UK Technology Development for Spaceborne Atmospheric Limb-Sounding Missions

Brian Moyna (RAL)

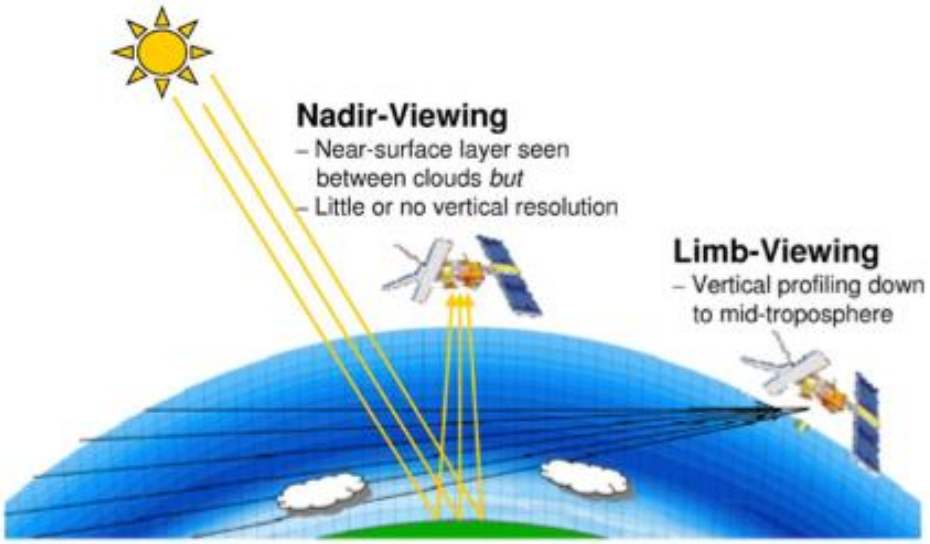
RAL Space

Outline

- Introduction: limb–sounding technique
- ALiSS
- MM-wave receiver technology
- SHIRM
- Complete breadboard radiometer
- WBS-II
- Deployment on JFJ
- Micro FTS
- Airborne Demonstration – StratoClim 2016
- Summary

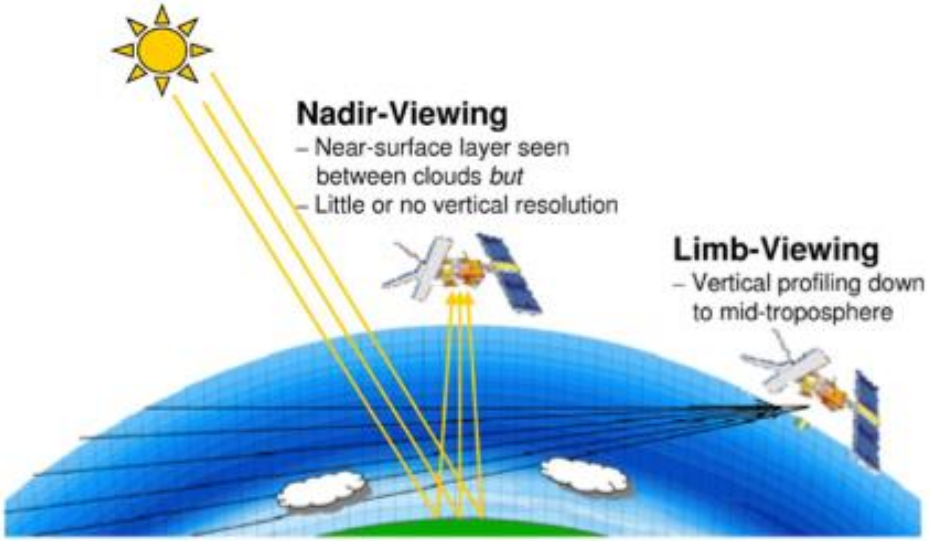
Limb Sounding Technique

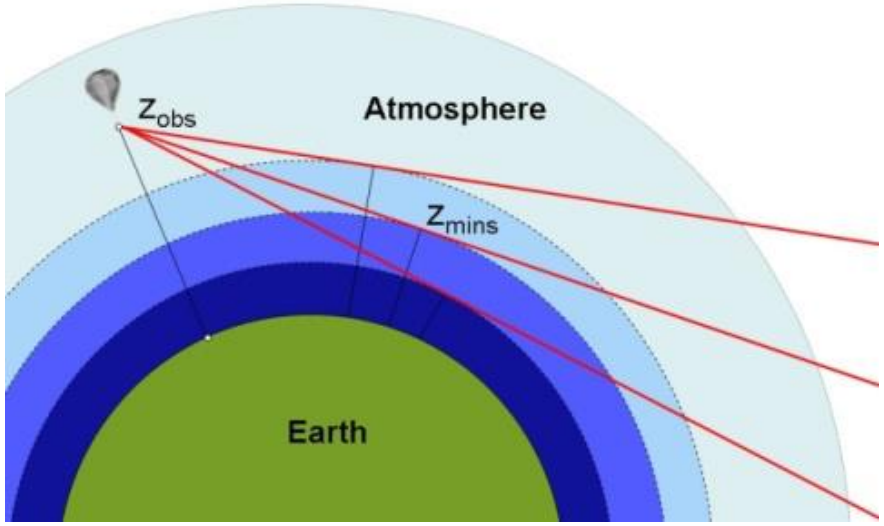
- Limb sounding gives much higher vertical resolution than nadir sounding, but its line of sight is often obstructed by clouds below the mid-troposphere.



Limb Sounding Technique

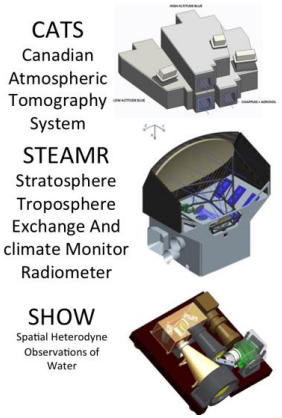
- Limb sounding gives much higher vertical resolution than nadir sounding, but its line of sight is often obstructed by clouds below the mid-troposphere.
- The atmospheric layer at the tangent point contributes most of the atmospheric signal.
- The tangent point of the line of sight moves towards the observer for higher scan angles.





ALiSS:
Atmospheric Limb Sounding Small satellite

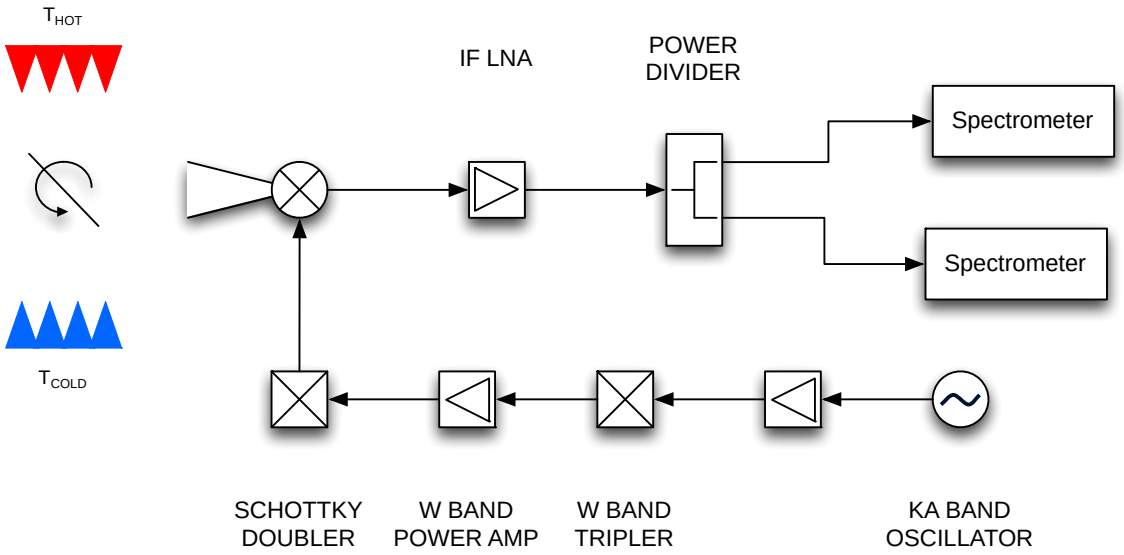
- ALiSS will provide high vertical and horizontal resolution measurements of the Upper Troposphere / Lower Stratosphere region (UT/LS) to specifically address the looming gap in limb profiling data for science and, in near real time, for operational systems



