Miniature Fourier Transform Spectrometer for Environmental Monitoring Applications

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Fourier Transform Spectrometers

Measures the intensity of radiation as a function of wavelength.

Fourier Transform Spectrometers

• High spectral resolution

• Good discrimination between different gases

• High sensitivity to weakly absorbing gases.

• High Signal to Noise Ratio (SNR)

MIPAS water ice concentrations
Ref. Institute for Meteorology and Climate Research
KIT
Outline

• Background to the Spectroscopy Group
  – The capabilities of the Molecular Spectroscopy Facility at RAL

• Introduction to Fourier Transform Spectrometers

• Static Imaging Fourier Transform Spectrometry (SIFTS)
  – The Micro-FTS
  – Theory
  – Experimental Performance
The Molecular Spectroscopy Facility Capabilities

The MSF operates a variety of state-of-the-art spectrometers spanning far-infrared to ultraviolet wavelengths:

- Fourier transform spectrometers.
- Miniature CCD grating spectrometers.
- Tuneable infrared laser systems.

Bruker IFS 125HR Fourier transform spectrometer

Quantum cascade laser system
Previous Studies

Methane for Titan studies
Bowles et al. 2008

Industrial compounds: HFC’s and PFC’s
Fourier Transform Spectroscopy

Monochromatic Light - Laser

FFT

Sinusoidal Interference Pattern

Michelson Spectrometer
Fourier Transform Spectrometers

Water vapour H$_2$O

Detector
Mirror
Beam splitter
Light

Complex Interference Pattern - Interferogram
Michelson Spectrometer
Fourier Transform Spectrometers

- Complex optics
- Large Instruments
- Heavy
- Slow scan speeds

Bruker FTIR

Infrared Atmospheric Sounding Interferometer (IASI) – Metop - A
The Micro-FTS – Operating principles

Mirror 1

Mirror 2

reflected
ray

transmitted
ray

Beam
Splitter

Light Source

Detector
Array

θ_R
The Micro-FTS – Optical Design

Source

Modelled Interference Pattern

Detector Array
The Micro-FTS\textsubscript{VIS} Handheld Instrument

High Temporal Resolution
Frame rate - 10kHz
(1 spectra per 0.1ms)

Moderate Spectral Resolution
\sim 2\text{nm} – 0.5\text{nm}

Low mass \sim 300\text{ grams}

Compact \; 90 \times 60 \times 35\text{mm}

Low cost – COTS components
Microsatellite Based Infrared Static Imaging FTS (SIFTS)

Original concept designed for space with alternative optical configuration

- Spectral resolution of 4 cm$^{-1}$
- Low mass spectrometer ~ 1.56 kg
- Compact ~ 350 x 300 x 50 mm
- Low power ~ 0.5 W (average)
- SNR ~ 513
Future Work

• Perform sensitivity study
  – Calibration gas
  – Field Trial

• Optimise and build an operational infrared instrument Micro-FTS\textsubscript{IR}
  – Design for use on radiosonde or UAV

• Develop the design into a single monolithic block
  – Optimise the optics (custom fabrication)
  – Miniaturise the design
  – The design is scalable (Limited by wavefront errors)
Comparison of the two spectra
Examples 3
Gas cells

• Variable temperature from 77 to 473 K.
• Pressures from high vacuum to 5 bar.
• Optical path lengths from 5 mm to 1 km.
• Interchangeable windows to suit spectral region (IR to UV).
• Pressure, temperature and humidity logged automatically.
The Static Imaging Fourier Transform Spectrometer (SIFTS)
The SIFTS Design

Lateral Beam Shearing Prism
The SIFTS Design

Focal Plane Detector Array

The laterally sheared beam is passed through the Fourier lens and recombined at the pupil. The combination of the two beams creates an interferogram which is then sampled by a focal plane array detector.
Breadboard Instrument

Collimator

Detector array

Fibre fed light source

Concave mirrors

Beam splitter

1 inch
The Micro-FTS – Operating principles

Mirror 1

Mirror 2

reflected ray

transmitted ray

Beam Splitter $\theta_R$

Light Source

Detector Array

Detector Array