Mid-Infrared Laser Heterodyne Systems

From Earth Observation to Security and Defence

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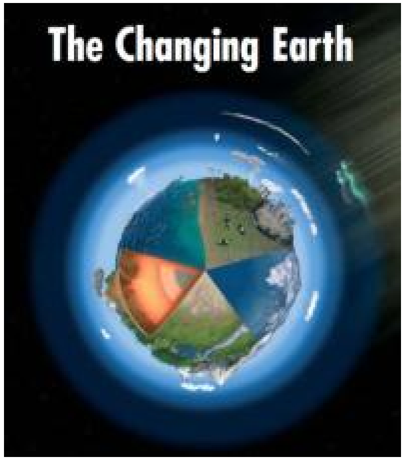
Outline

- Laser Heterodyne Radiometer (LHR)
  - Earth Observation rationale
  - Principles and capabilities
  - Hollow waveguide miniaturization
- Security & Defence applications
  - Capability Gap
  - Adapting LHR to the problem
  - Early demonstration
  - Prospects

Earth Observation Needs

LHR capabilities well aligned



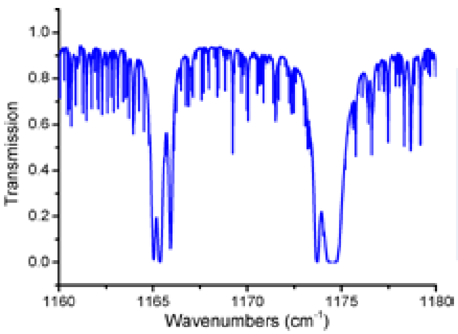
- Atmospheric composition measurements
  - Finer geographical coverage
  - Better vertical resolution
  - Improved sensitivity
  - From light and compact platforms

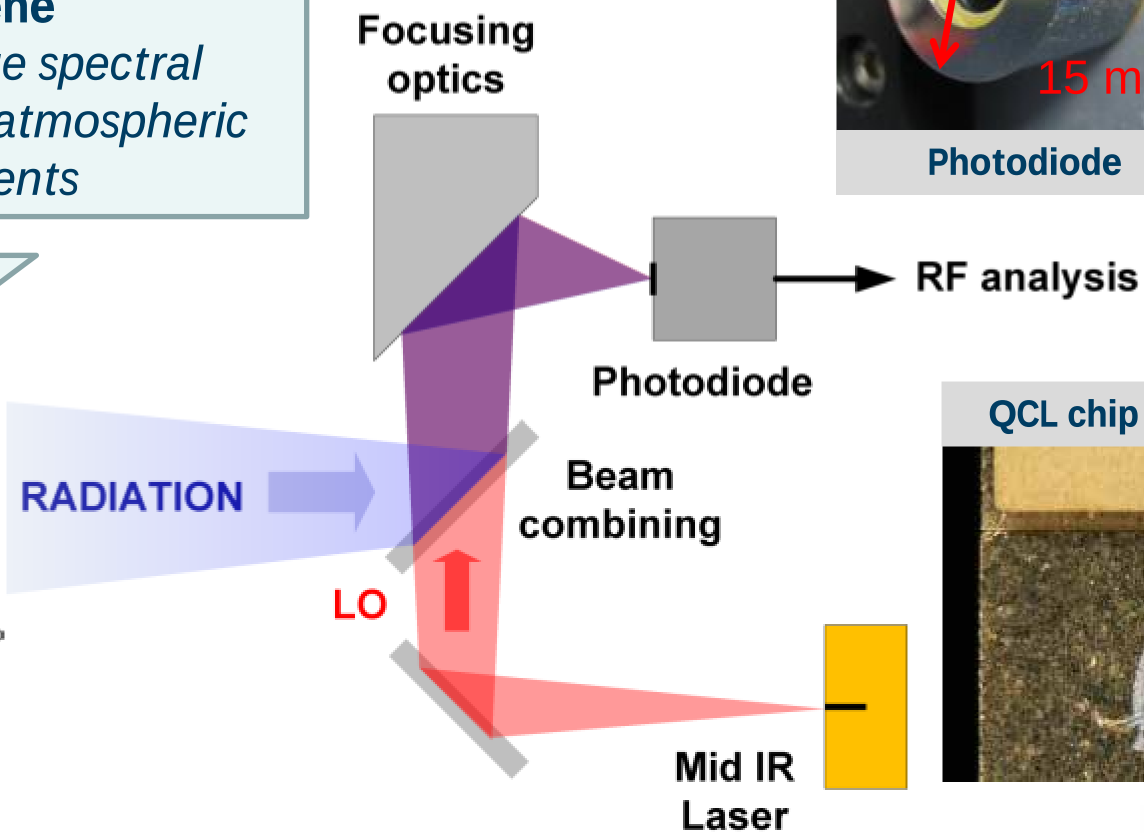
- Laser heterodyne radiometer (LHR)
  - High sensitivity in the thermal and far IR
  - Ultra-high spectral resolution -> vertical profiling
  - Ultra-high spatial resolution (< mrad)

