Demonstration of a thermal IR Laser Heterodyne Radiometer (LHR) in emission sounding mode

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RAL Space

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Outline

- Introduction
- LHR basics
- The LHR emission radiometer
- Validation / Performance
- Results
- Conclusion

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Introduction

Observational requirements in remote sensing

Scientific rationale

- Global atmospheric composition
- Global change and air quality

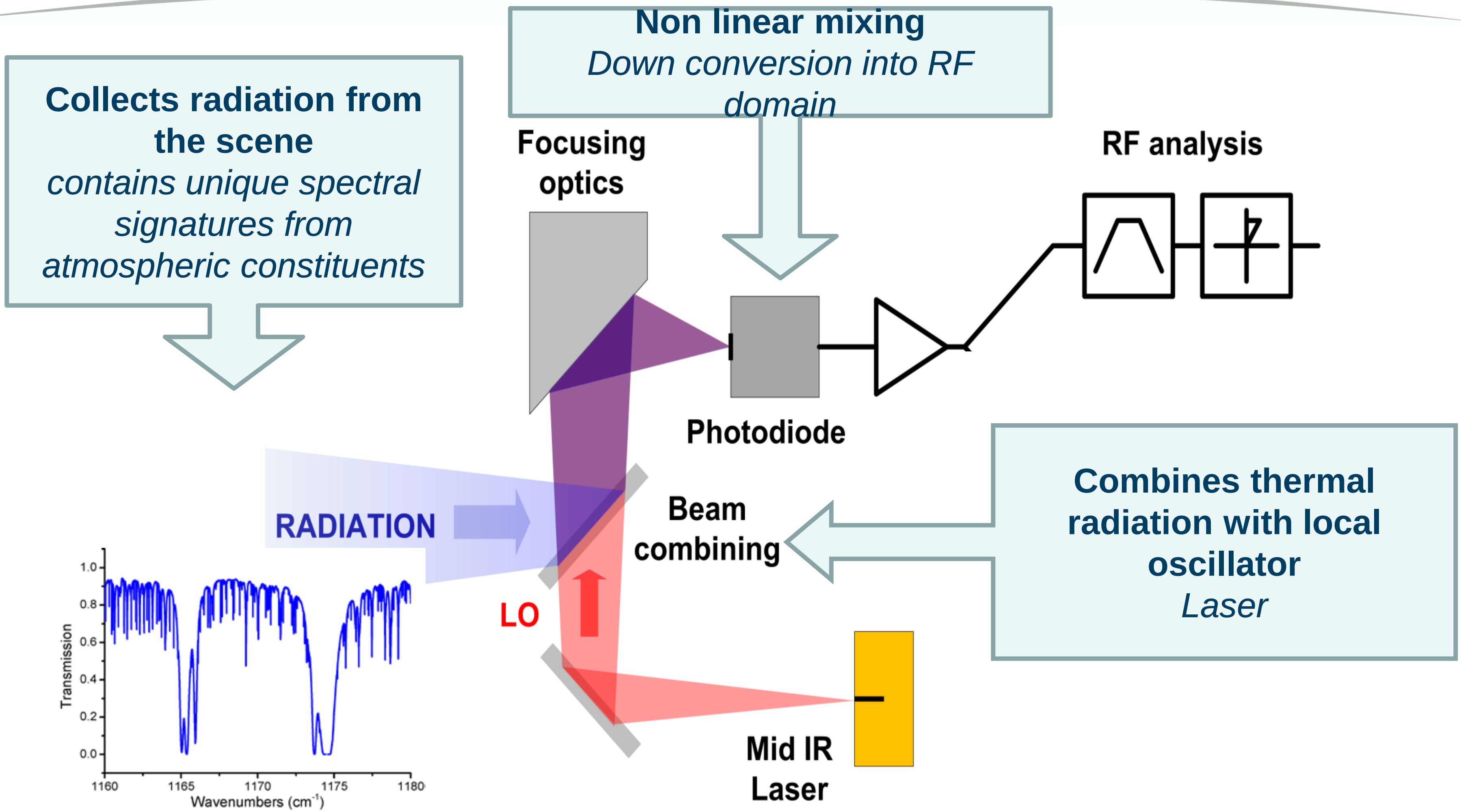
Requirements for remote sounders

- Driven by the need of finer grid meshes for more local information
- High resolutions (geographical, altitudinal, vertical, radiometric & spectral)
- Cost effective, compact instrumentation => Laser Heterodyne Radiometer (LHR)

