(Some) Current & imminent developments for microwave EO applications

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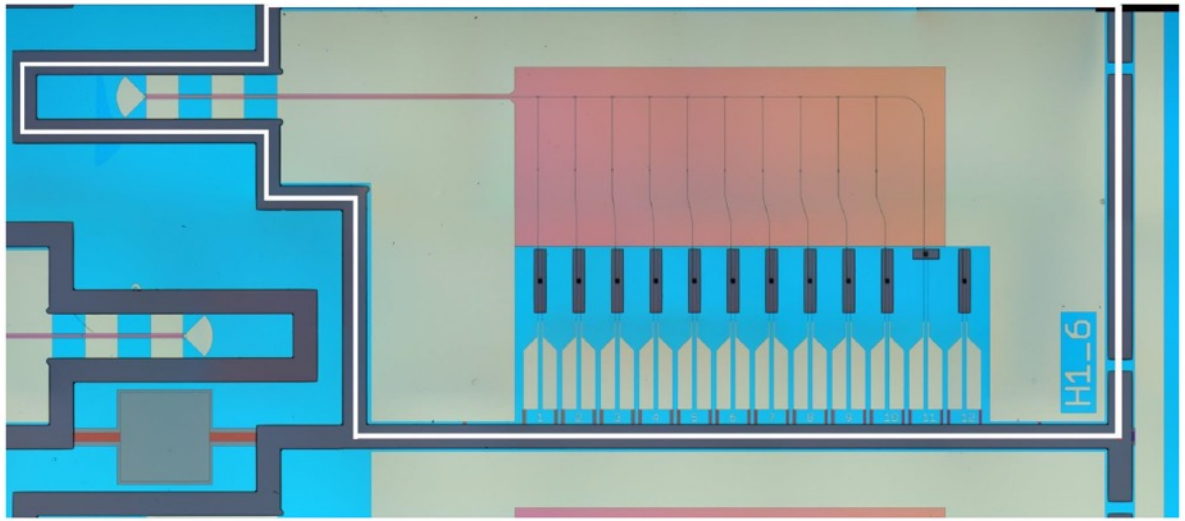
2 Major development areas

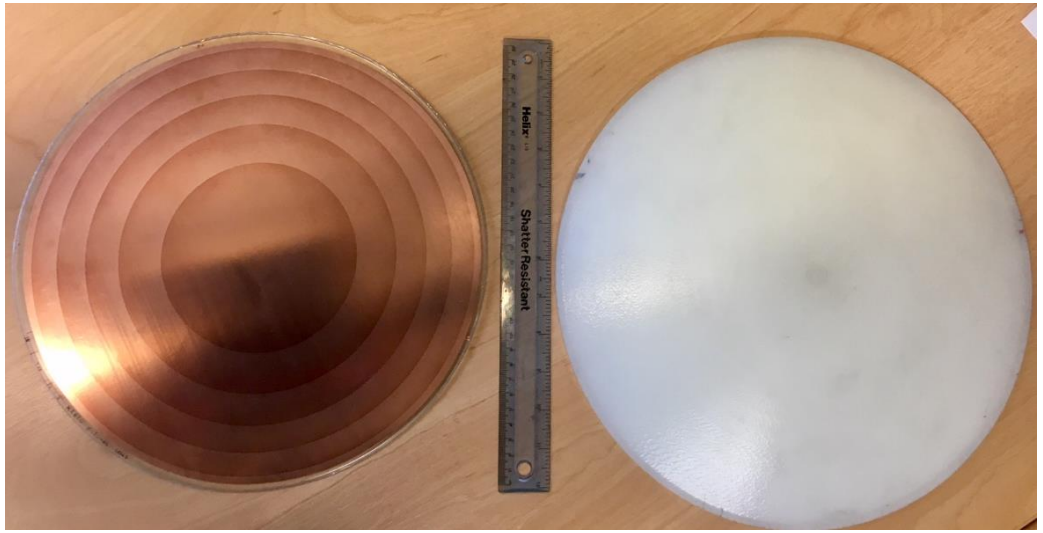
Filterbank spectrometers

- Large potenrial impact on NWP capability & climatology
- CEOI – HyMAS & HyMAS-X



Flat lenses

- Metamaterial optics – reduced mass, improved performance & capabilities of optical systems
- CEOI - MetaTel



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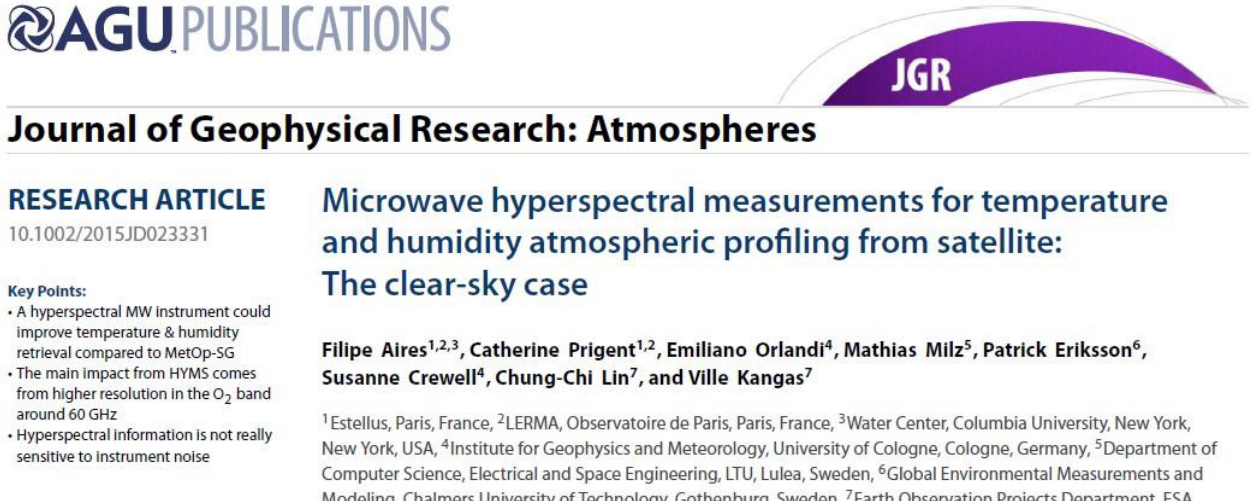
Hyperspectral microwave sounding

- Current & planned MW sounders – few channels with relatively high radiometric noise
- Hyperspectral MW sounder should have significant impact on NWP ability
  - Hypothetical instrument – "HYMS"
  - Factor of 2 reduction in retrieval uncertainty c.w. MetOp-SG
  - Several hundred channels observing major lines & continuum simultaneously
- Climatology – ice clouds in global climate system



AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2015JD023331

Key Points:

