Compact High-Resolution Infrared Heterodyne Spectrometer for Studying Planetary Atmospheres

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Motivation:

State of the Art:

- two IR-Heterodyne spectrometers in operation for ground based planetary astronomy:

***THIS** (Tuneable Heterodyne Infrared Spectrometer, University of Cologne)* and

***HIPWAC** (Heterodyne Instrument for Planetary Wind And Composition, NASA GSFC)*

- spectral range from 7 µm to 13 µm

Main objectives: size and weight reduction

- **current size and weight of optical setup: 40x60x40cm³, 60 kg**
- **estimated: 10x10x5cm³, <5 kg**

- easier handling in ground-based observation
- breadboard for flight instrument
  – SOFIA, ISS, …

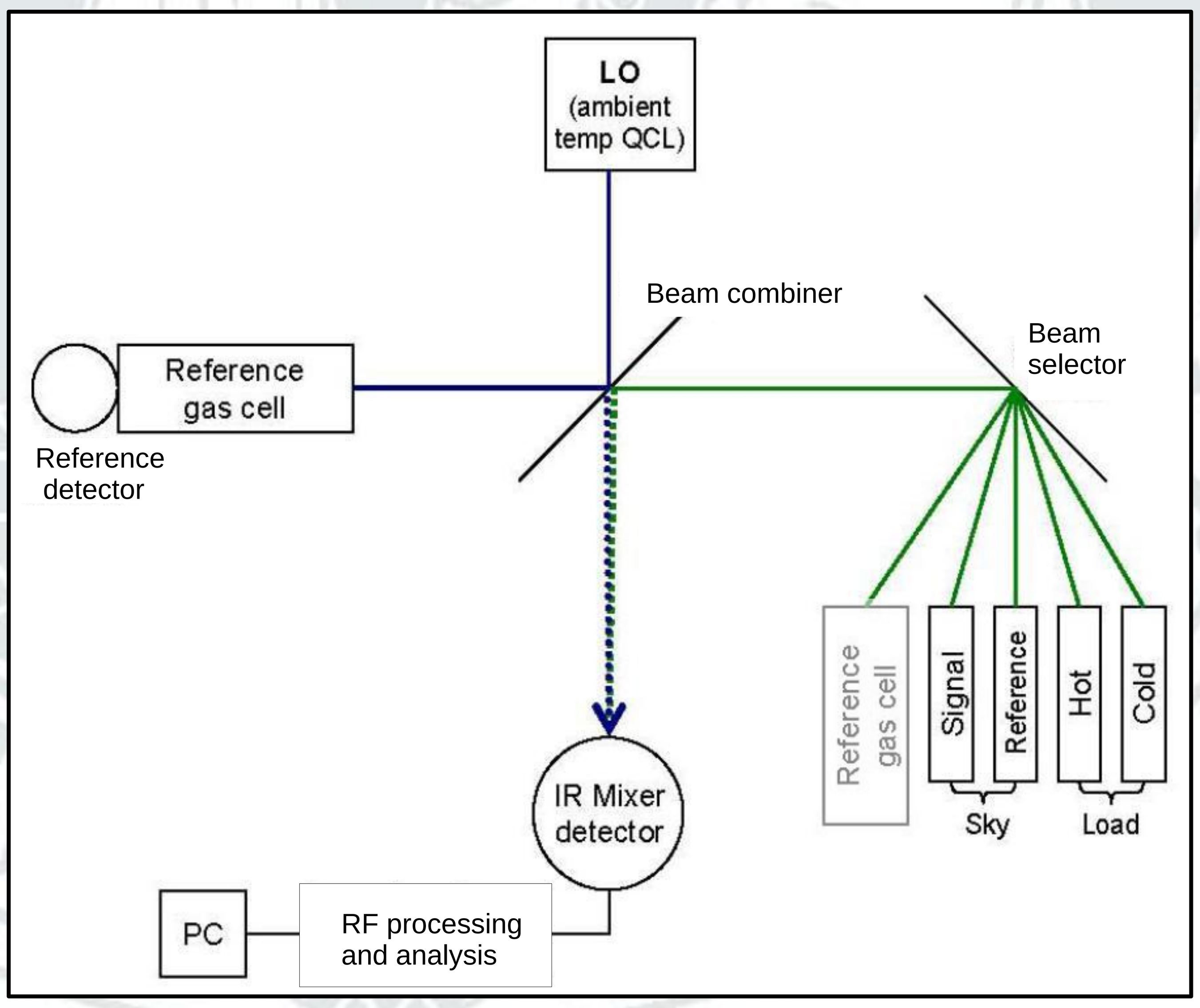
Heterodyne principle:

