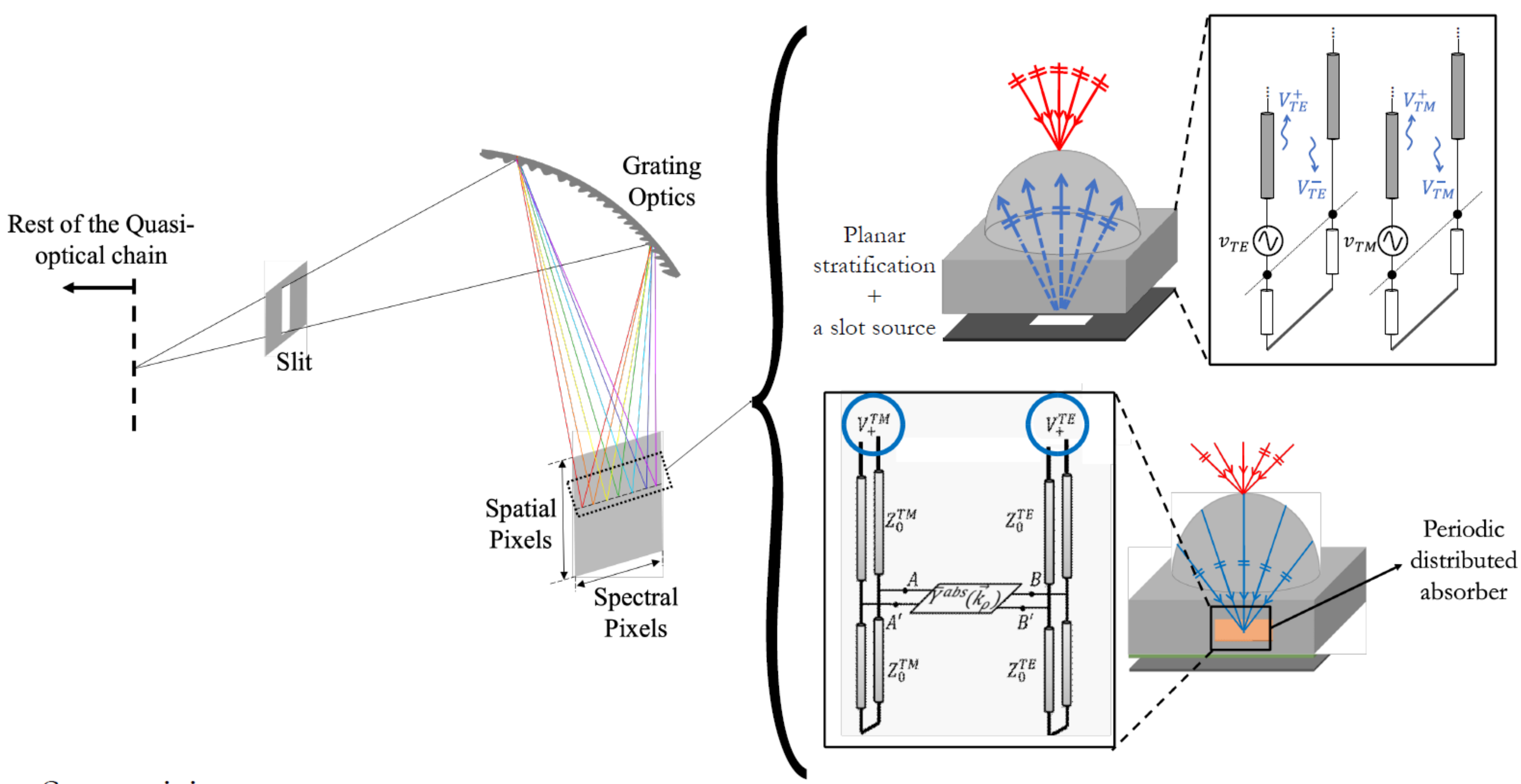
Highly sensitive detector arrays are required for the future FIR probe missions operating over a frequency range of 1 to 12 THz. A combination of lens antenna and lens absorber array coupled MKID solutions are proposed to cover this frequency range. The former is more sensitive but difficult to fabricate at the higher portion of FIR band while latter is more robust to fabrication tolerances due to its incoherent nature.