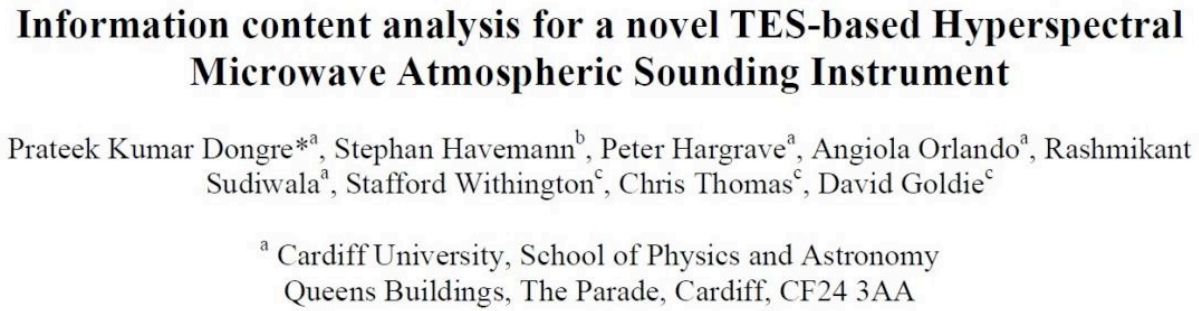
- A hyperspectral MW instrument could improve temperature & humidity retrieval compared to MetOp-SG
- The main impact from HYMS comes from higher resolution in the O_2 band around 60 GHz
- Hyperspectral information is not really sensitive to instrument noise

Microwave hyperspectral measurements for temperature and humidity atmospheric profiling from satellite: The clear-sky case

Filipe Aires[1,2,3], Catherine Prigent[1,2], Emiliano Orlandi[4], Mathias Milz[5], Patrick Eriksson[6], Susanne Crewell[4], Chung-Chi Lin[7], and Ville Kangas[7]

[1]Estellus, Paris, France, [2]LERMA, Observatoire de Paris, Paris, France, [3]Water Center, Columbia University, New York, New York, USA, [4]Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany, [5]Department of Computer Science, Electrical and Space Engineering, LTU, Lulea, Sweden, [6]Global Environmental Measurements and Modeling, Chalmers University of Technology, Gothenburg, Sweden, [7]Earth Observation Projects Department, ESA

F. Aires et al. DOI: 10.1002/2015JD023331



Information content analysis for a novel TES-based Hyperspectral Microwave Atmospheric Sounding Instrument

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Dongre et al. DOI: 10.1117/12.2500516

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Technology development under CEOI programmes

- Novel on-chip filterbank spectrometers - HyMAS
  - **Demonstration** of hyperspectral sampling in in range 50-190 GHz
  - Photon-noise-limited detection – NEP ~few x 10^{-17} $WHz^{-1/2}$
  - **Demonstrate** channel resolution of up to 1000 (nu/Dnu)
  - NEDT of ~20mK per channel for example implementation – high spatial resolution conical scan
  - Achieved by single spatial antenna coupled to filterbank, readout by superconducting Transition-Edge-Superconducting detectors.

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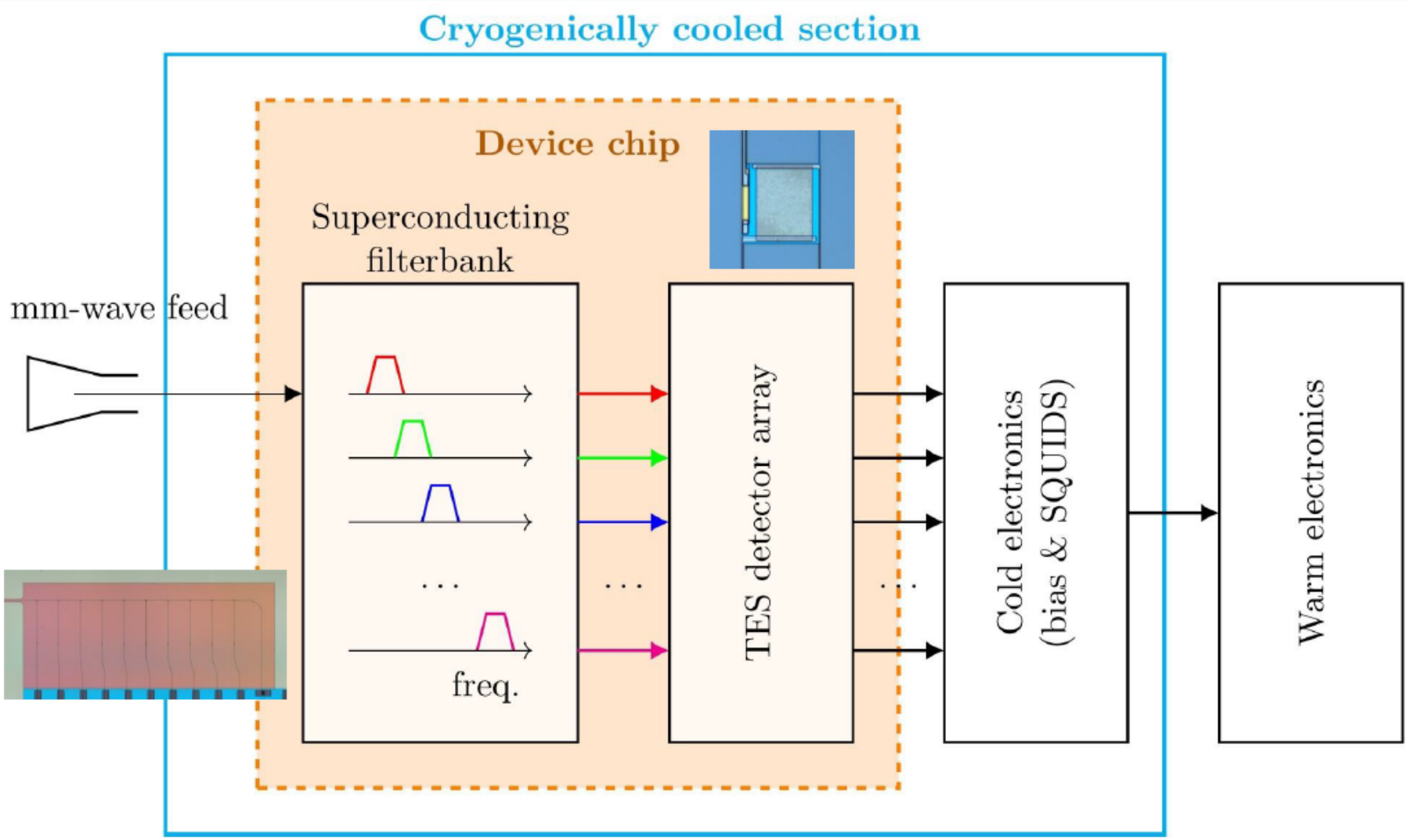
Filterbank spectrometer