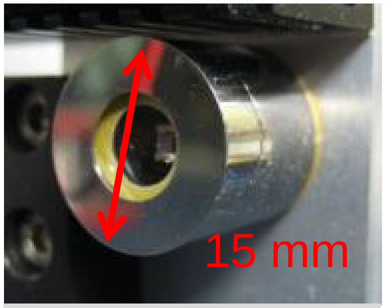
Laser Heterodyne Radiometer

Passive – Laser is only local oscillator

Collects thermal radiation from the scene
contains unique spectral signatures from atmospheric constituents

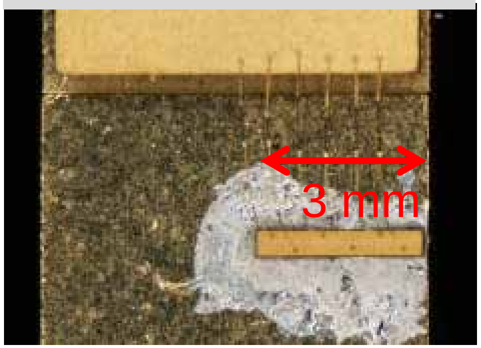






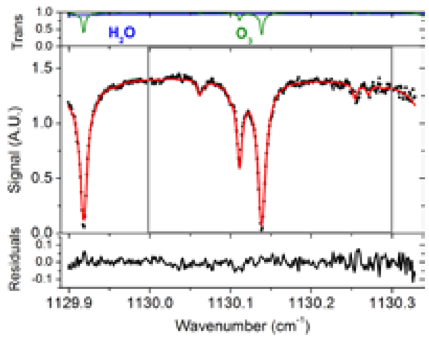
Photodiode

QCL chip on submount



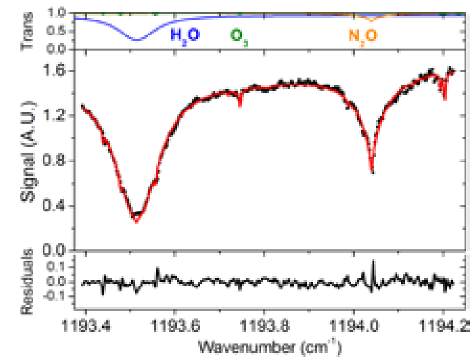
Vertical Profile Measurements

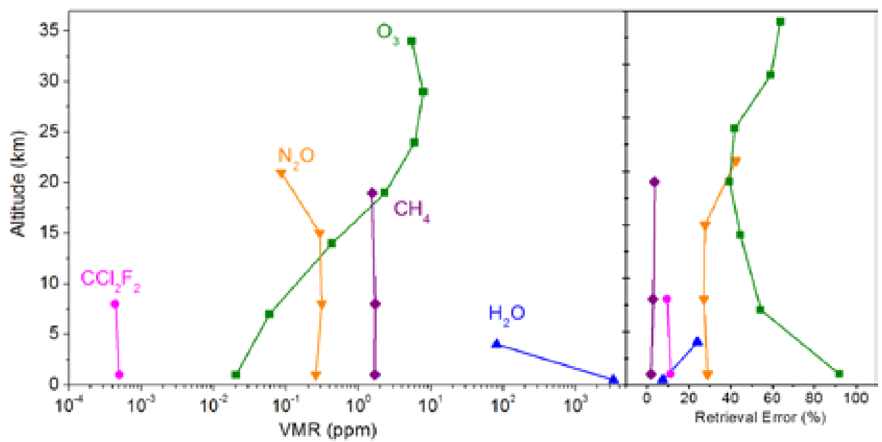
Solar occultation ground based