Project goal:

Evaluating the performance of the detector lens arrays coupled to a model of the envisioned quasi-optical (QO) chain using EM spectral based methods and optimizing the overall performance of the QO + detector array system. Comparing the overall performance of absorber based solution to the more standard antenna based one.

Proposed approach:

We will represent the response of the QO system using a Fourier Optics (FO) method as a summation of plane waves. This response will be then coupled to a Floquet based plane wave response of the periodic distributed absorber.



Supervision team:

Shahab Oddin Dabironezare, Jochem Baselmans

TU Delft SRON

Project
Photon counting in the THz - the ultimate FIR detector

SRON-TU Delft MKIDs have reached a sensitivity that is enough for future space projects (figure 1). But, very interestingly, these devices are so sensitive that they should be able to detect, in theory, single photon pulses from a THz source. The SNR=1 energy resolution

$dE = NEP \cdot \sqrt{\tau}$,

which is given in Figure 2. For a reliable detection the actual a SNR = 5 would be needed, so frequencies of order of 4 THz should result in single photon detection. The problem is, how do we develop an algorithm to detect these pulses efficiently. An example of a time stream is given in Fig.3, which shows detected pulses, some undetected pulses and one large pulse. This illustrates the complexity of the problem. The goal of the project is to make a reliable pulse detection scheme, that could be used in very near future space based observatories.

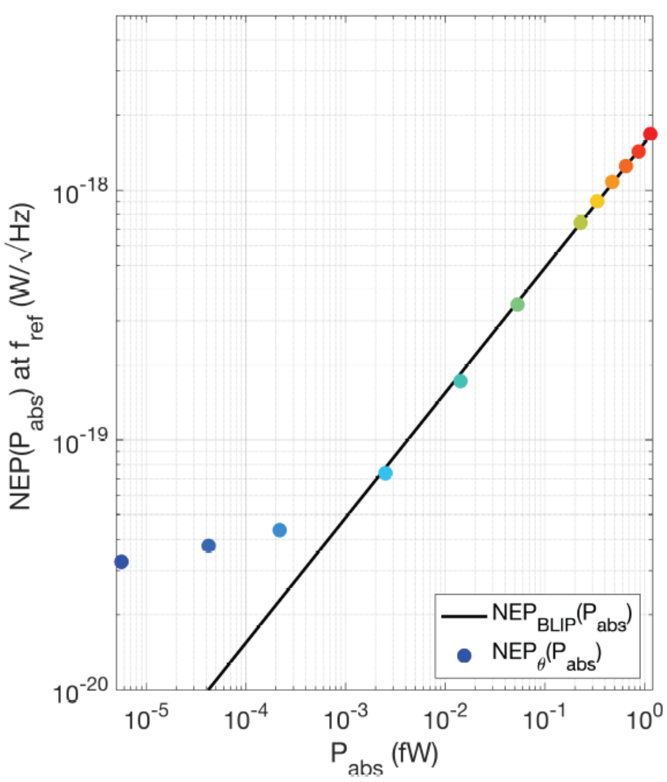


Figure 1: NEP of SRON-TU Delft MKIDs, representing the world's best FIR detectors.