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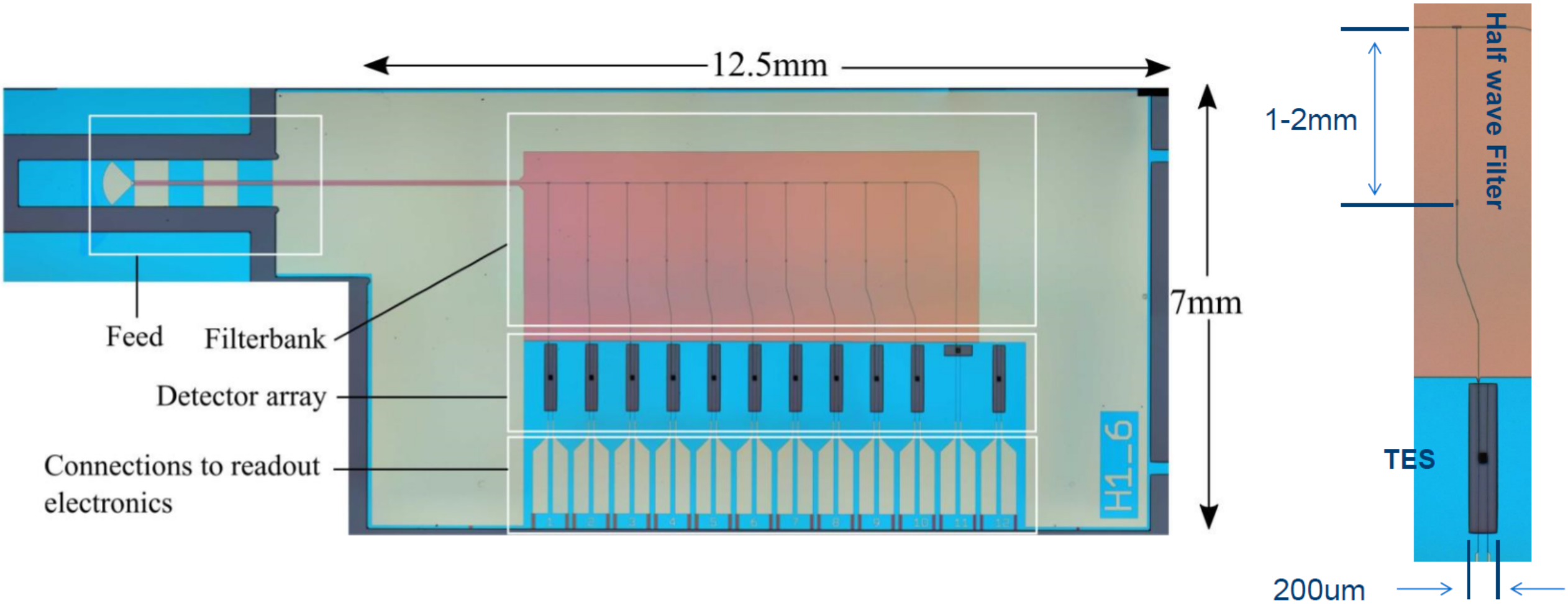
Filterbank spectrometer chip



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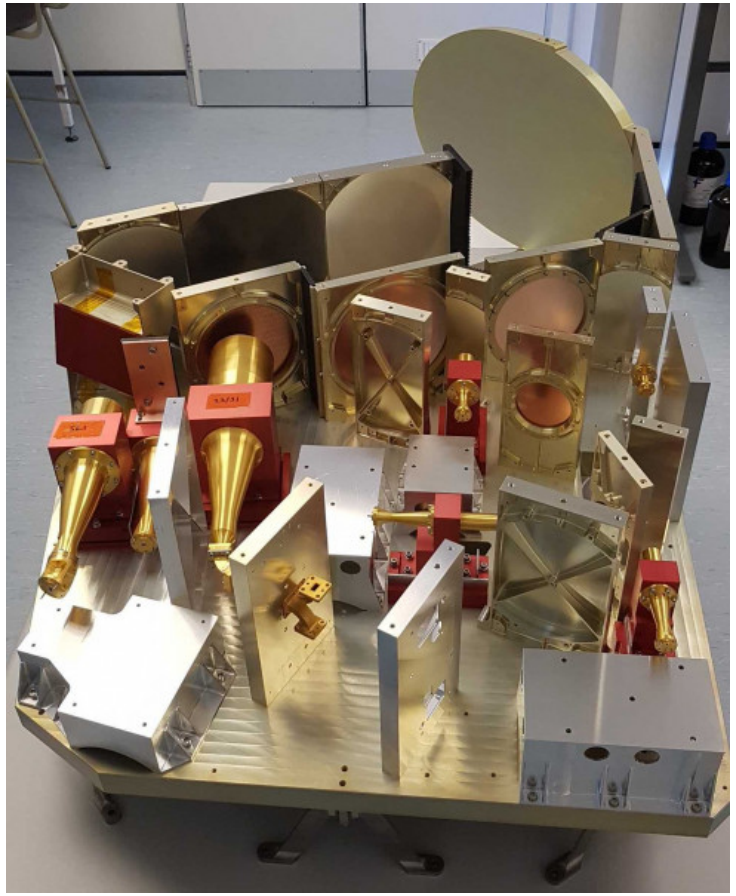
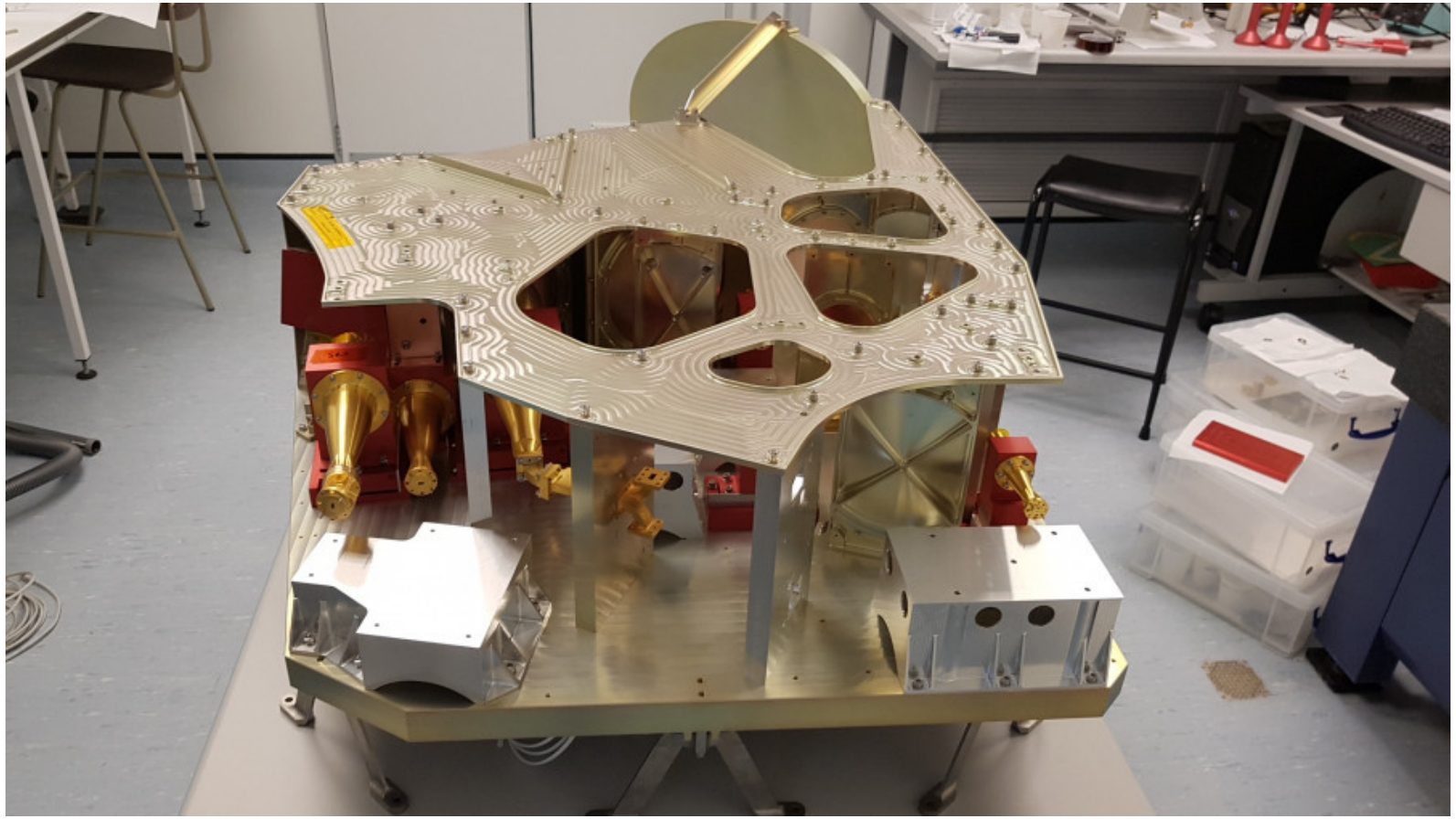
Miniaturisation…