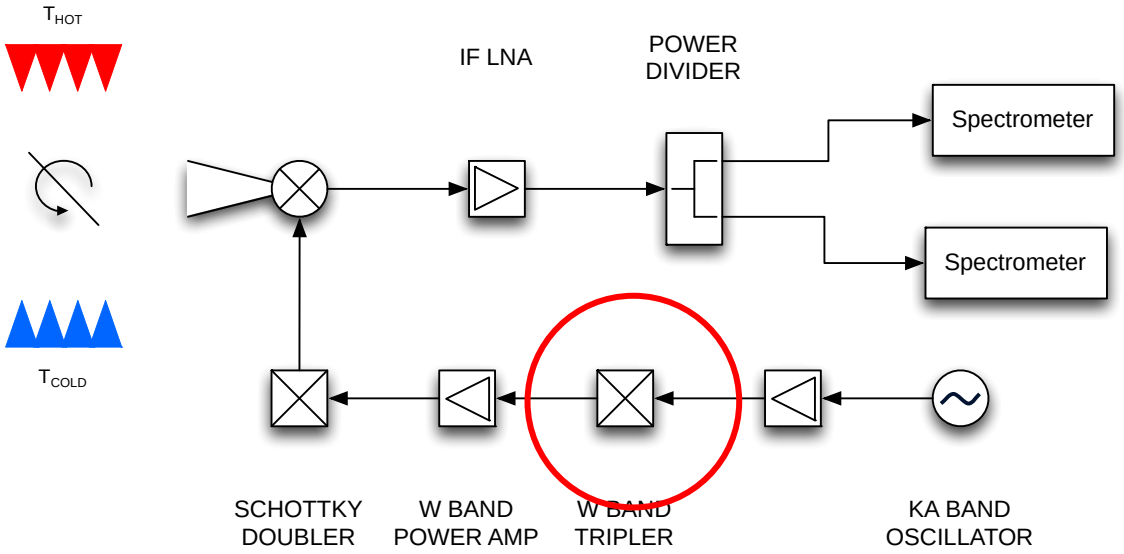
Instrument	Mass	Power
CATS	25 kg	20W
STEAMR	65 kg (Mini-STEAMR)	150W (Mini-STEAMR)
SHOW (optional)	25 kg	20W

- A unique contribution of STEAMR will be to extend the ALiSS measurement range into the UT, including convective regions important to troposphere-stratosphere exchange e.g. the Asian Monsoon region, where cirrus clouds are ubiquitous
  - Clouds opaque to IR, transparent at mm-wave
  - Sideband-separating SHIRM mixers, a high priority option from the PREMIER study, will improve the accuracy of trace gas retrievals in the UT by minimizing spectral confusion and allowing the spectral dependence of *continua* to be determined