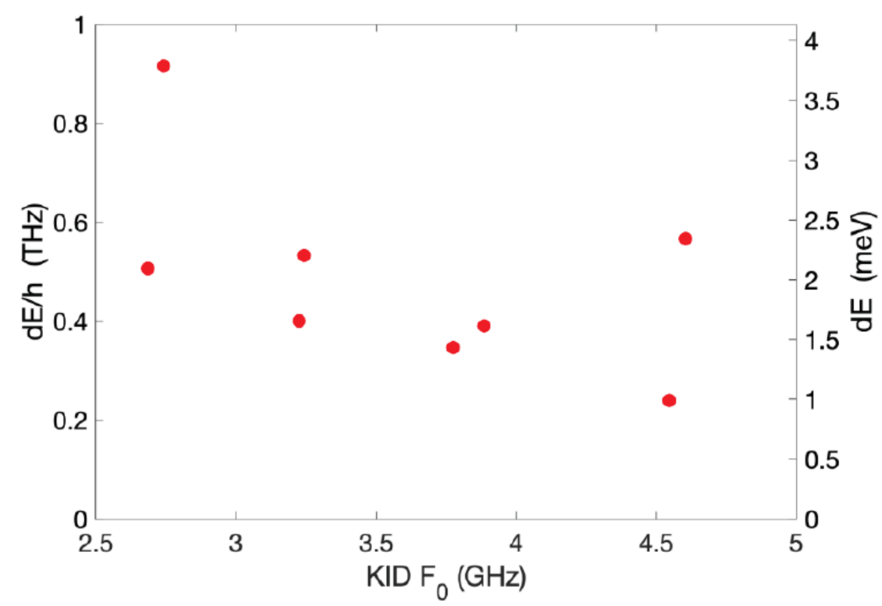


Figure 2: Energy resolution for single photon detection.