Current state-of-the-art – MWS (MetOp-SG)





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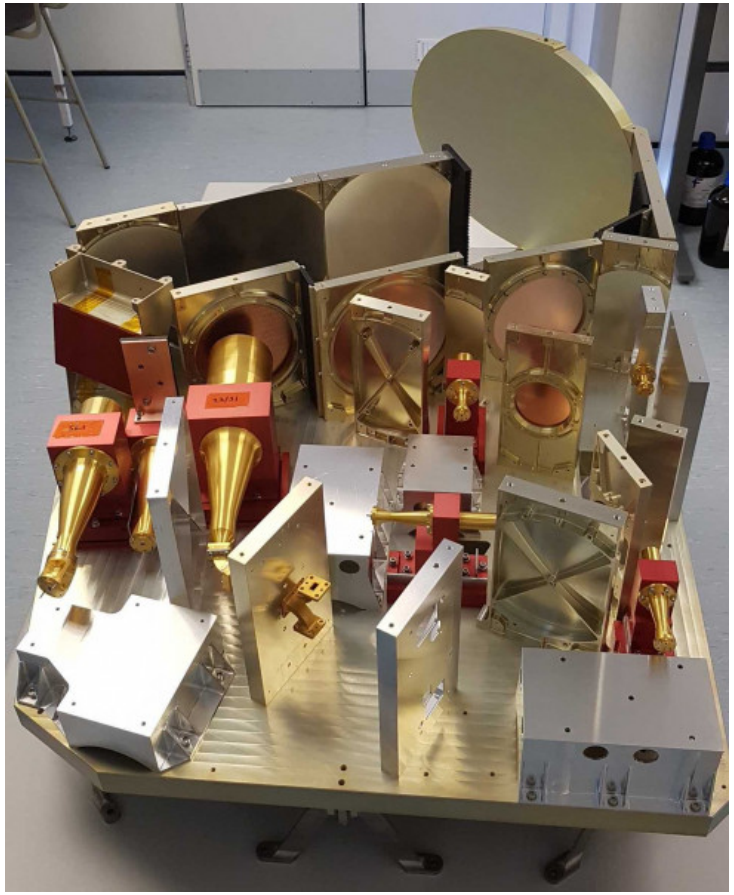
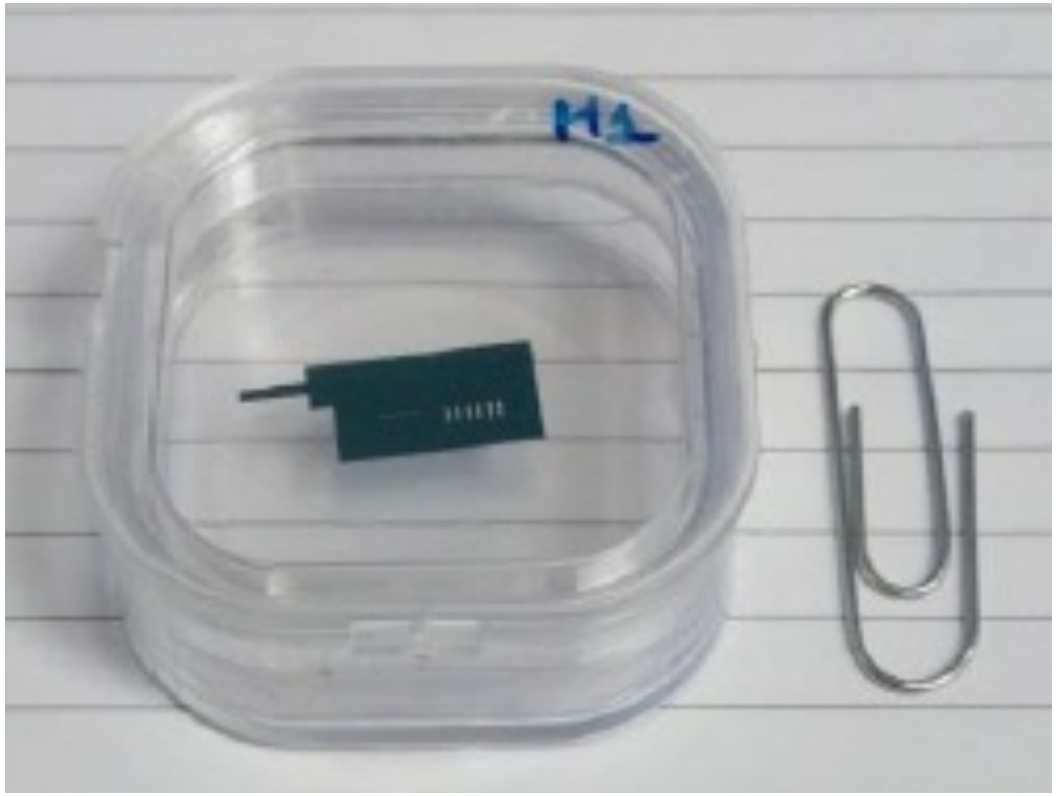