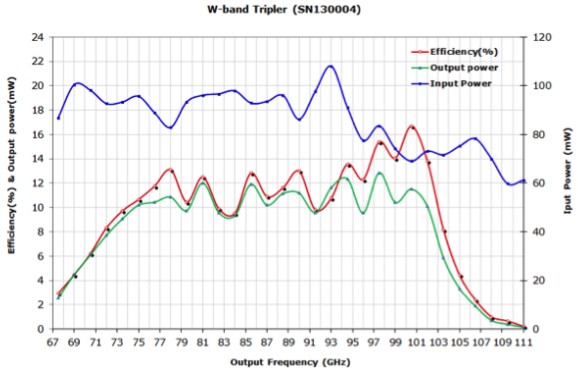
Mm-wave Receiver Technology



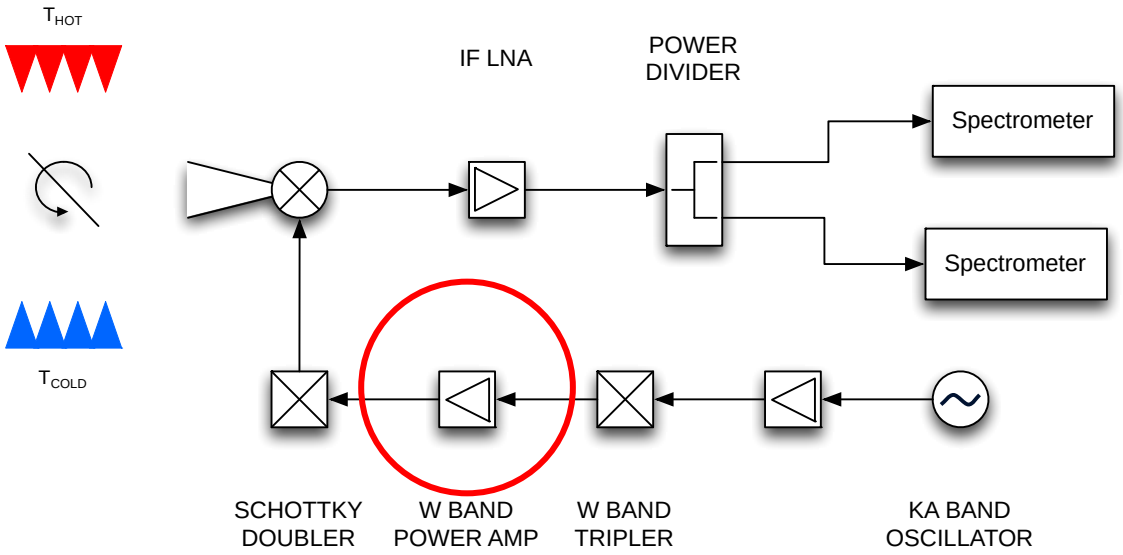
Mm-wave Receiver Technology

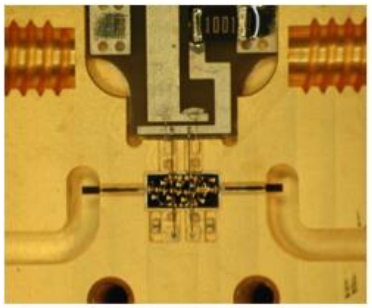


- Pin: 60-110mW
- Max efficiency ~16%
- 5mW/7dBm output: 70-104 GHz

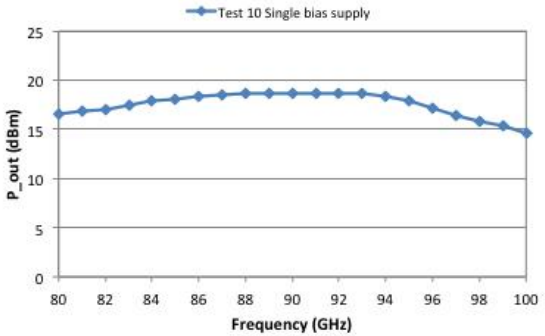


Mm-wave Receiver Technology



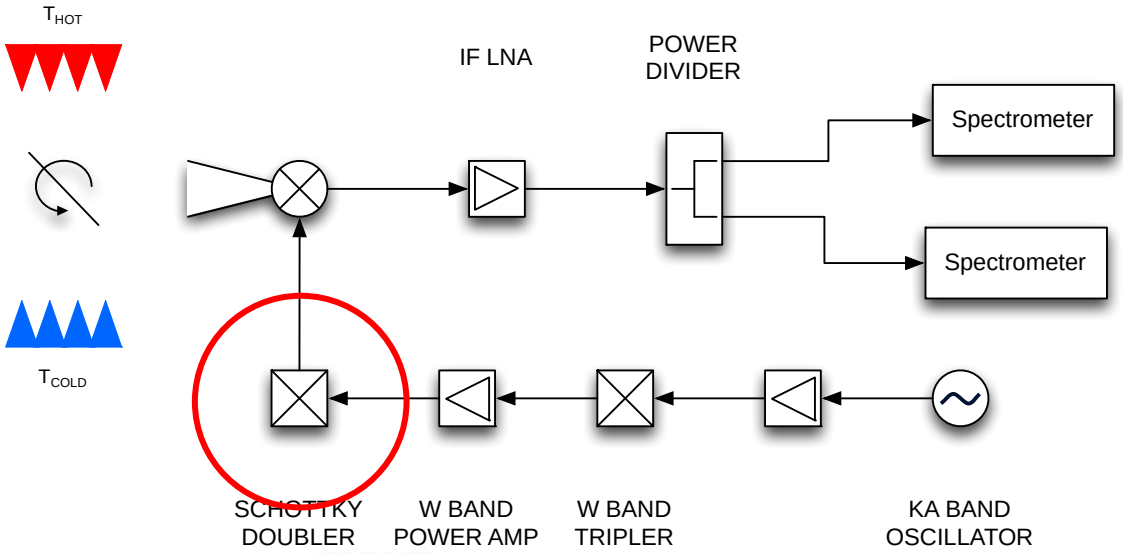


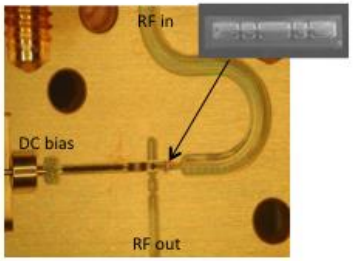
W-Band Power amplifier chip packaged at RAL



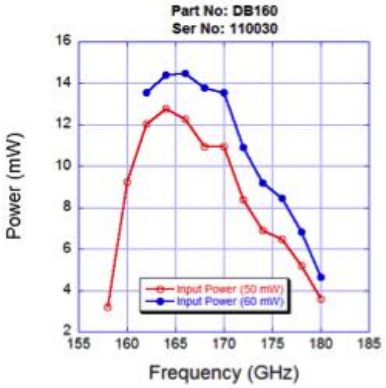
Saturated Output Power

Mm-wave Receiver Technology



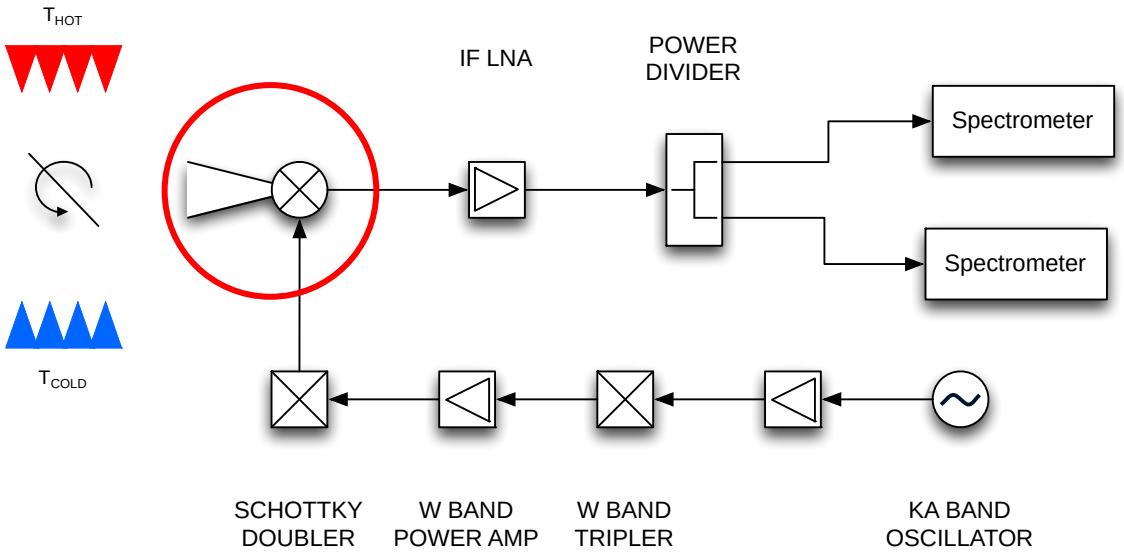


RAL 160-180 GHz Schottky Doubler



Output Power

Mm-wave Receiver Technology

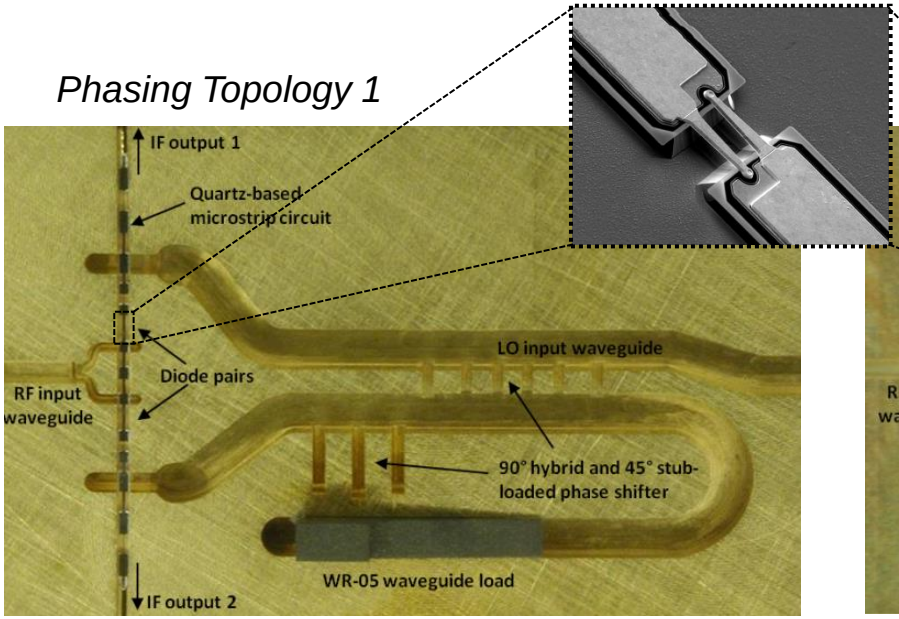


SHIRM: Sub-Harmonic Image-Rejection Mixer

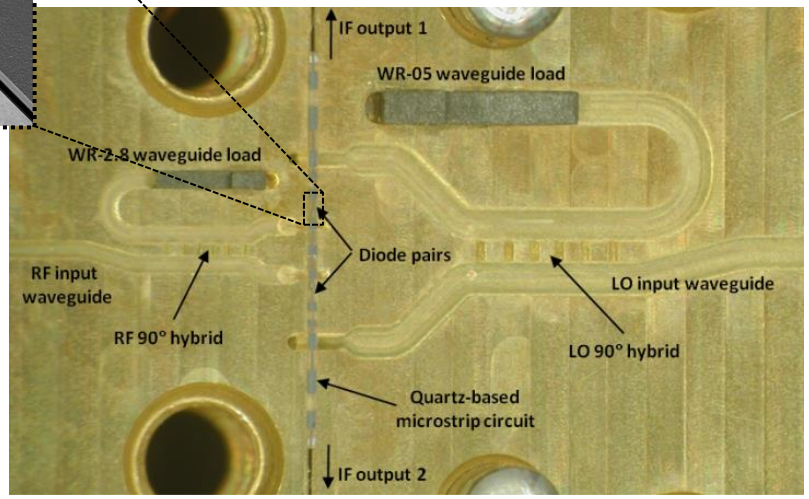
- SHIRM Optimised performance
  - Sideband rejection: 15 dB min. (>20 dB nom.), IF BW = 2-14 GHz
  - SSB receiver noise temperature: ~3000 K