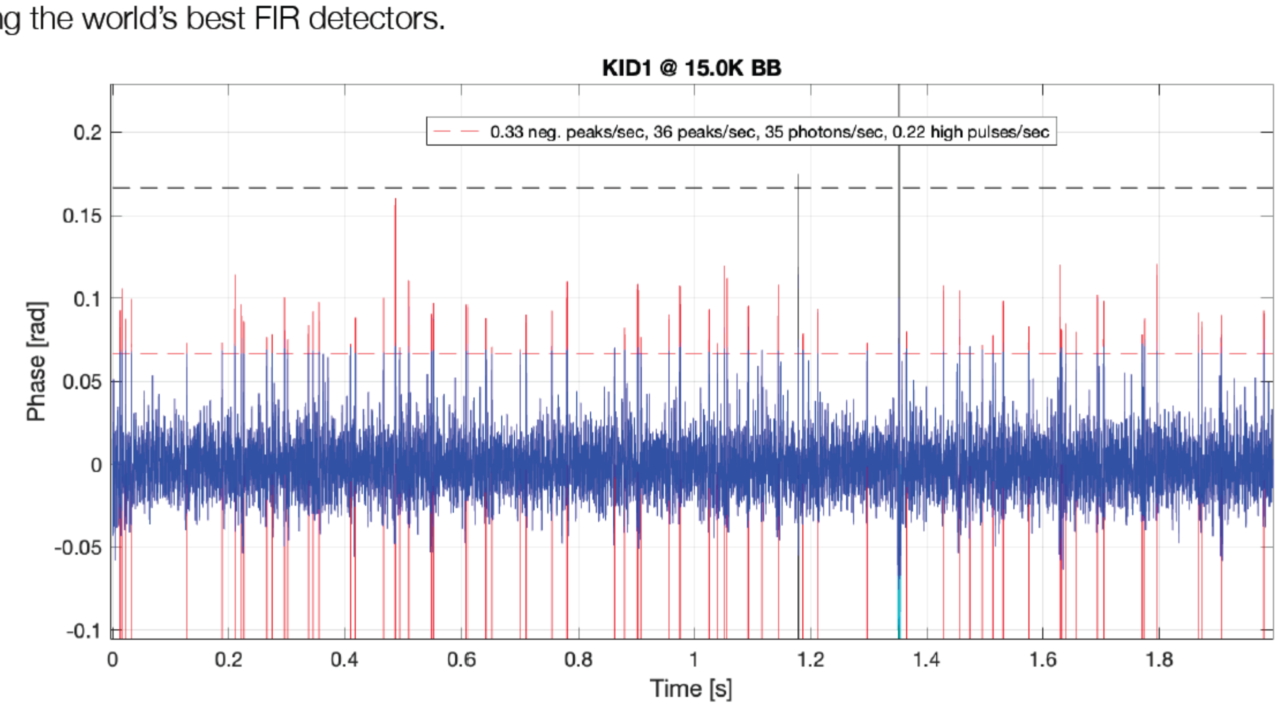
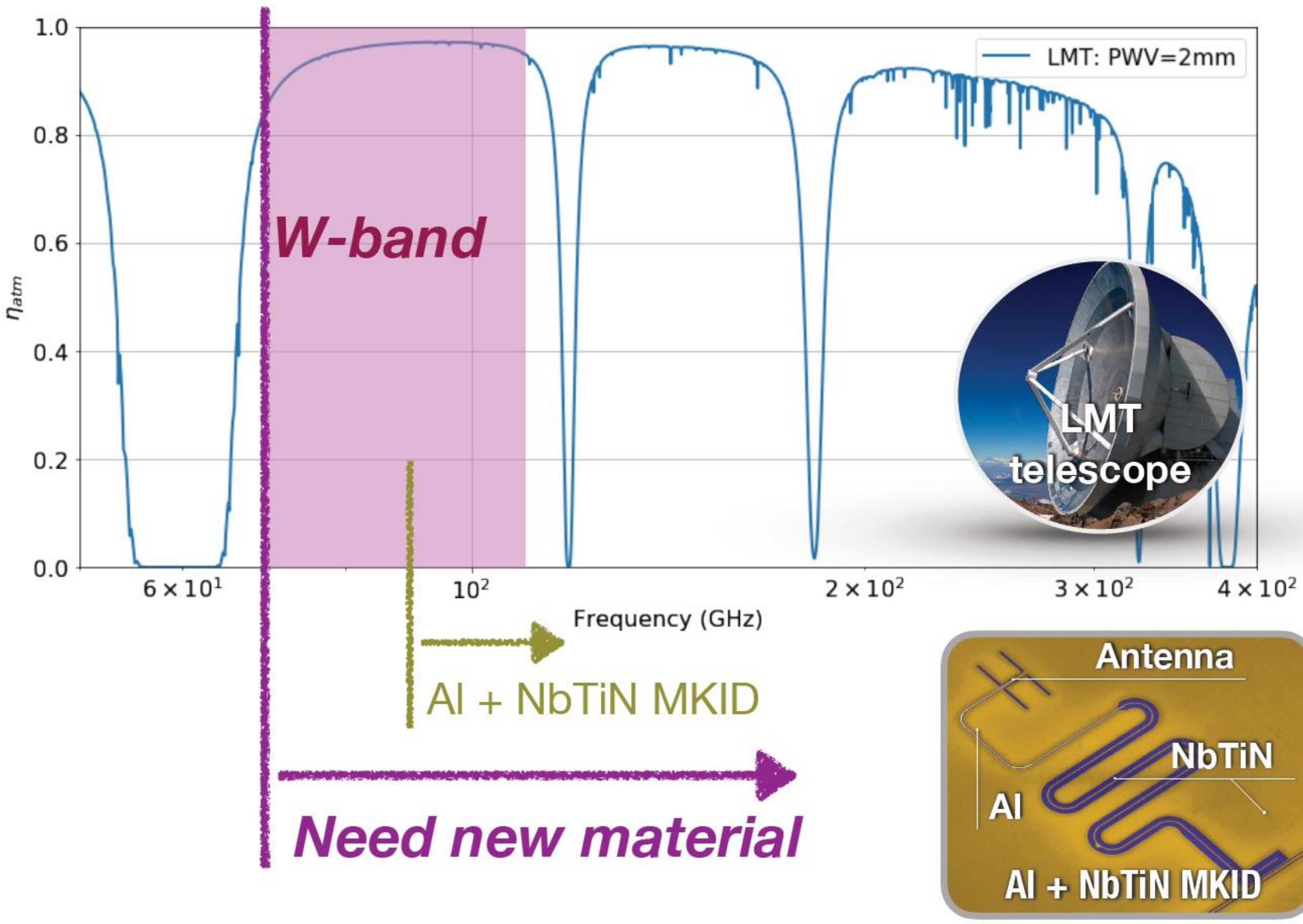