- All done in solar occultation
- Assessment of pure emission measurements

Optical Heterodyne Spectroscopy

Basic principles

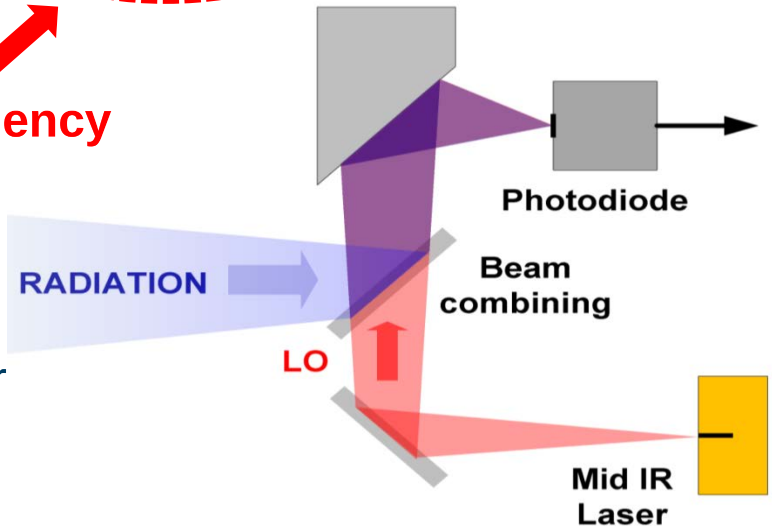


LHR Basics

$$E_S = A_S cos(\omega_S - \phi_S) \qquad E_L = A_L cos(\omega_L - \phi_L)$$

$$I_{ph} \propto {A_S}^2 + {A_L}^2 + 2A_S\,A_L\,cos[(\omega_S - \omega_L)t + (\phi_S - \phi_L)]$$