HyMAS filterbank



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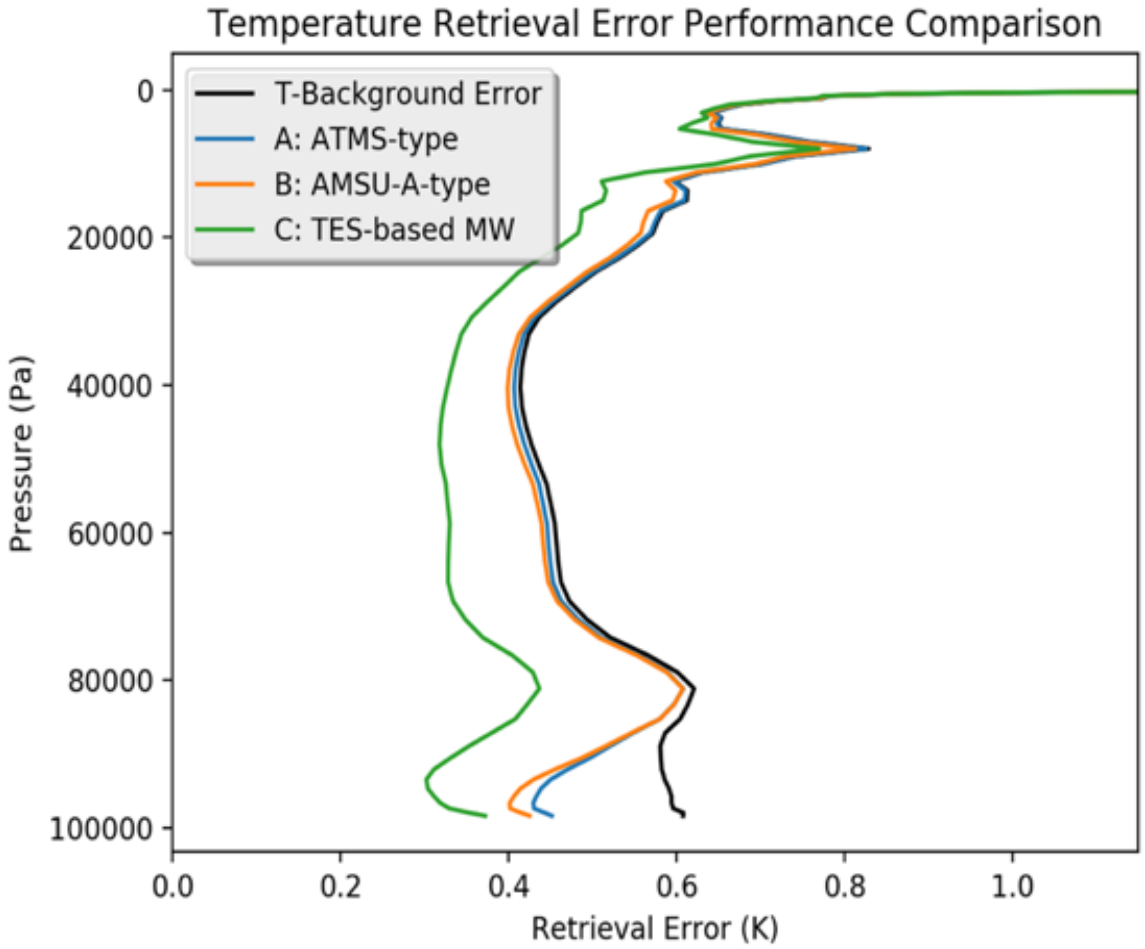
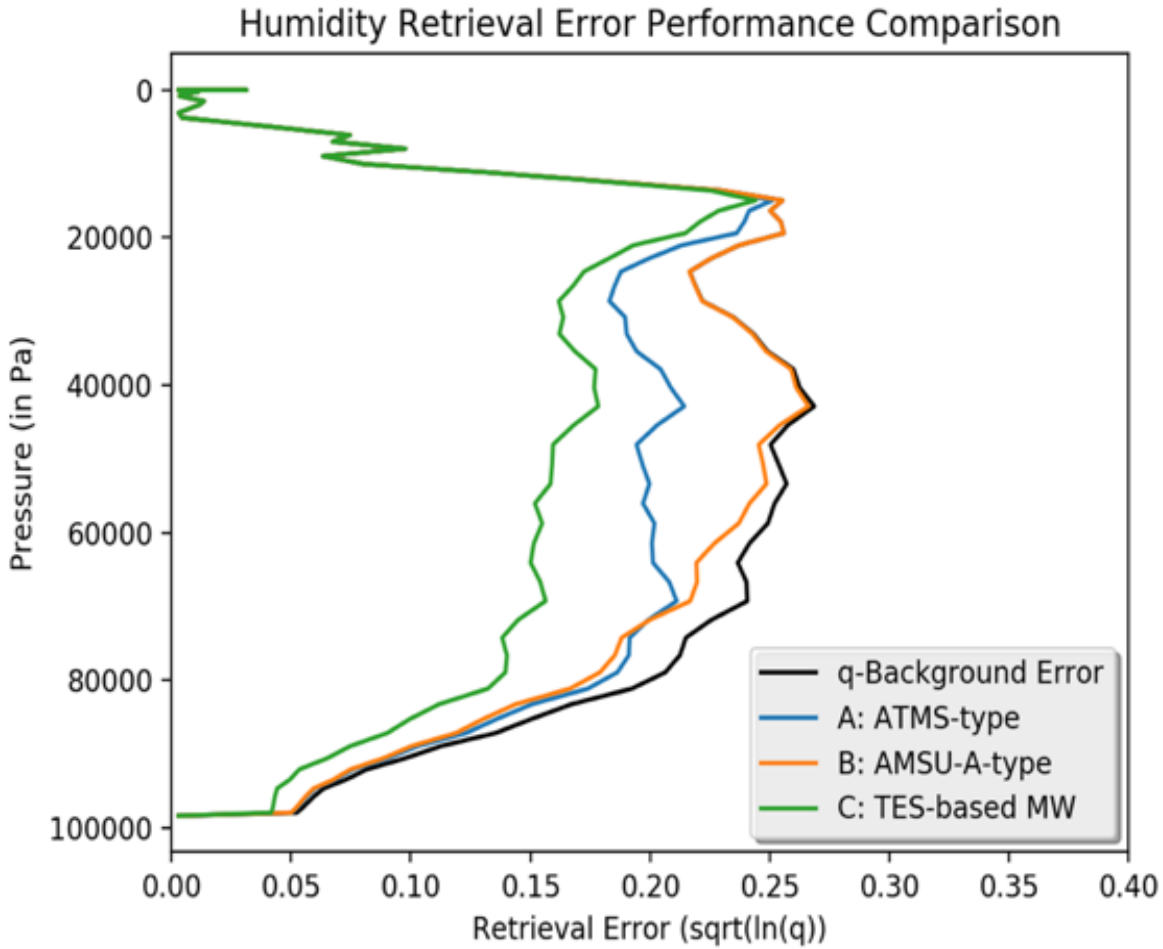
Performance predictions – HyMAS / AMSU-A / ATMS

HyMAS modelled with ATMS & AMSU-A channels, HyMAS noise (better than ~20mK per channel)