Figure 3: Timeline of a single MKID response under 7 THz illumination.

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

Project:
W-band superconducting detector

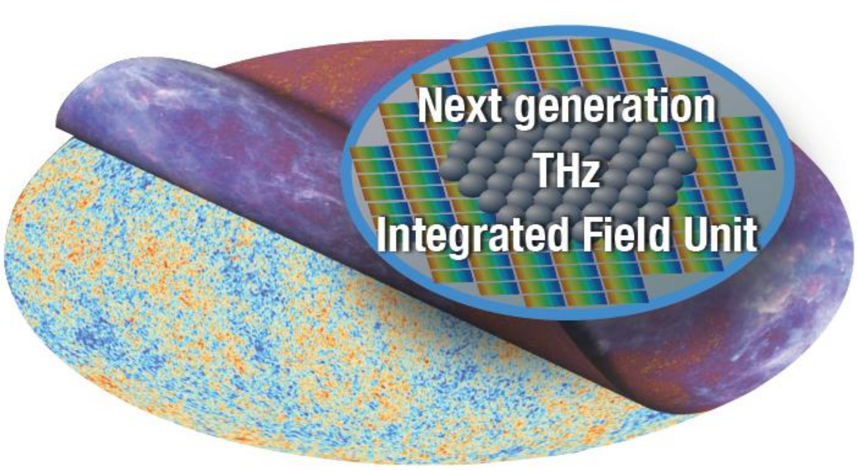
We have been developing a superconducting detector called MKID for astronomical instruments for years. Currently used material for MKID is aluminum (Al) that determines the lowest frequency threshold as 90 GHz.



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)



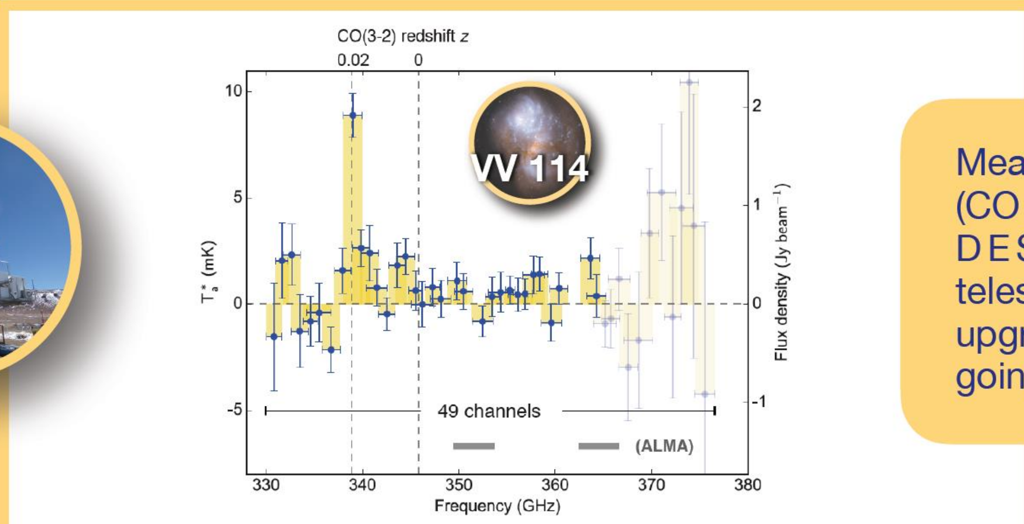
- Sunyaev Zel'dovich effect
  → galaxy cluster science
- CMB polarization
  → neutrino mass, cosmic inflation