- Devices employ planar Schottky diode technology from RAL Space

Phasing Topology 1

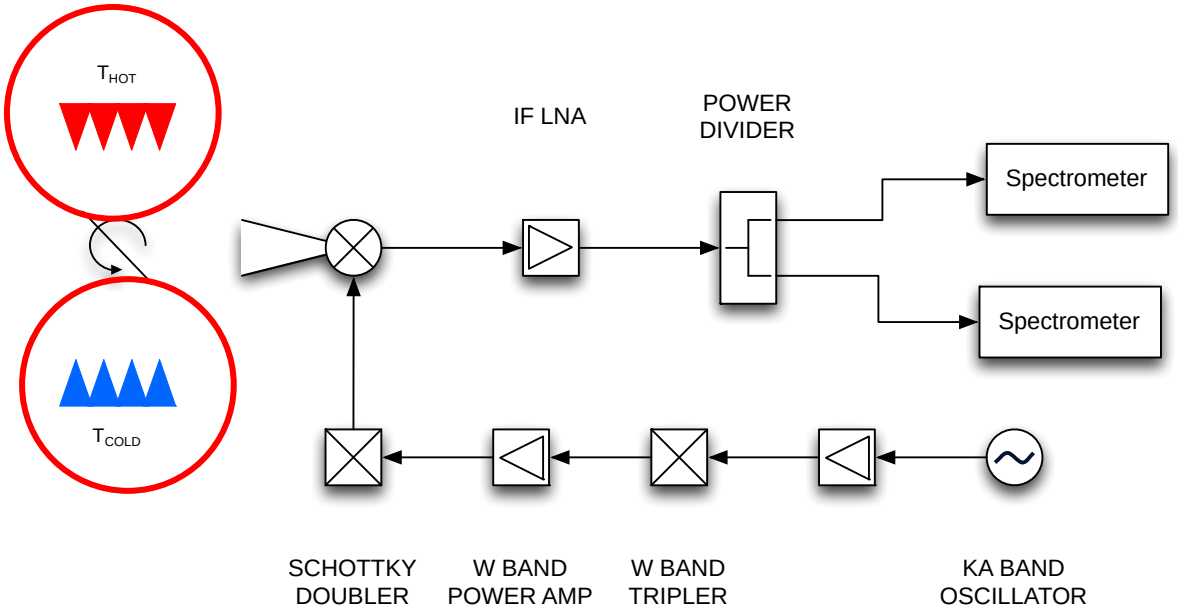


Phasing Topology 2

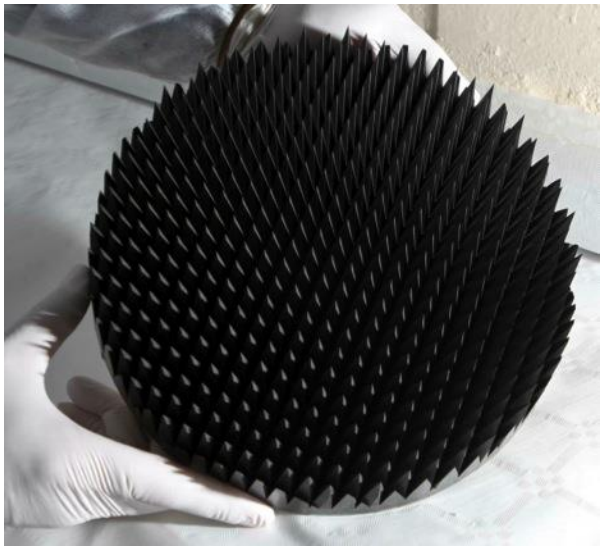


SHIRM development at RAL, Astrium, supported by CEOI

Mm-wave Receiver Technology



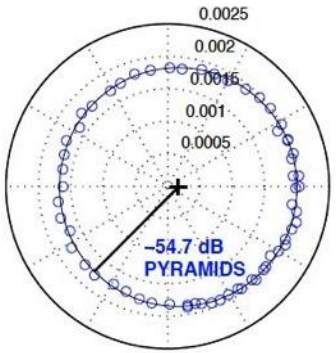
Technology – Calibration Targets



245mm diameter mg-alloy-cored calibration load for ISMAR airborne radiometer

- Metal-cored black body calibration loads for radiometer calibration:
  - Ground-based (ALMA)
  - Airborne (MARSCHALS, ISMAR)
  - Space
  - Lightweight aluminium or magnesium alloy core
  - Wide temperature range 77-370k

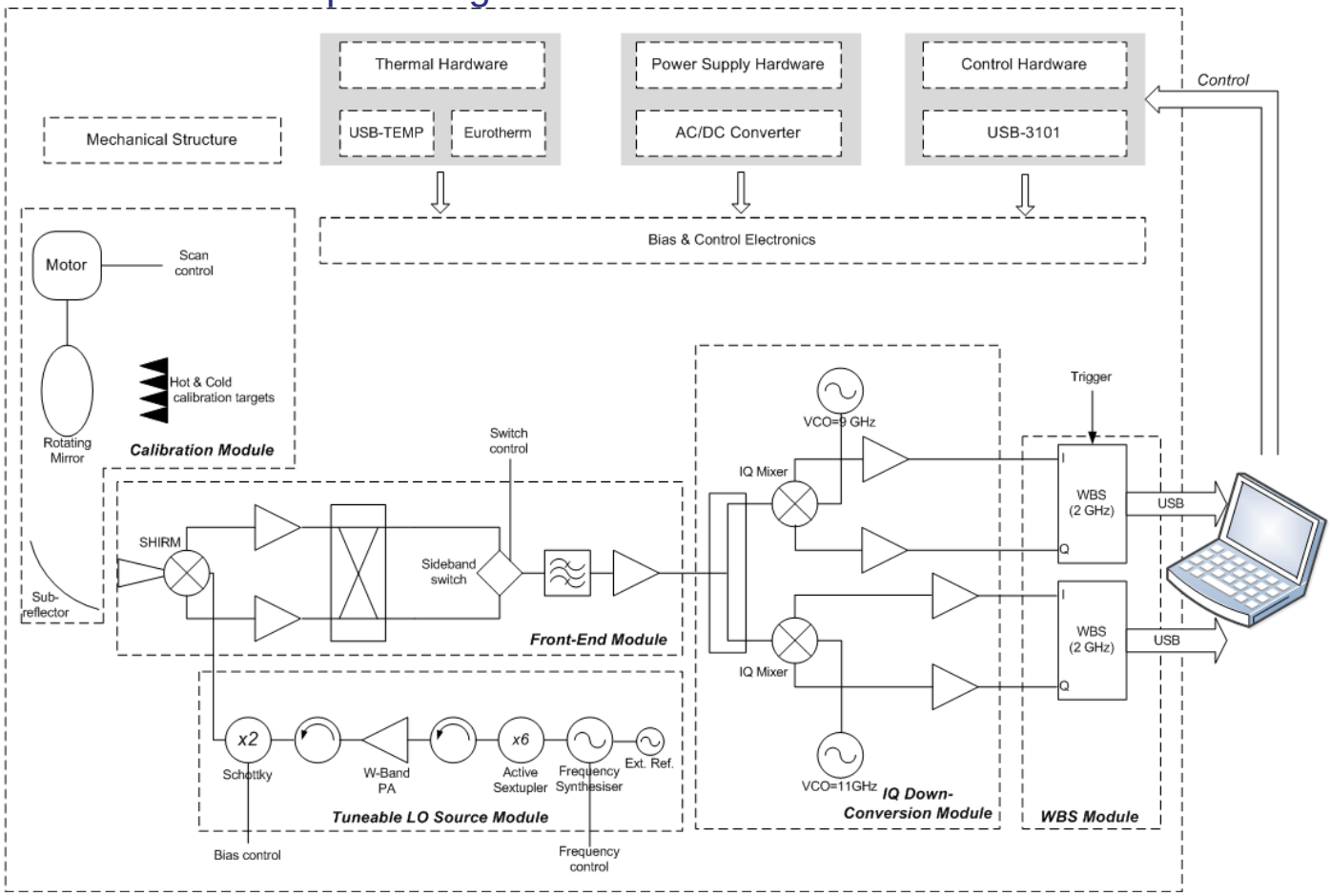
- Wideband performance
  - Typically better than 50dB return loss from 100GHz to at least 700GHz
  - Can be optimised for other frequency ranges