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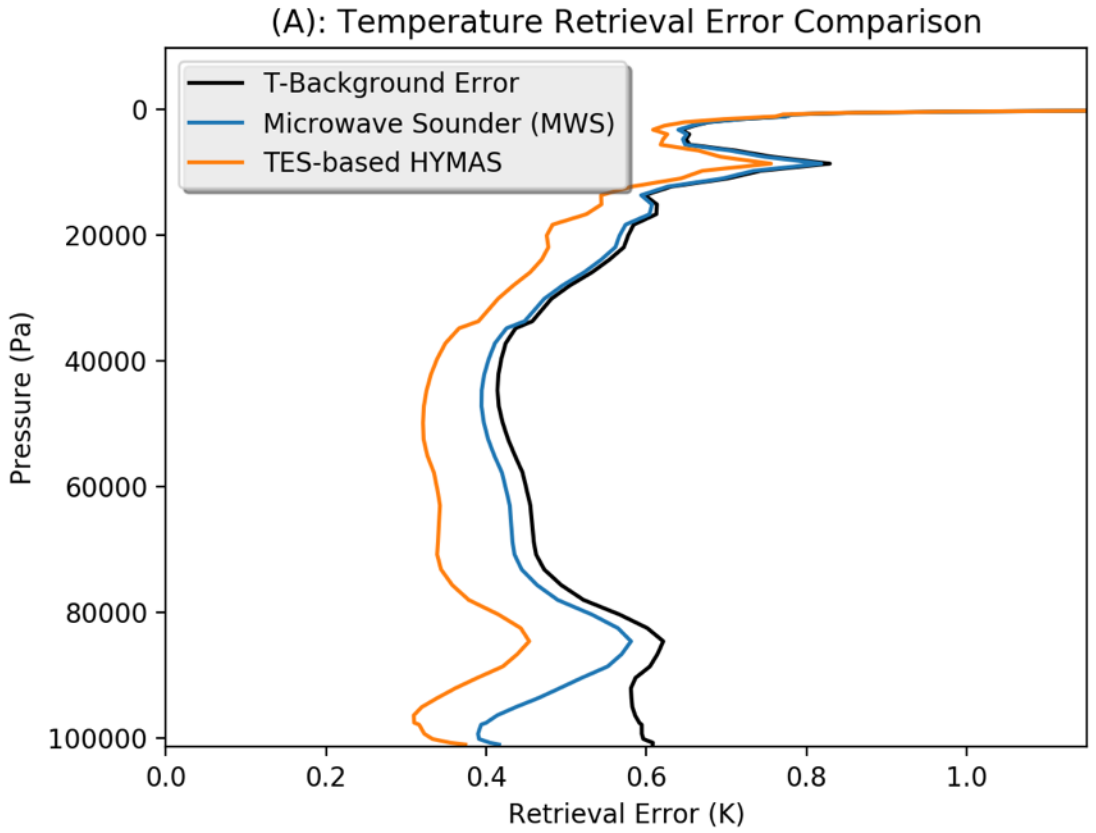
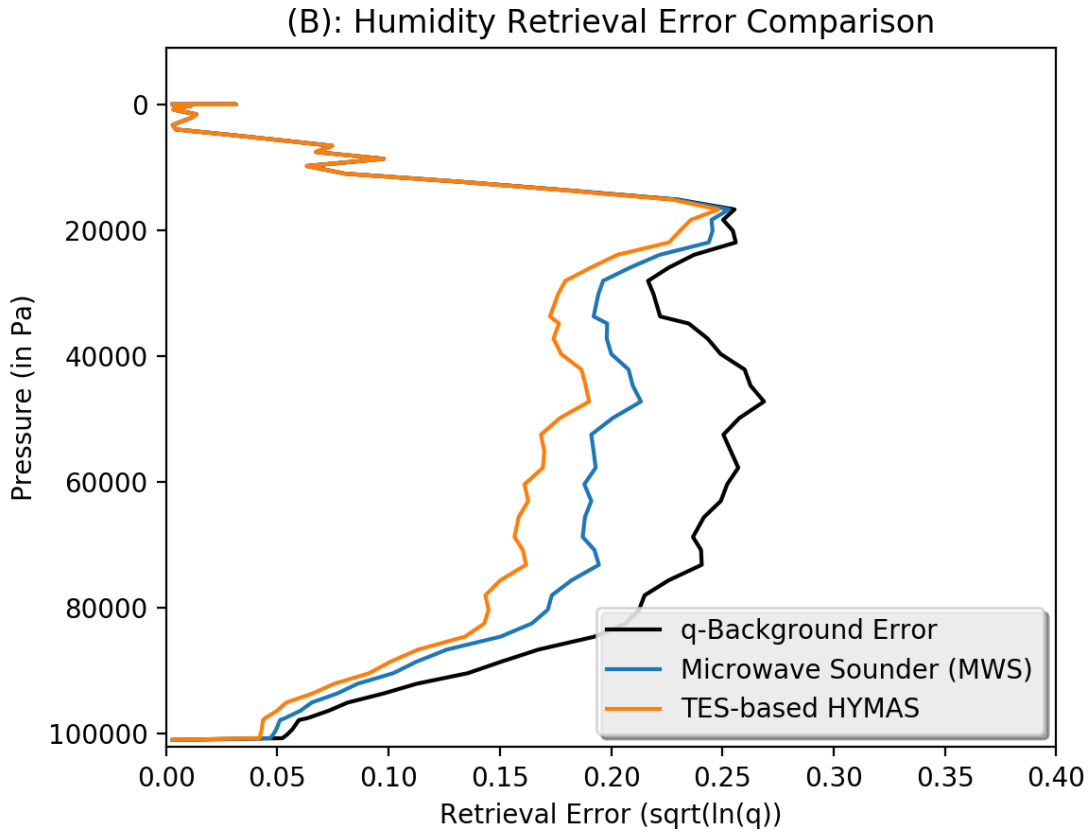
Performance predictions – HyMAS vs MWS

MWS – MetOp-SG (NEDT ~300-1800 mK)
HyMAS modelled with MWS channels, HyMAS noise (better than ~21mK per channel)





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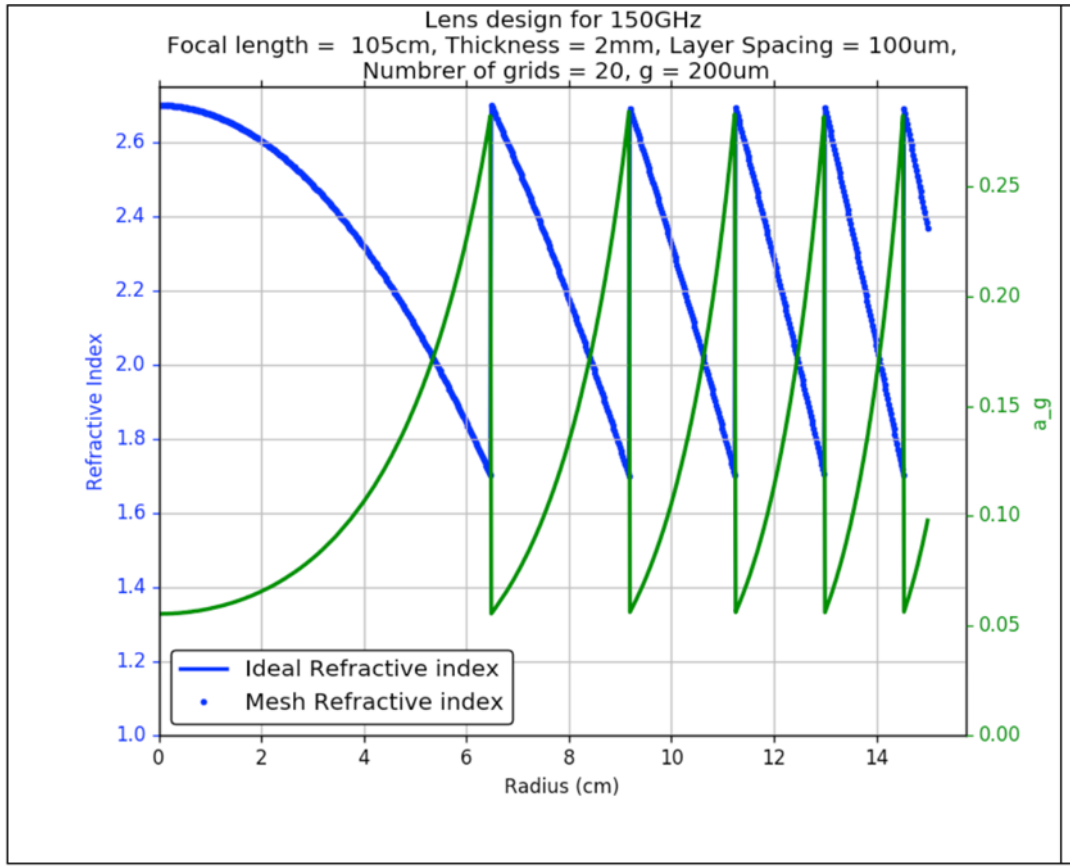
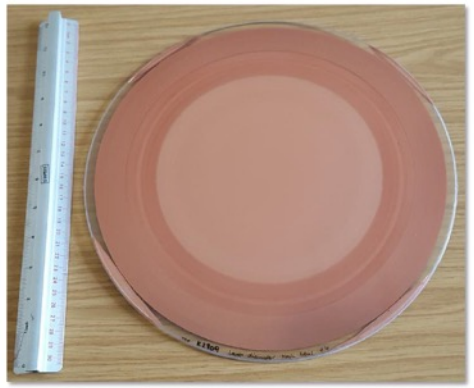
Metamaterial flat lenses and telescopes