Beat Frequency



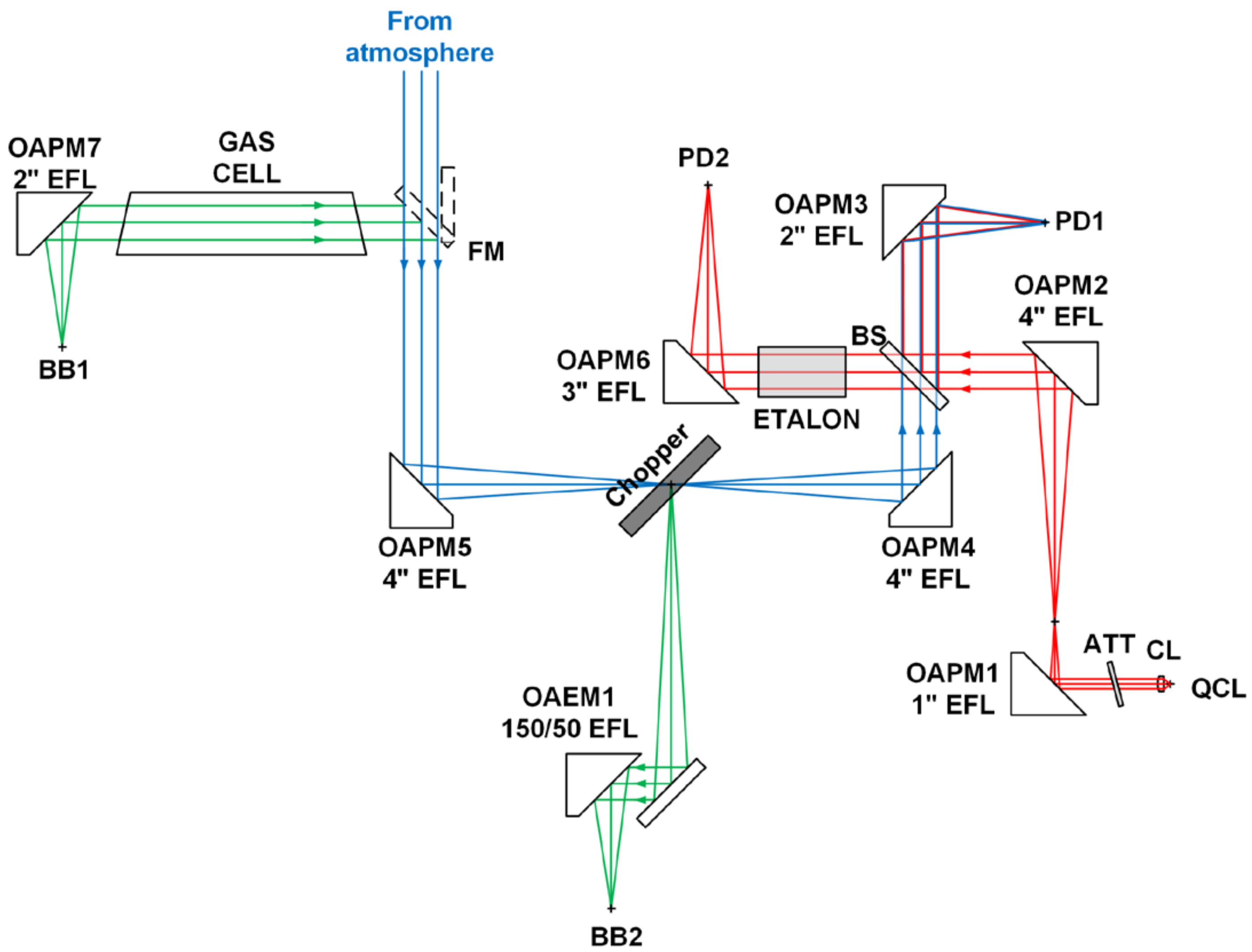
- A <u>PASSIVE</u> thermal infrared sounder
  - Even though there is a laser in it
- A <u>SPECTRO</u>-radiometer
  - Observes the unique spectral signatures of chemicals in the atmosphere