Return Loss of ALMA prototype load at 600GHz

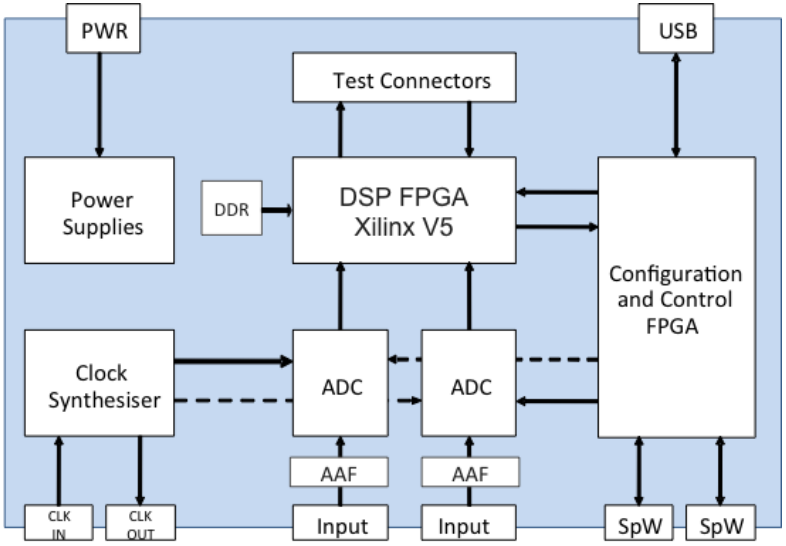
Breadboard Sideband-Separating High Resolution Radiometer (CEOI 5th Call)

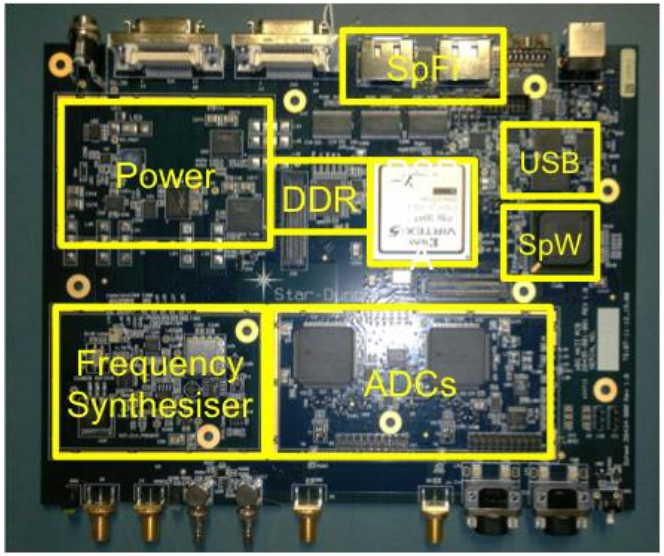
- Development of total-power radiometer comprising
  - 340 GHz sideband-separating receiver
  - 2x WBS II units providing 4 GHz bandwidth



Wideband Spectrometer II
STAR Dundee

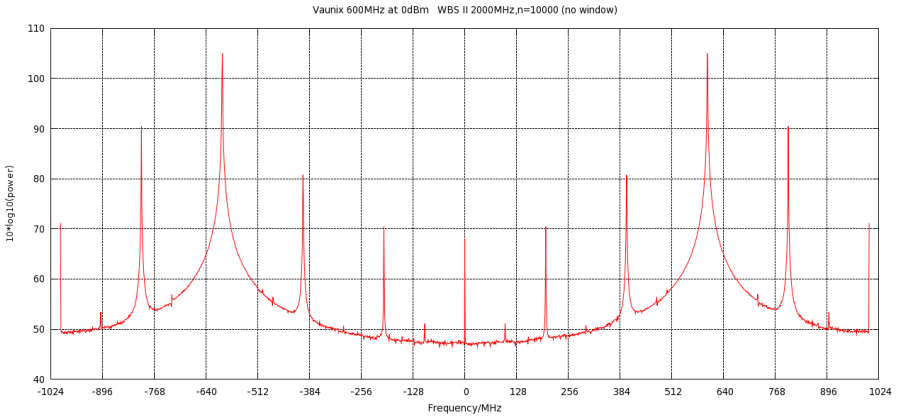
- Two ADCs sampling at 3 Gsamples/s
  - I & Q sampling
  - Resulting signal bandwidth > 2 GHz
- Custom Fast Fourier Transform (FFT) chip design
  - Windowing
  - 2048 point complex FFT at 3 Gsamples/s
    ~ 1.5 MHz resolution
  - Power detection and accumulation
  - Zero dead-time between data acquisitions