Two approaches – GrIn and phase engineered





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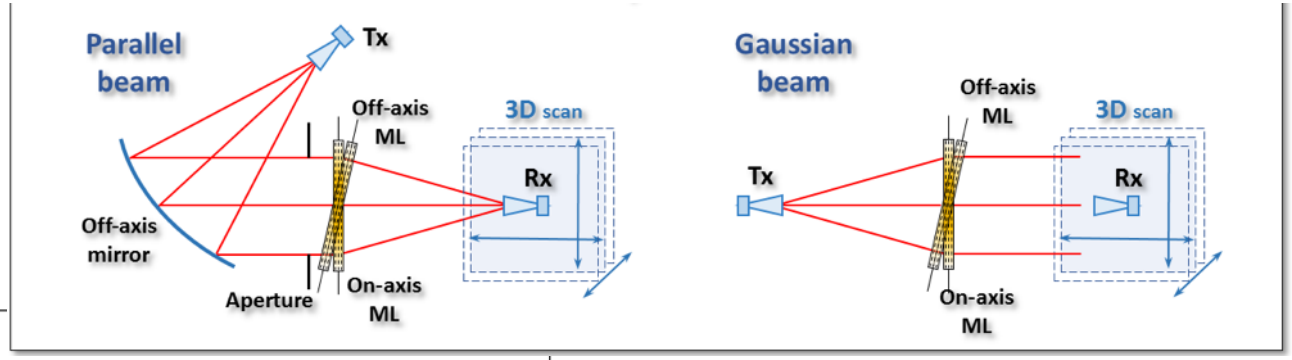
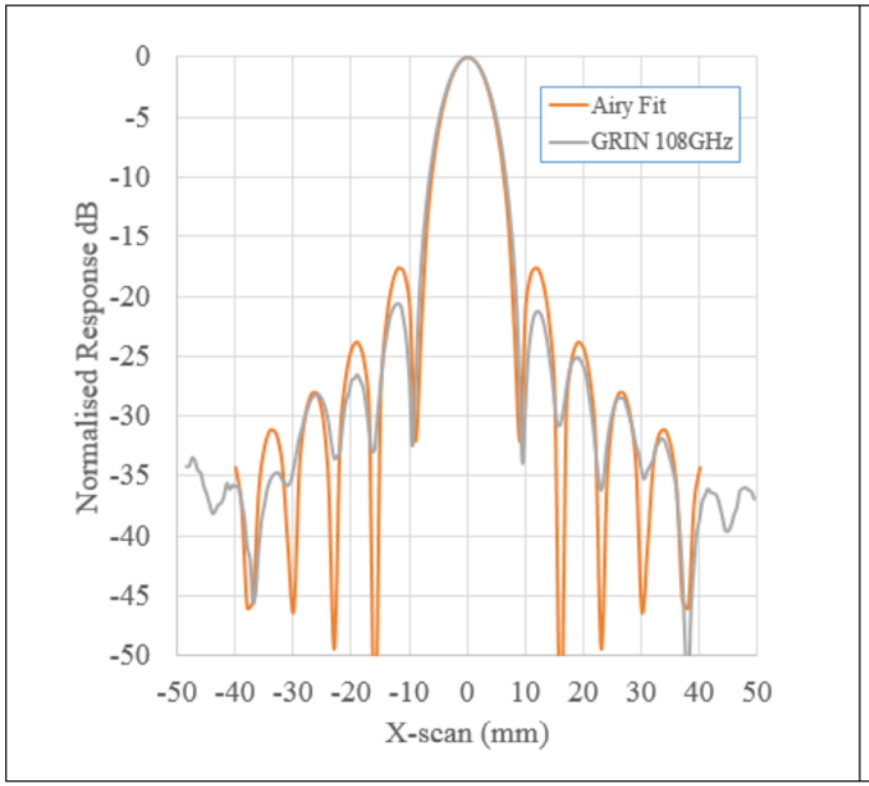
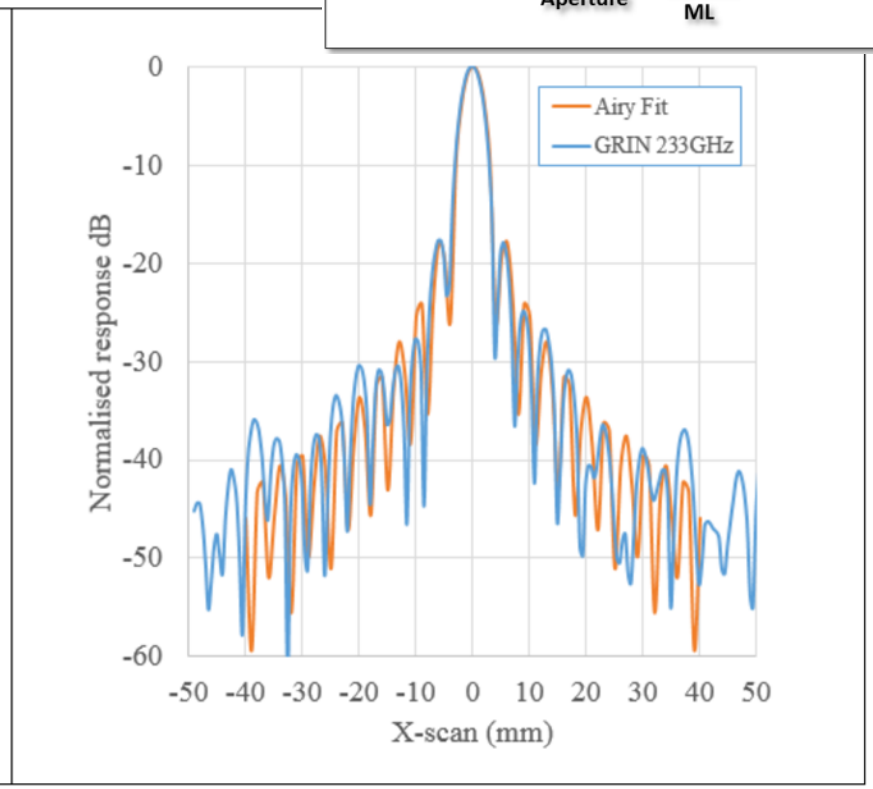
Metamaterial flat lenses and telescopes