- superimposing signal + local oscillator (LO)
  → all spectroscopic information preserved
- ultra high spectral resolution (R > 10^7)
  → fully resolved molecular features
  → sensitive for dynamics down to m/s
- LO: Distributed feedback-QC Laser (DFB-QCL) offers complete wavelength coverage in the mid-IR
- mixer: Mercury-Cadmium-Telluride
- spectral analysis: Acousto-Optical-Spectrometer, DFT

Science:

- dynamics, composition of planetary atmospheres
- H_2 in the interstellar medium

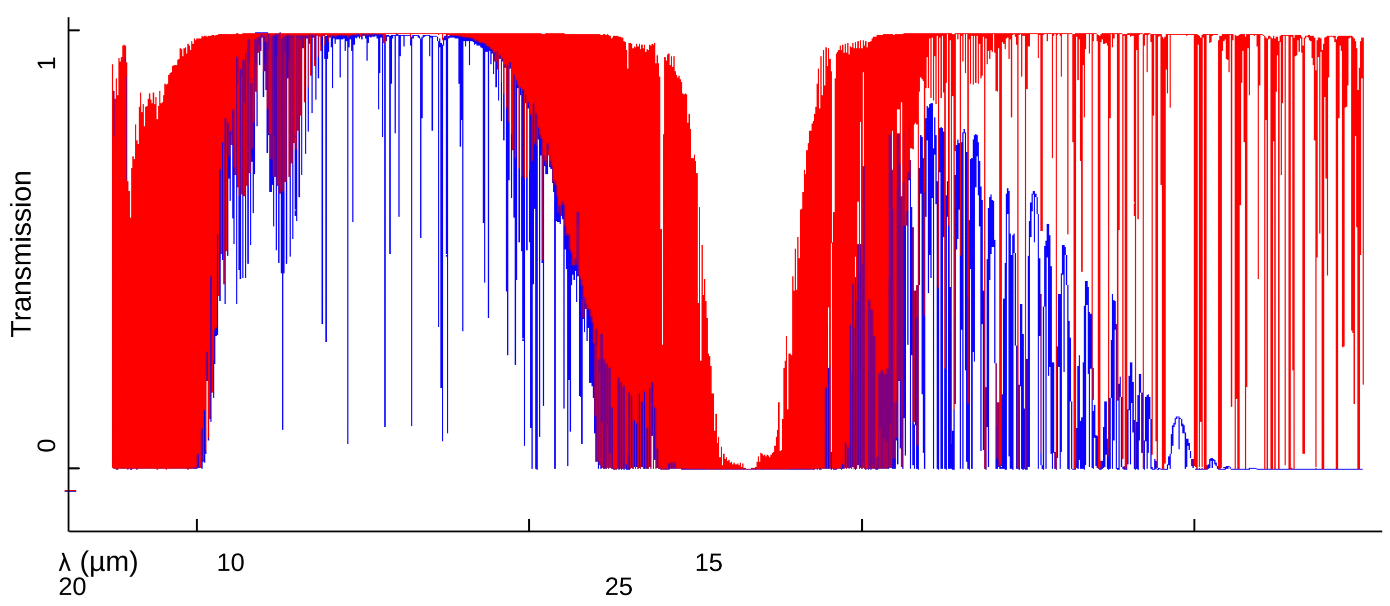
Schematic setup of heterodyne receiver:



Advantages of heterodyne measurements:

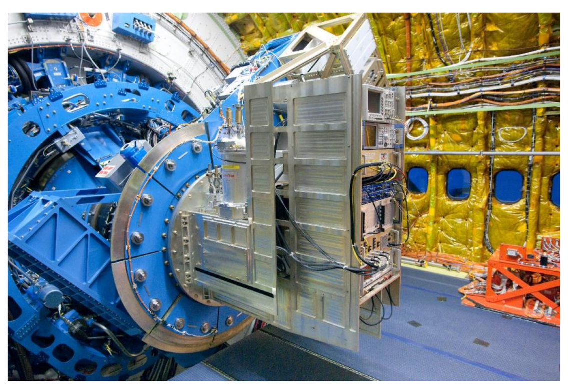
- transmittance of the Earth's atmosphere has strong variety between 7 to 20 µm → high resolution allows "peeking through the picket fence" of telluric lines
- infrared heterodyne spectroscopy fully resolves individual features → no ambiguity
- decent spatial resolution due to short wavelength
- fully resolved individual spectral lines yield information on various physical parameters
- 1st instrument for upper atmospheric (mesosphere) winds and temperatures in Mars or Venus