Laser Heterodyne Radiometers

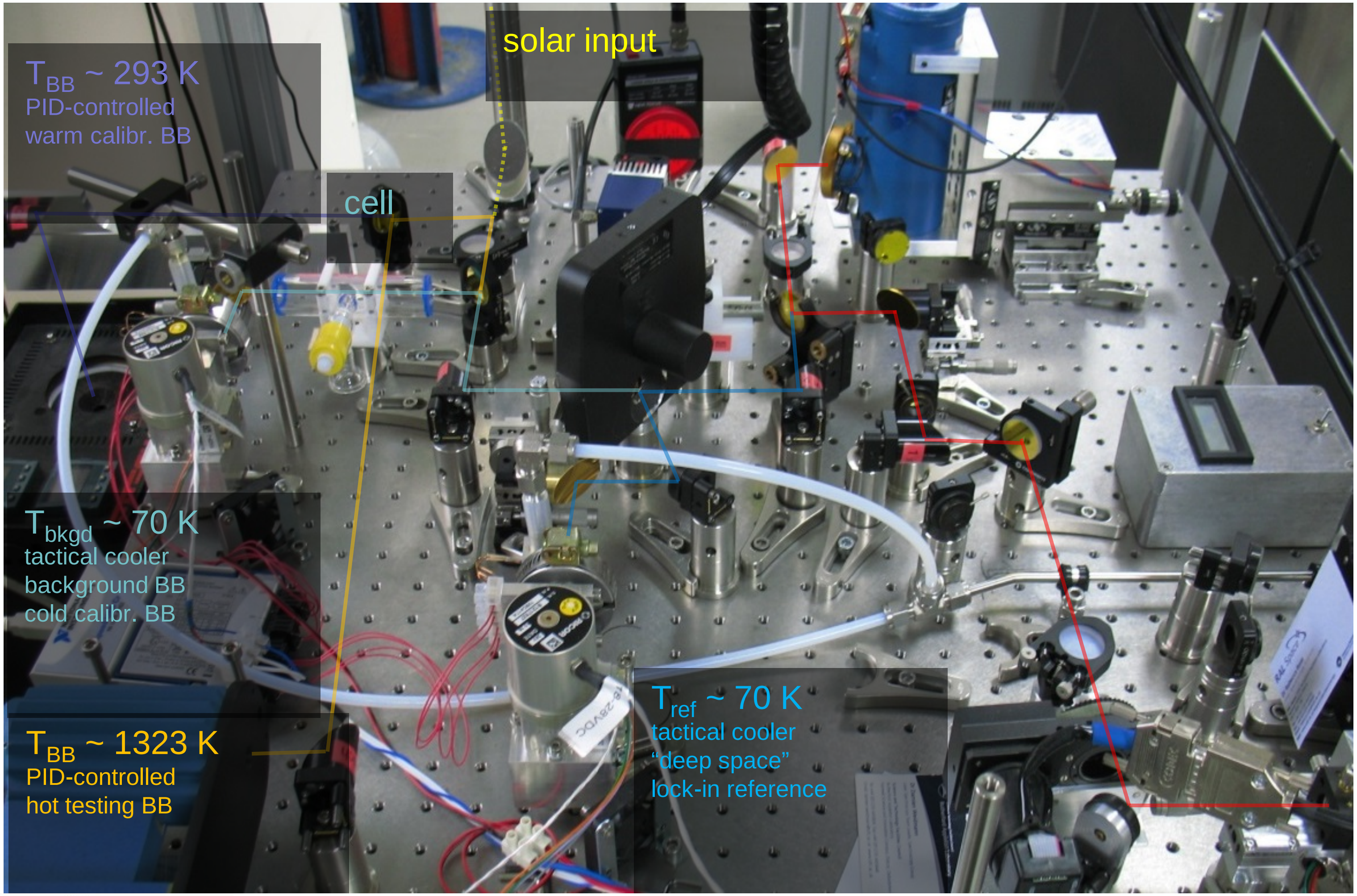
Benefits for Earth Observation

Merits	Figures	Remote sounding benefits
High sensitivity Shot noise limited	**NEP = 4.10^{-16} W** (λ=10µm - τ=1s) **NESR = 120 nW/cm^{-2}.sr.cm^{-1}**	**Detection of ultra-low concentration traces** **High accuracy**
High spectral resolution Set by electronic filters	**Resolving power > 10^6** Resolution down to **~10 MHz** Highest in the thermal IR	**Full lineshape resolution** **Deconvolution of altitudinal information** **Interference discrimination** **Usage of spectral micro-windows**
High spatial resolution Coherent FoV	10 cm aperture gives **FoV = 0.13 mrad = 27 arcsec** $\Rightarrow$~50 m LEO , ~4km GEO	**Ultrafine geographical coverage** **Higher altitude resolution (limb)** **Less cloud interferences** **Localized emission before dispersion** **Local sampling from GEO**
Electrical definition of **Instrument Lineshape**	**Directly measureable** to a high level of accuracy	**No ILS artefact** **ILS stability with sounding configuration**