For more information, please contact:
Kenichi Karatsu (   )

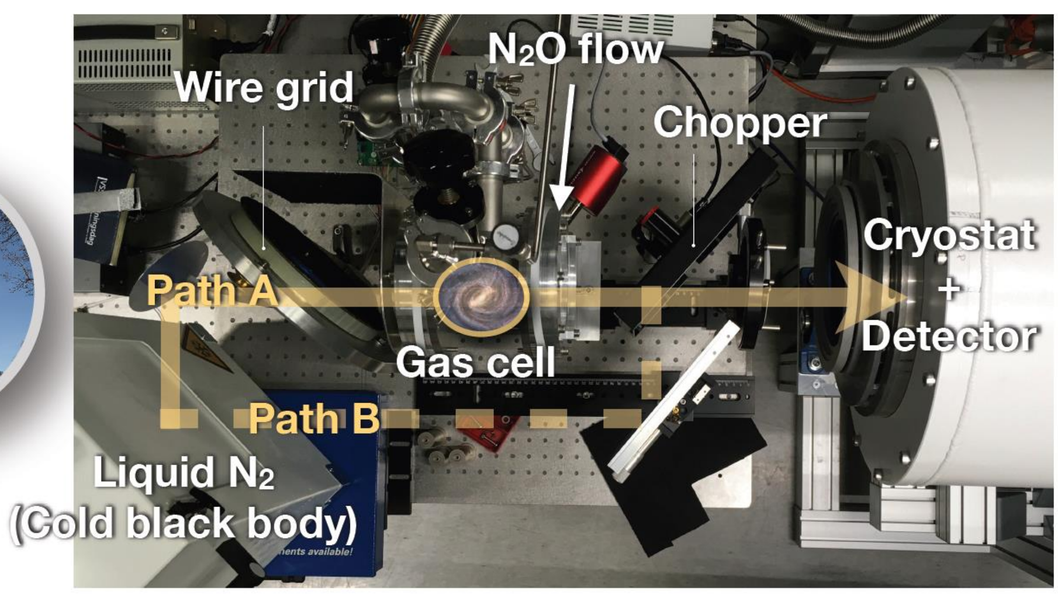
Project:
Quasi-astronomical observations in the lab

DESHIMA is a wideband superconducting spectrometer for sub-millimeter wave astronomy. It covers an instantaneous frequency band of 220 - 440 GHz. For the absolute frequency calibration of DESHIMA, we have developed a gas-cell calibration system using N_2O gas.

The system can be also used as quasi-astronomical source (~10^{-20} W of signal power) by lowering the pressure of N_2O gas. We can simulate a telescope observation of faint extra-galactic lines in order to evaluate the DESHIMA performance in the lab



Measured extra-galactic line (CO line from VV 114) with DESHIMA at the ASTE telescope (4800 m alt.). The upgrade of DESHIMA is on-going.



Gas-cell set up in TU Delft. Two paths (path A and path B) are switched by the chopper to modulate the signal from N_2O gas inside the gas cell. A quasi-astronomical signal can be realised by lowering the pressure of N_2O gas.