Possible application on SOFIA:



Comparison of atmospheric transmission between Mauna Kea, Hawaii and SOFIA

- **S**tratospheric **O**bservatory **F**or **I**nfrared **A**stronomy
- flight altitude ~ 14km
- reduction of telluric water vapour and atmospheric trace gases
- IR channel in GREAT possible

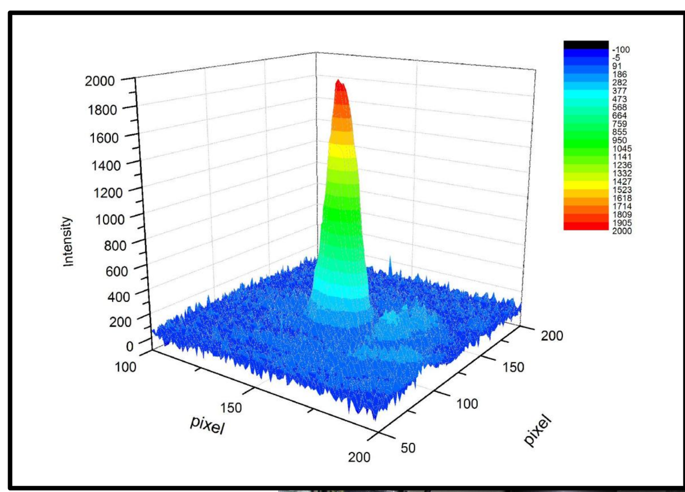


The Cologne receiver GREAT onboard the SOFIA observatory. An IR channel upgrade is possible

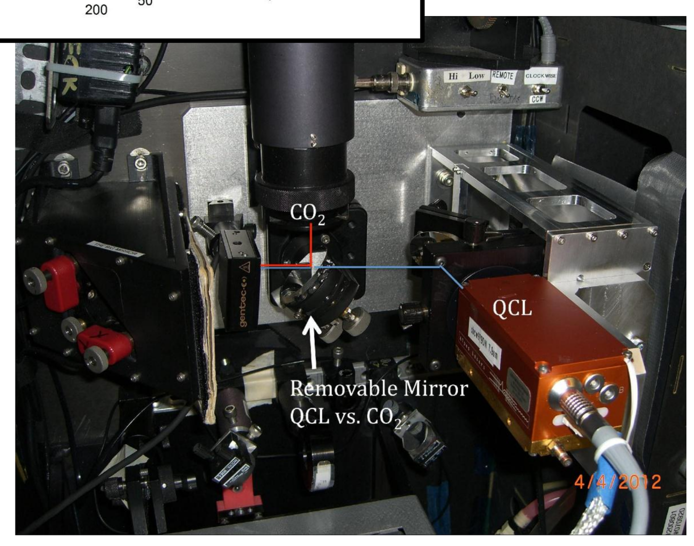
New technologies:

New concepts will or have been tested for key components:

- ***Local oscillator:***
  - room temperature quantum cascade lasers (commercial device, Alpeslasers, Switzerland)
  - recently tested in NASA GSFCs HIPWAC instrument
  - successful observations of Mars at 7.8 µm
  - sensitivity and stability comparable to gas laser system