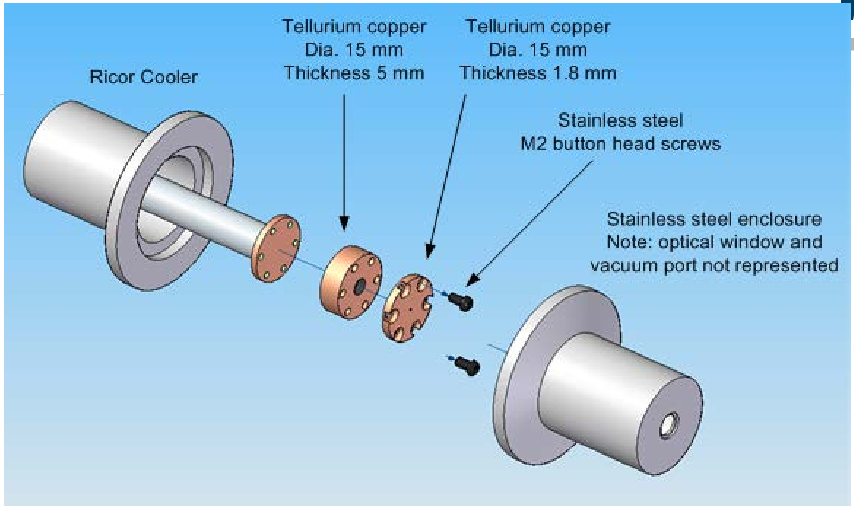
Optical layout

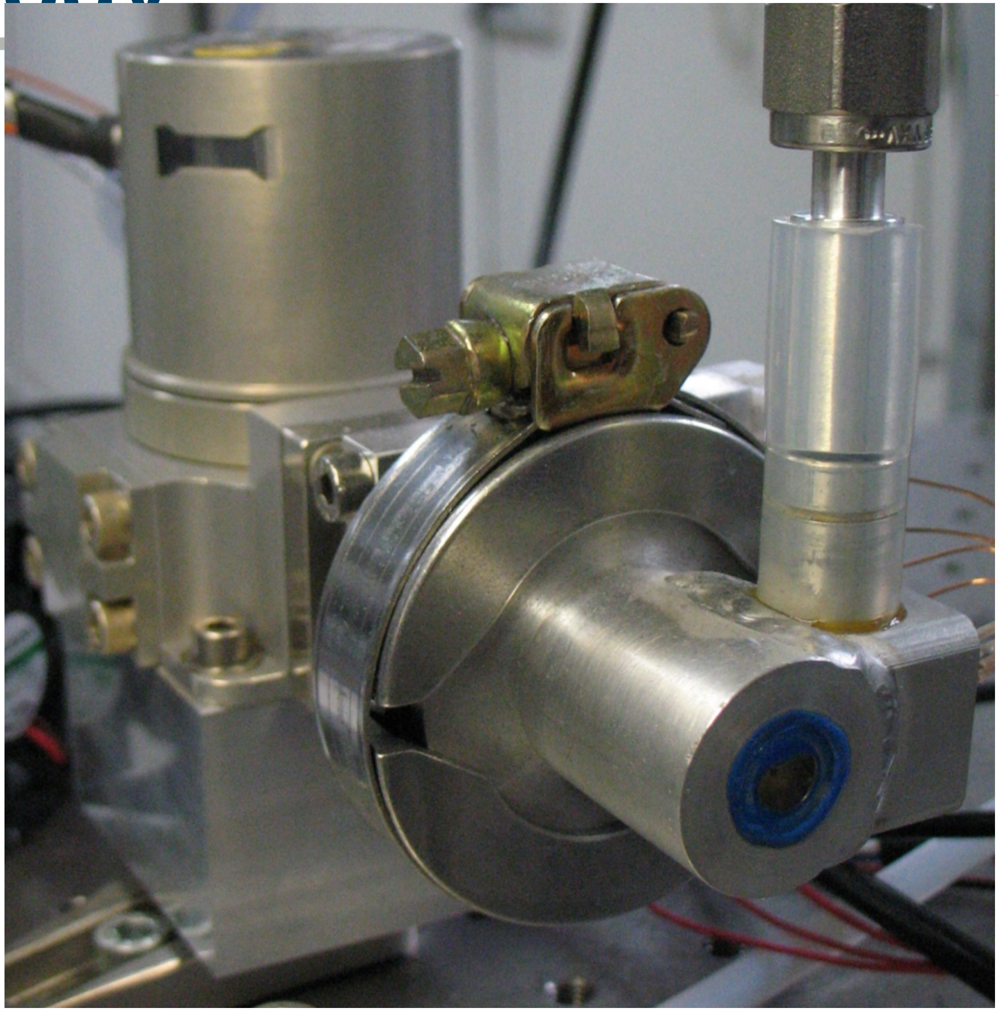


Emission LHR in the Lab



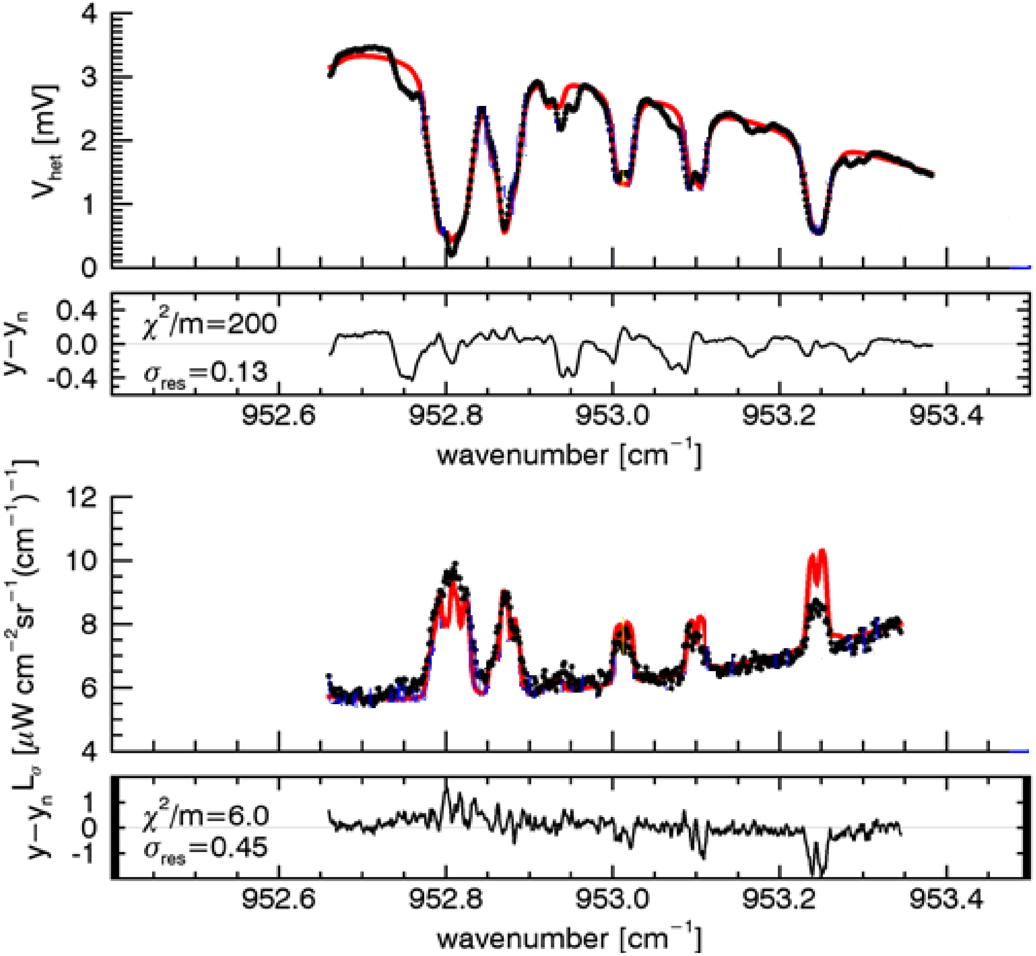