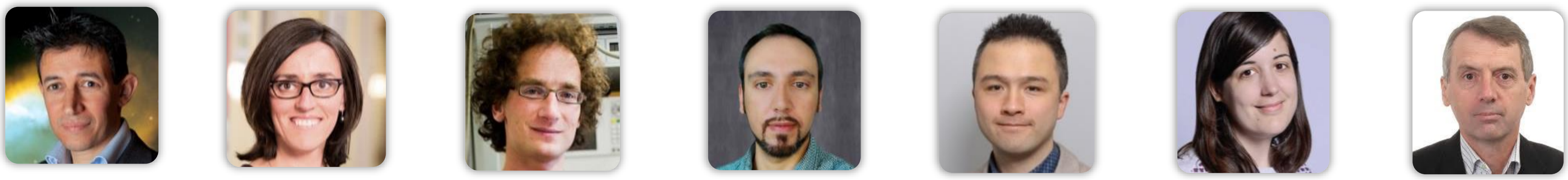
The stability of the gas-cell system is critical for such a quasi-astronomical observation because it requires a long integration time (> 8 hours) to detect faint signal. However, the stability of the setup is currently limited up to ~10^3 sec due to environmental fluctuation and/or insufficient signal modulation.

In this project, you will carry out several experiments by introducing a new signal modulation scheme, and try to remove possible systematic errors to **realise a quasi-astronomical observation in the lab!**

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

Master Thesis Supervision
TeraHertz Sensing Group

Thesis supervisors



Andrea Neto	Nuria Llombart	Jochem Baselmans	Daniele Cavallo	Akira Endo	Maria Alonso-delPino	Ioan Lager
Full professor	Full professor	Full professor	Associate Prof.	Assistant Prof.	Assistant Prof.	Associate Prof.

One of Europe's Leading Research Group on Antennas and Experimental Astronomy

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

NXP TNO IMST THALES SRON HUAWEI esa ERICSSON NASA JPL

You need these courses in your IEP

COURSES

- EE4C05 Electromagnetics — Q1
- EE4510 Advanced Electromagnetics — Q2
- EE4580 Quasi Optical Systems — Q3
- EE4620 Spectral Methods in Electromagnetics — Q4
- Extra project, thesis

For thesis on astronomy, add

- EE4635 Superconducting Astronomical Instrumentation — Q4

Theory and Design:

TRULY IMPROVED DESIGNS ONLY COME FROM THEORETICAL KNOWLEDGE

Ask our ex-students

MSc students graduated with us since 2019
TeraHertz Sensing Group

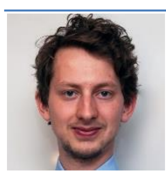
2022

Leila Gottmer
Thesis topic: *Shaped Multi-Surface Dielectric Lens Antennas*
Now: PhD at ELCA Group, TU Delft

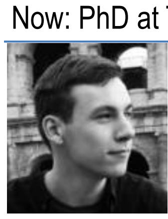
Wilbert Ras
Thesis topic: *Microwave Kinetic Inductance Detectors for the Mid-Infrared*
Now: PhD at TS Group, TU Delft

Junhong Gu
Thesis Topic: *Time-Domain Leaky Wave Radiation from a Long Slot*

Martijn Huiskes
Thesis Topic: *Imaging Setup Using Photoconductive Antennas*
Now: PhD at TS Group, TU Delft

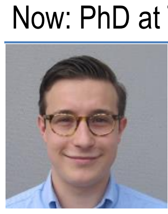


Sietse de Boer
Thesis Topic: *Compact Microwave Kinetic Inductance Detectors*
Now: PhD at TS Group, TU Delft

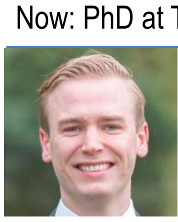


Rik Bokhorst
Thesis topic: *MMIC packaging using Flip-Chip technology at G band*
Now: Electric Engineer at Global Factories

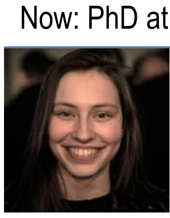
Jinglin Geng
Thesis Topic: *Volumetric Method of Moments*
Now: PhD at TS group, TU Delft



Caspar Coco Matrin
Thesis Topic: *Wideband Flat Lenses Based on Artificial Dielectric Layers*
Now: PhD at TS group, TU Delft



Louis Marting
Thesis Topic: *Enhanced Filterbanks for THz On-Chip Spectrometers*
Now: PhD at TS group, TU Delft