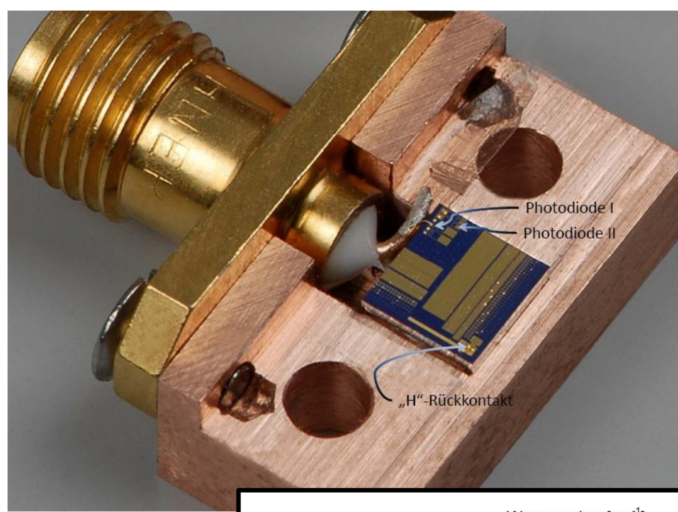


Beam profile of the QCL

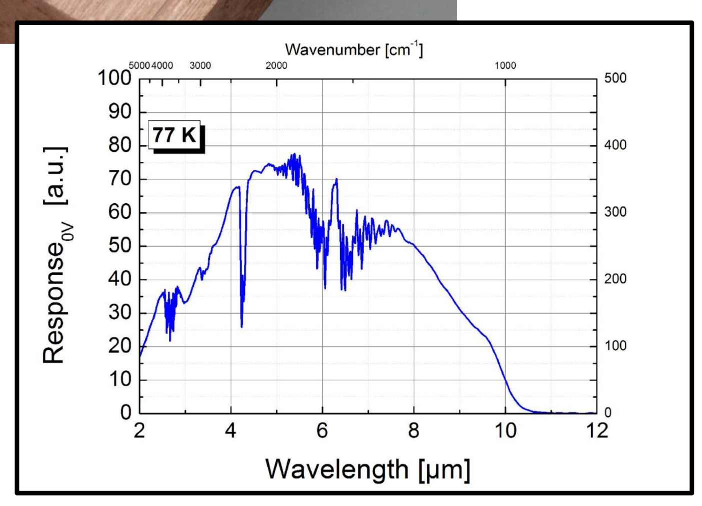


Room temperature QCL integrated into HIPWAC

- ***Detector***:
  - recently developed super lattice detectors (prototype, Fraunhofer Institute Freiburg, Germany)
  - high quantum efficiency
  - potentially room temperature operation
  - wavelength 7-20 µm

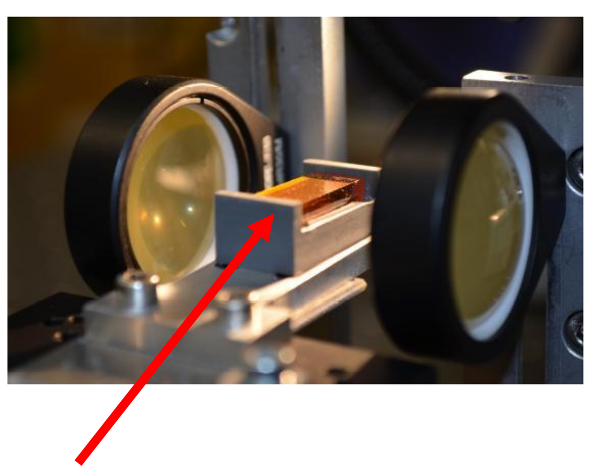


First super-lattice prototype to be tested in Cologne

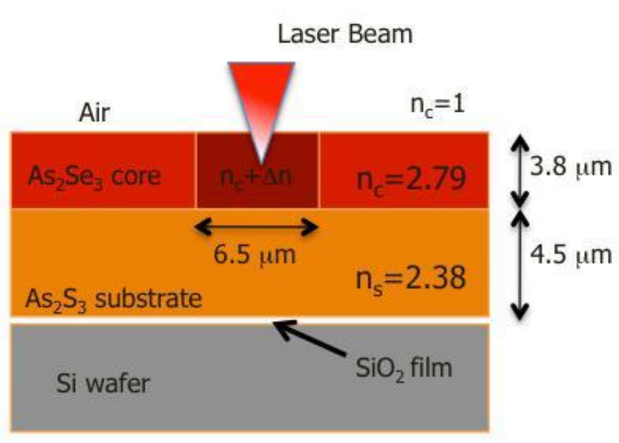


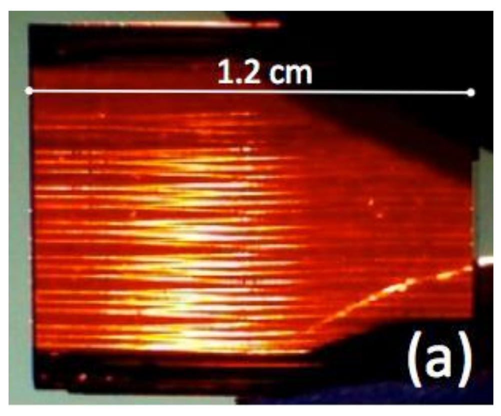
Response curve of the detector. Maximum QE is 70%

- ***Beam combiner:***
  - buried channel waveguide
  - chalcogenide glass
  - waveguide created by ultrafast laser inscription



Waveguide test structure for 8.6 µm wavelength. Coupling efficiency and optical losses are currently under investigation.





Left: cross-section of a two-dimensional channel waveguide used to produce a chalcogenide 2-telescope beam combiner. A similar device will be used to combine local oscillator and signal in a heterodyne setup
Right: Image of a 3-dimensional three-way combiner. Additional channels can be used for calibration sources.

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