Miniaturised low temperature black body

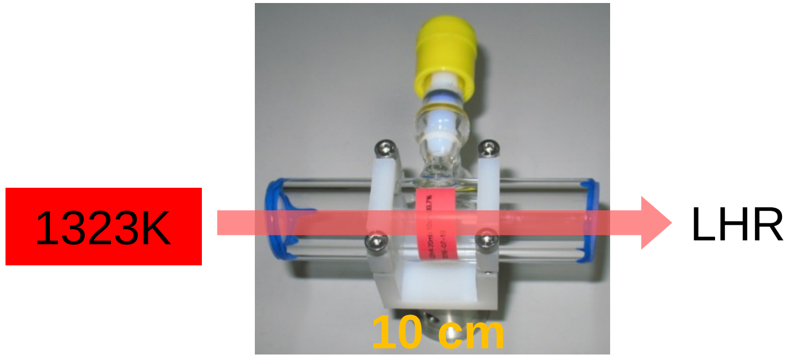




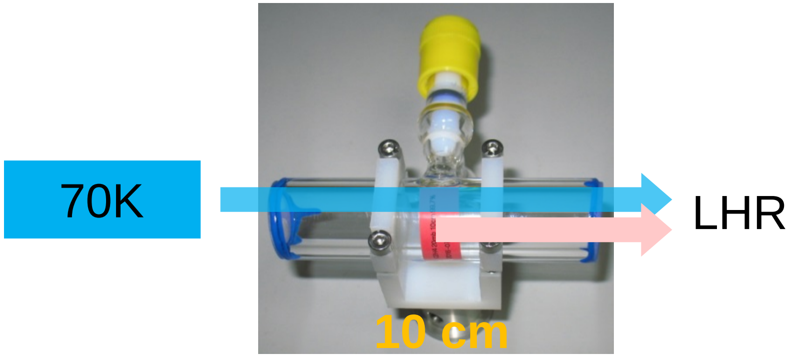
- Cavity with high emissivity coating
- 80K Stirling cooler
- Small, robust and stable
- Light weight airborne applications
- Few W power consumption
- 15min ready to use