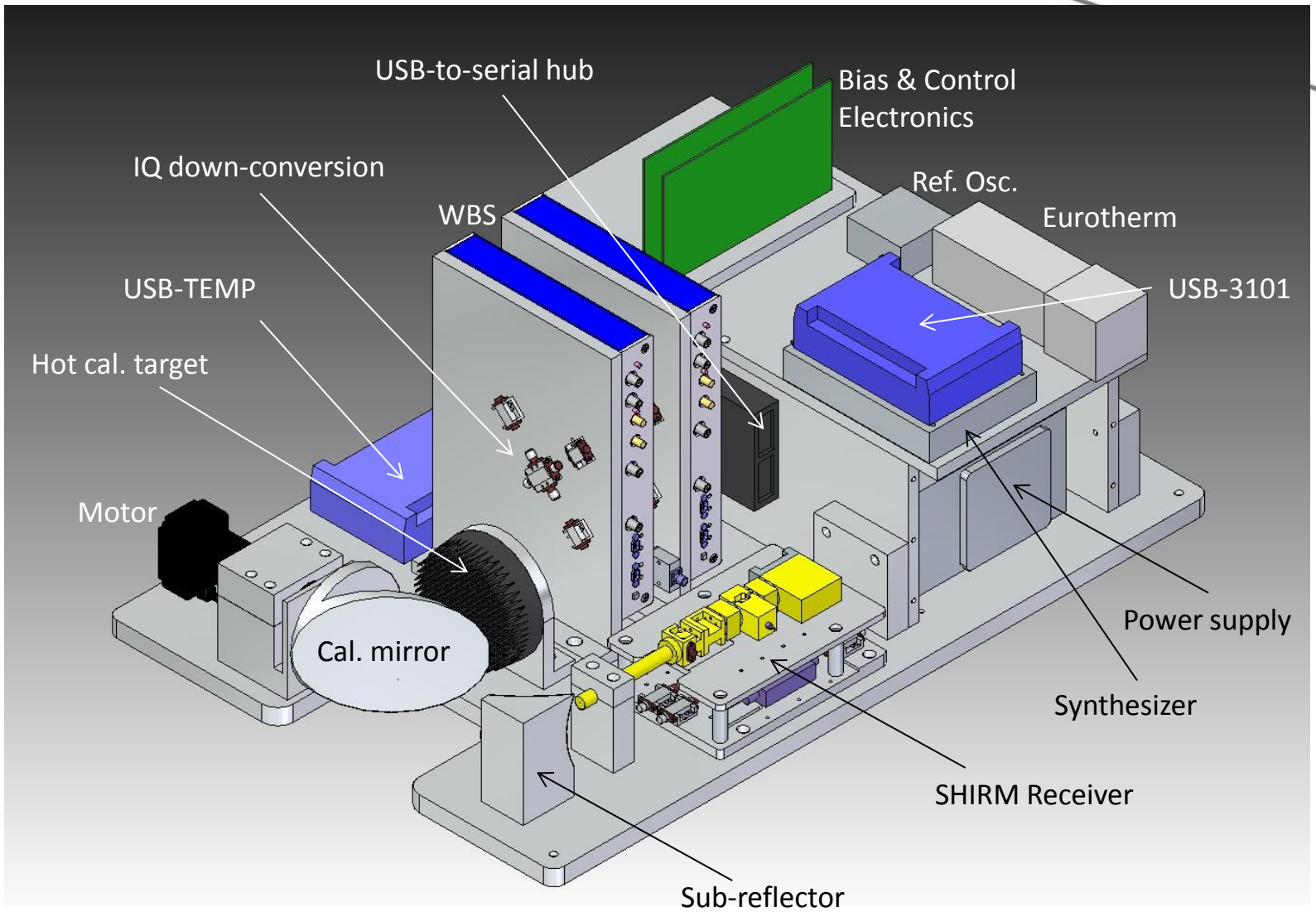
Wideband Spectrometer II

Dimensions
L= 165 mm
W= 220 mm
H= 30 mm

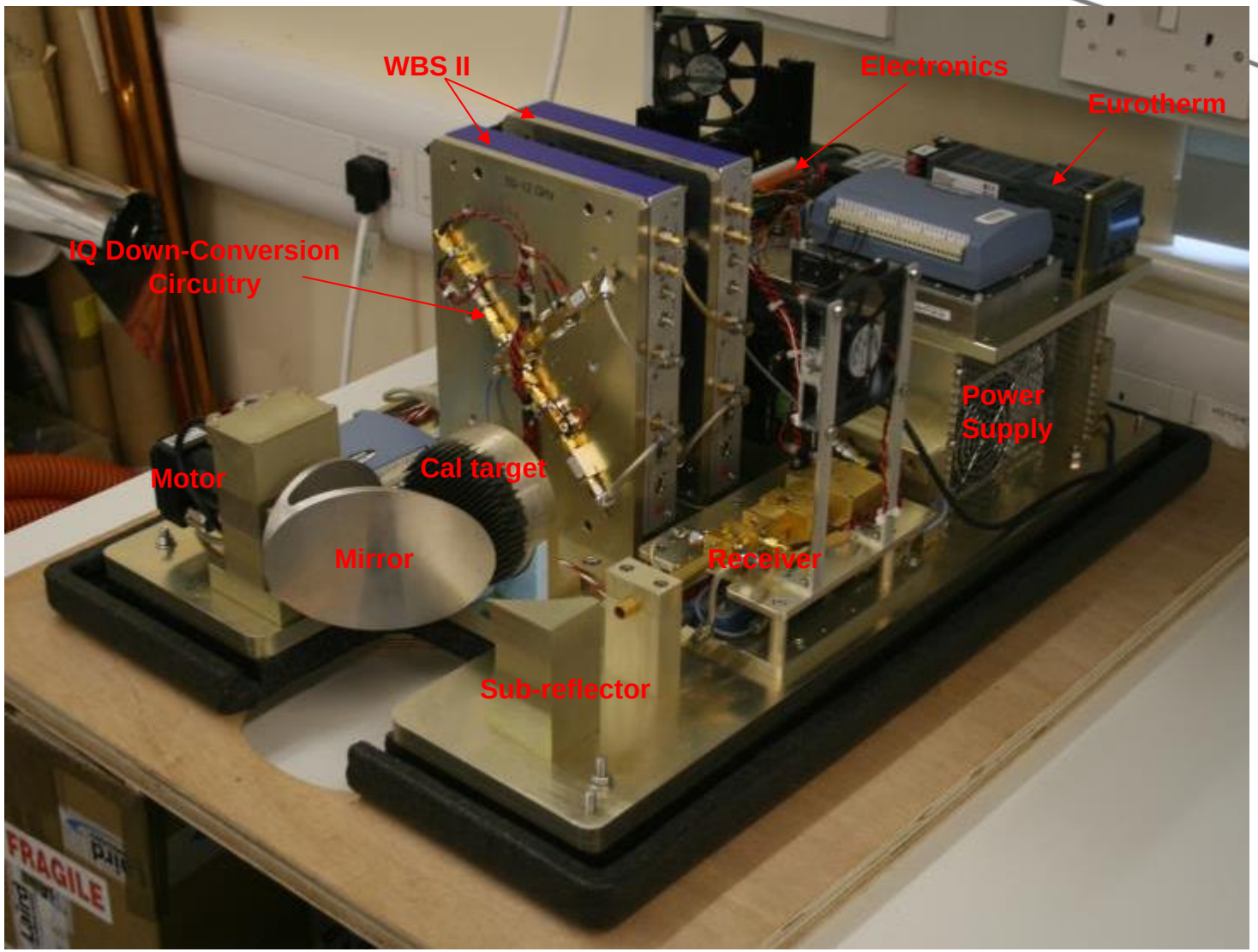


Signal fed into I input, Q input = 0
Averaged for 10,000 spectra
Primary signal at 600 MHz (spurs at ~200, 400 & 800)
Clock breakthrough is low (@ 100 MHz)