Dunja Lončarević
Thesis Topic: *Spectral Analysis of Slot Leaky Wave Antennas*
Now: PhD at TS group, TU Delft

2021

Nick van Rooijen
Thesis topic: *Lens Phased-Array at 100GHz*
Now: PhD at TU Delft, TS Group

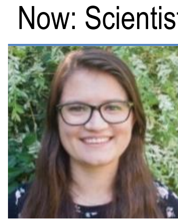
Nina Beschoor Plug
Thesis topic: *Superconducting Phase-Shifter*
Now: PhD at TU Delft, TS Group

Zhuang Chen
Thesis Topic: *Wideband Feeds for Connected Arrays*
Now: Engineer at Huawei (China)

Caspar van Wamel
Thesis Topic: *Cross-Pol Reduction in Connected Arrays*
Now: Engineer Officer at Royal Dutch Navy

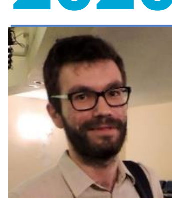
Ashwita Nair
Thesis Topic: *Mutual Coupling Analysis between Lens Antennas*
Now: PhD at TU Delft, TS Group

Saurabh Nerkar
Thesis topic: *GUI for Pulsed Pico-second Radar*
Now: Scientist at Bellatrix Aerospace (India)



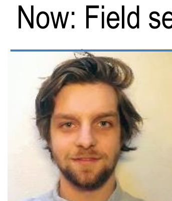
Stefanie Brackenhoff
Thesis Topic: *Detection of high-redshift galaxies using DESHIMA 2.0*
Now: PhD at Univ. of Groningen (NL)

2020



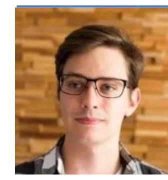
Antonios Pelekanidis
Thesis topic: *THz Lens Antenna fed by Photoconductive Connected Array*
Now: PhD at Vrije Uiversiteit Amsterdam

Federica Facchin
Thesis topic: *Single Photon Microwave Kinetic Inductance Detectors*
Now: Field service engineer at Single Quantum

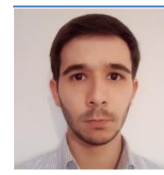


Steven de Rooij
Thesis topic: *Quasiparticle Dynamics in Optical MKIDs*
Now: Assistant Instrument Scientist at SRON

2019

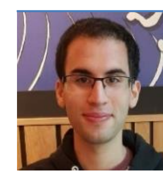


Kevin Kouwenhoven
Thesis topic: *Dielectric Loss at Sub-K Temp. and THz Freq.*
Now: PhD at TU Delft, TS Group

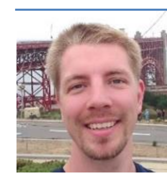


Riccardo Ozzola
Thesis topic: *Analysis of Wide-Band Phased Arrays*
Now: PhD at TU Delft, TS Group

Bruno Buijtendorp
Thesis Topic: *Properties of Deposited Dielectrics at Cryogenic and Room Temp.*
Now: PhD at TU Delft, TS Group



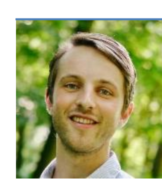
Cyrus Tirband Dastgerdi
Thesis Topic: *Non-Galvanic Chip-to-Waveguide Transition*
Now: PhD at University of Rennes (France)



Alexander van Katwijk
Thesis Topic: *Design of a Wideband Wide-Scan Connected Arrays*
Now: PhD at TU Delft, TS Group

Andrea Degasperi
Thesis topic: *Time Domain Modelling of Photo-Conductive Antennas*
Now: Design Engineer at ASML

Zhongyue Zhang
Thesis Topic: *Experimental Astronomy*
Now: Researcher at Univ. of Hamburg



Stefan Verheul
Thesis Topic: *Ultra High Kinetic Inductance Detectors*
Now: Design Engineer at ASML