Cell experiment





Cell: 20mbar C_2H_4



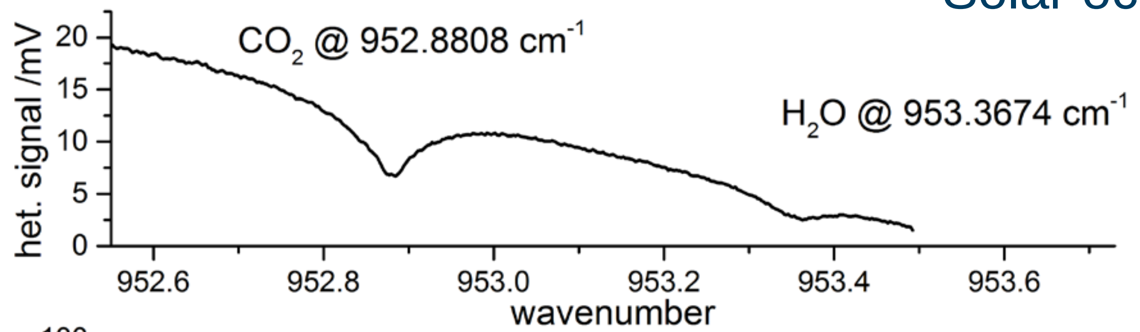
Instrument performance, SNR table

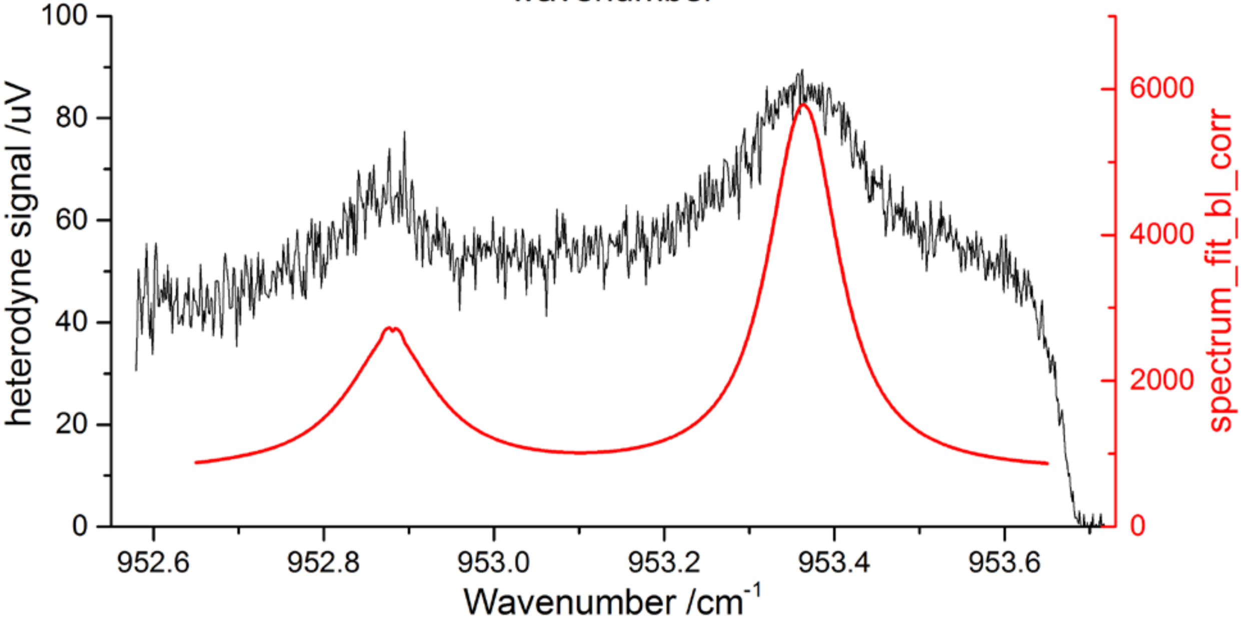
	τ [ms]	50	100	200	500
T_{BB} [K]	T_{ref} [K]	modelled SNR: σ=953.1 cm^{-1}; η=0.26; κ_{BB}=κ_{ref}=0.5; B=600 MHz ρ=2			
1323	293	192	272	385	608
353	293	4	6	8	13
1323	70	196	277	391	619
353	70	7	11	15	24
293	70	3	5	7	11
70	293	-3	-5	-7	-11

measured SNR

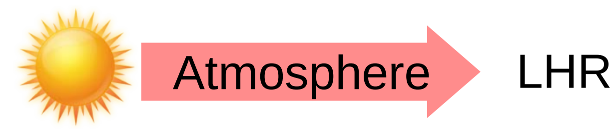
		50	100	200	500
1323	293	239	279	370	522
353	293	5	6	11	14
1323	70	235	352	356	475
353	70	8	11	15	24
293	70	4	5	8	13
70	293	3	4	4	8

Very first atmospheric spectrum

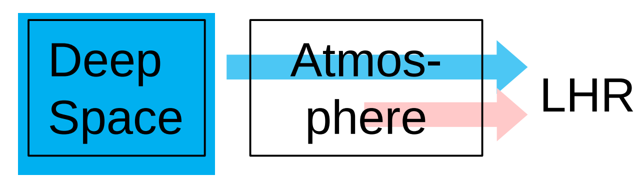




Solar occultation measurement



Zenith emission



Summary / Conclusion / Take away…

- Very first demonstration of an emission LHR
- Emission lines of atmospheric CO_2 and H_2O well resolved
- Factor 2 against ultimate limit
- Suitable for Nadir sounding and Limb emission

But:

- LO sweeping mode

Next Step:

- Multiplexing

Acknowledgements

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UK SPACE AGENCY

Centre for eo Instrumentation

Thank you