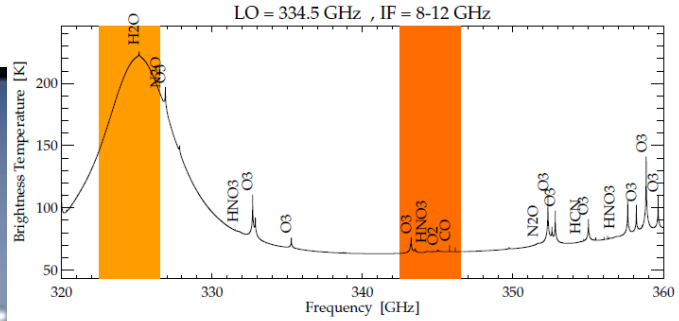
Instrument CAD Model

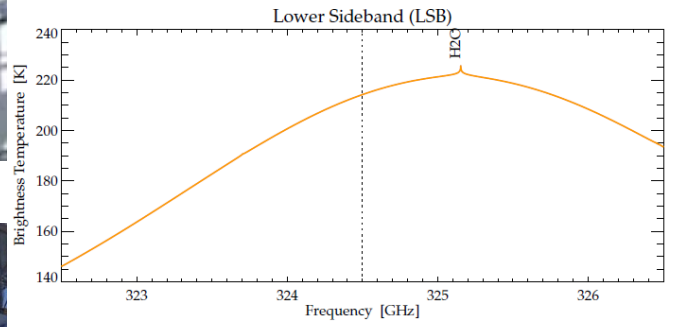


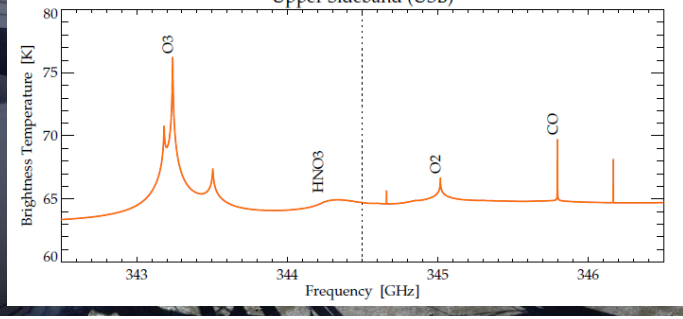
Complete Instrument

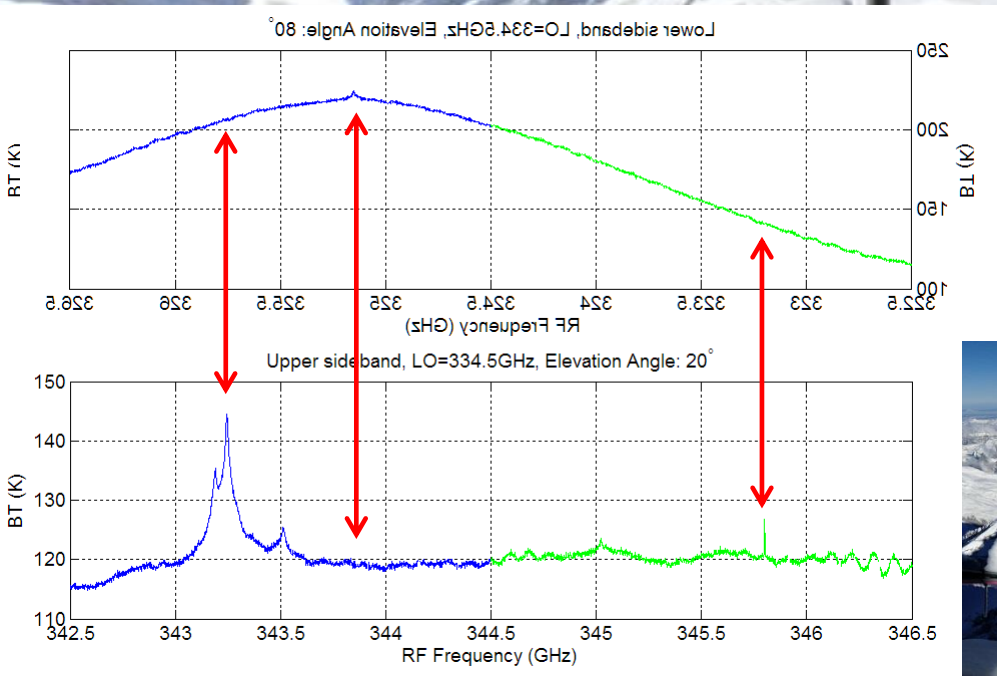


Field-Test of SHIRM Receiver at Jungfraujoch (3.5 km)









The microFTS:
Miniature Fourier Transform Spectrometer.

Low mass, low power, imaging Fourier Transform Spectrometer (FTS) with no moving components

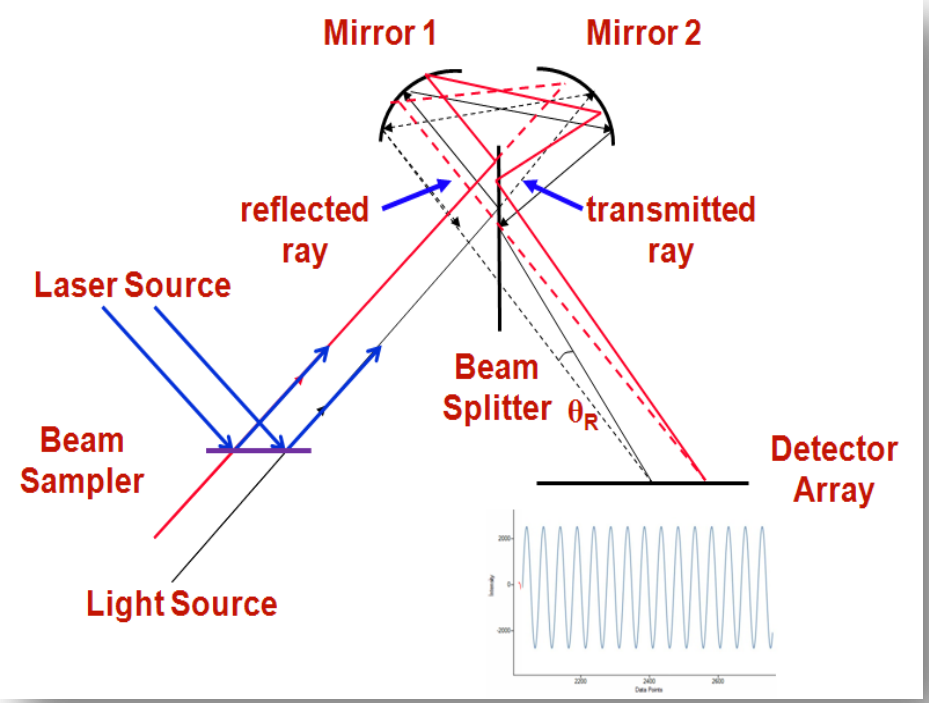
.

•Spectral performance:
  2 to 20µm @ 16cm^{-1} FWHM
  200 to 1100nm @ 0.5nm FWHM

•Low mass spectrometer: 1.56kg

•Compact: 350 x 300 x 50mm

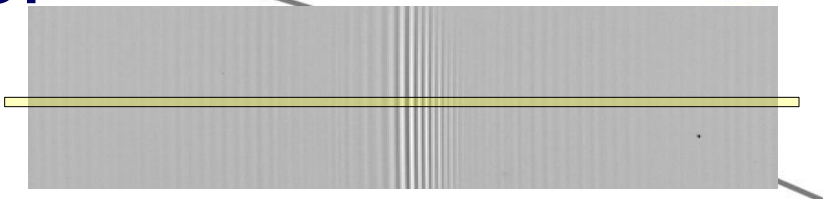
•Low power:0.5mW (average)