GrIn lens performance







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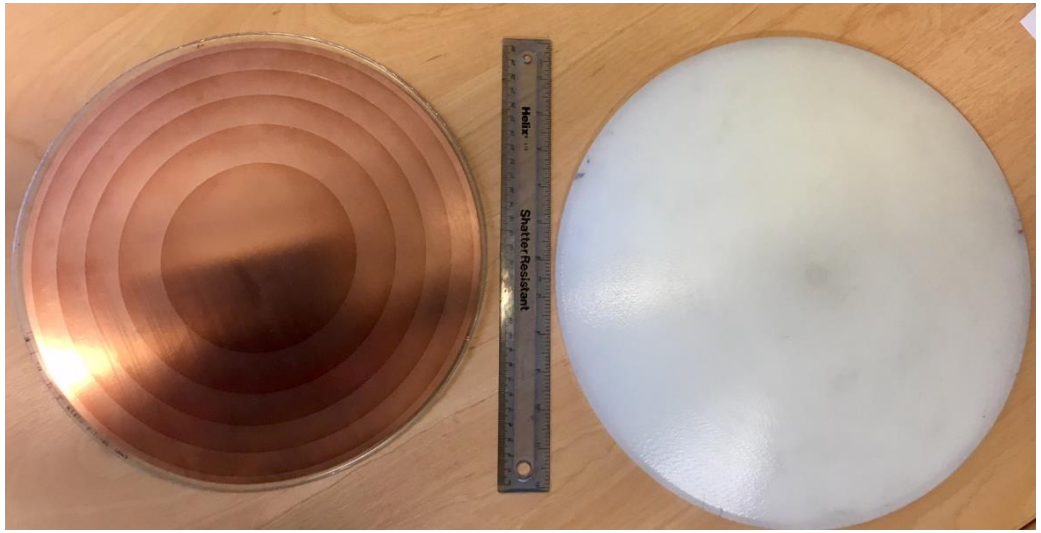
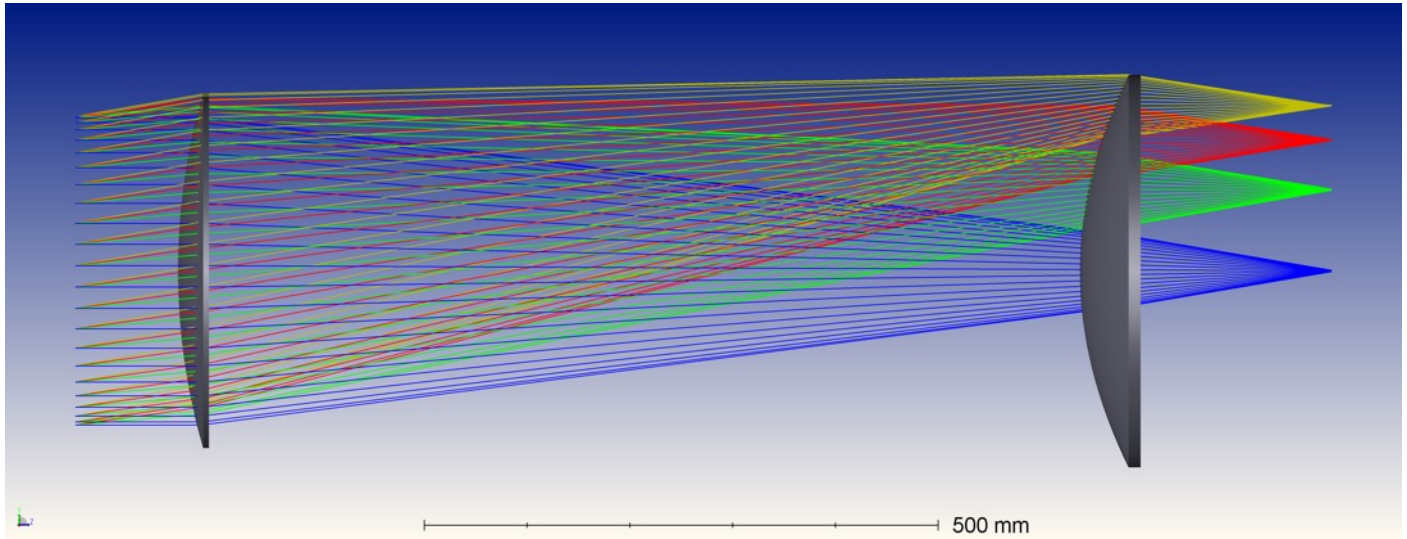
Metamaterial flat lenses and telescopes

Example:
“Traditional” lens is 40 mm thick through the centre, quite lossy, and weighs 3.5 kg. The metamaterial equivalent is flat, only 2mm thick, and weighs only 100 g, with excellent thermo-mechanical stability.

Metamaterial telescope:

- Lightweight
- Low loss
- Axial system – excellent beam quality over large, telecentric focal plane





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Predicted impacts

- Metamaterial optics
  - Ultralightweight, low-loss optical systems
  - Large focal planes – non-scanning?
  - Compact quasi-optical networks
  - Novel instrument configurations
  - Commercial applications
    - Radar absorbers
    - Compact antennas
    - …
- Filterbank spectrometers
  - Next gen. NWP and climatology mission – hundreds of photon-noise-limited channels
  - Single instrument could replace ALL 3 MetOp MW instruments (MWS, MWI, ICI), with much better resolution & accuracy
  - Commercial
    - *Characterisation* of hidden threats for THz security scanners

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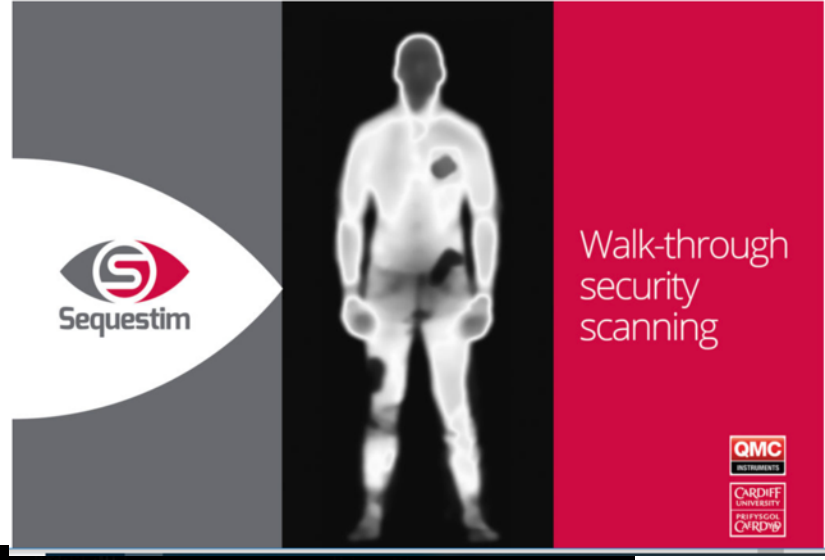
Predicted impacts



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