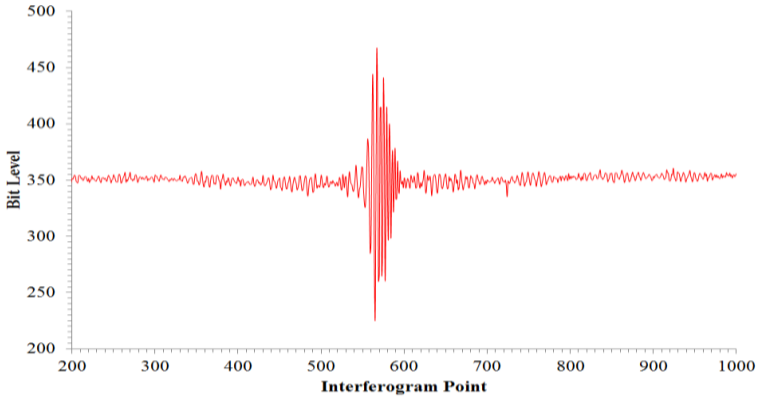
The microFTS operational principle

MicroFTS spectrometer

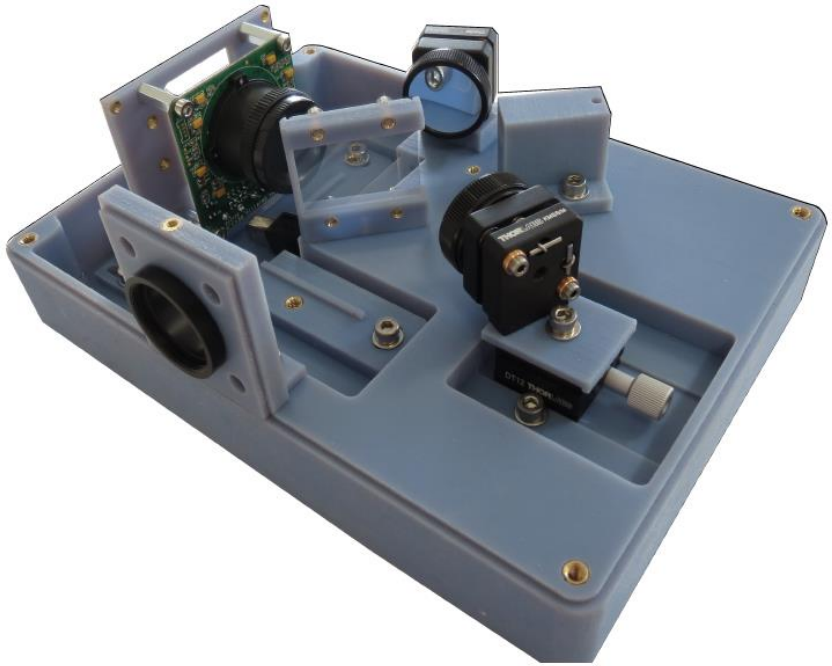
The microFTS is limited by the detection limits of the detector array used. The microFTS has been demonstrated in the UV, Visible, NIR, Mid and Far IR.



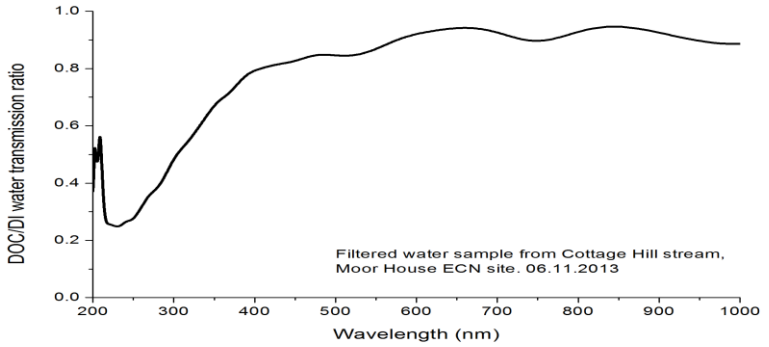
2D Image of Interferogram



Single Interferogram Line



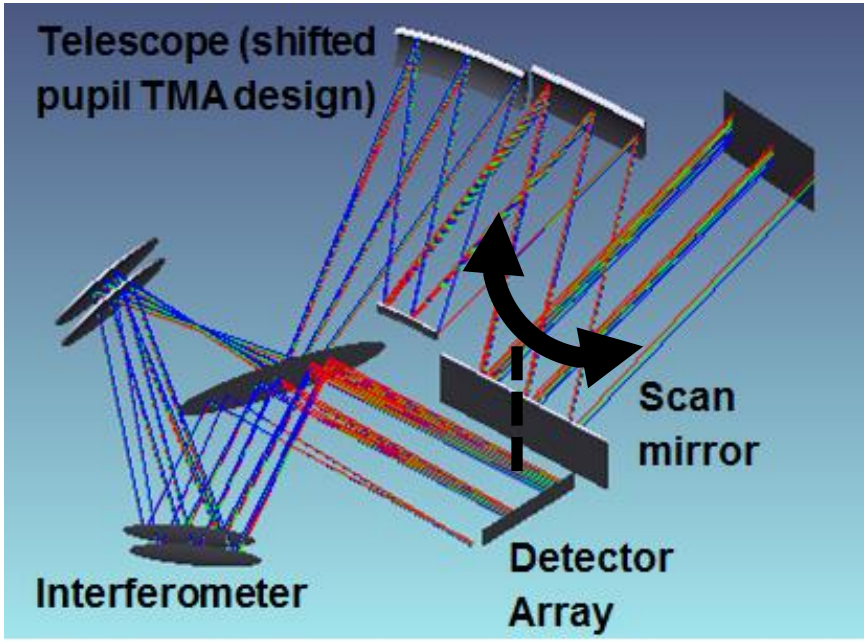
The MicroFTS UV spectrometer



UV Transmission Spectra – H2O

Technology Development: 2D Imaging Spectrometer

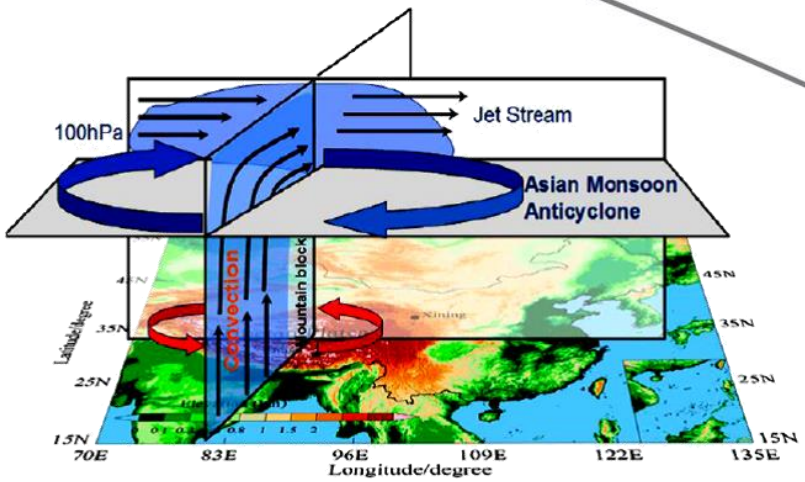
Imaging development work links the imaging capability with an optically encoded scan mirror

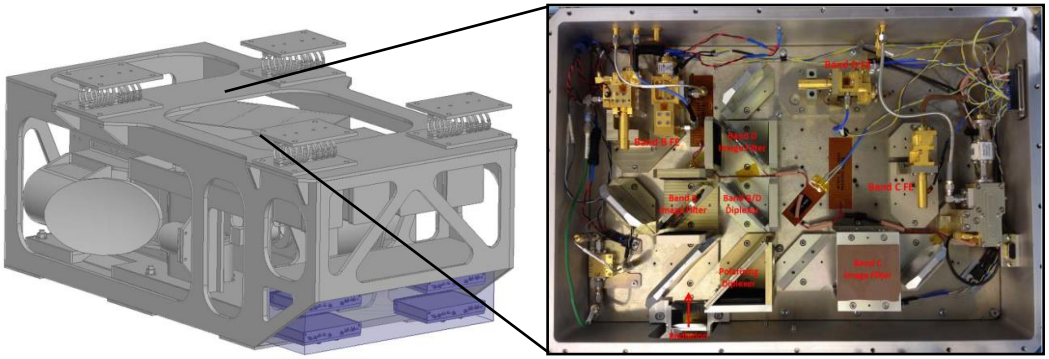


Detector	Vanadium Oxide Microbolometer
Spectral Bandwidth	2 - 14µm
Resolution	4cm^{-1} @ 10µm
FOV	0.24rad
iFOV	9.4mrad
Mass	<1.2kg

Airborne demonstration: StratoClim 2016

- STEAMR demonstration from M55 “Geophysica”
- MARSCHALS upgrade:
  - SHIRM receiver with WBS-III spectrometer (see STAR Dundee Poster!)
  - MicroFTS?





Summary

- Mission opportunity (ALiSS) for combined IR/mm-wave limb sounders
- UK well-placed to provide mm-wave receiver hardware
- Novel Micro FTS would be of interest as a complete UK instrument contribution
- Airborne demonstration of sideband-separating receiver, Wideband FFT spectrometer (and optionally Micro FTS) in StratoClim 2016

Thank You!

- brian.moyna@stfc.ac.uk