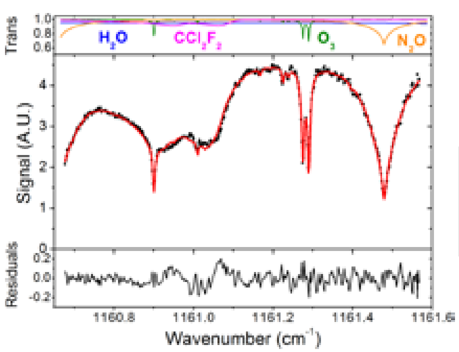


Ozone

Water vapour

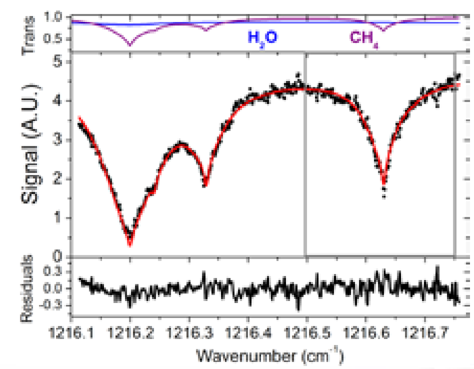






Freon 12
Nitrous oxide

Methane



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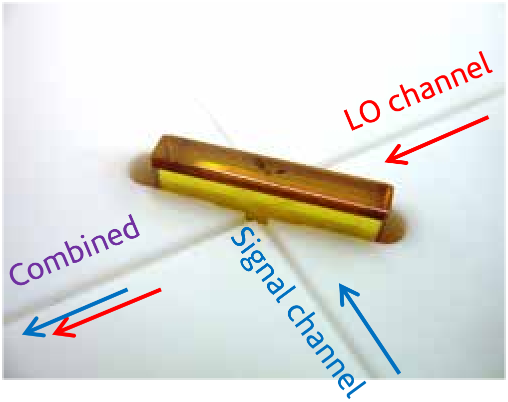
HOLLOWGUIDE LTD
Prof. Mike Jenkins

Miniaturization

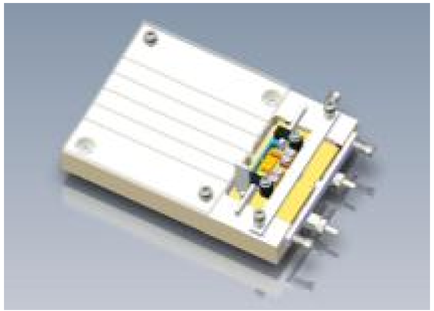
Hollow waveguide integration

Bench top 75x75cm

Hollow waveguide channels

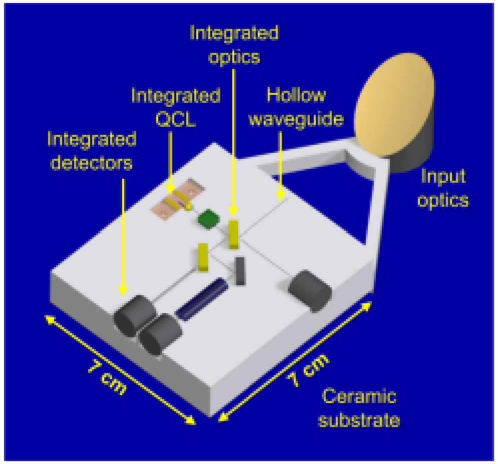


Passive component integration



Active component integration

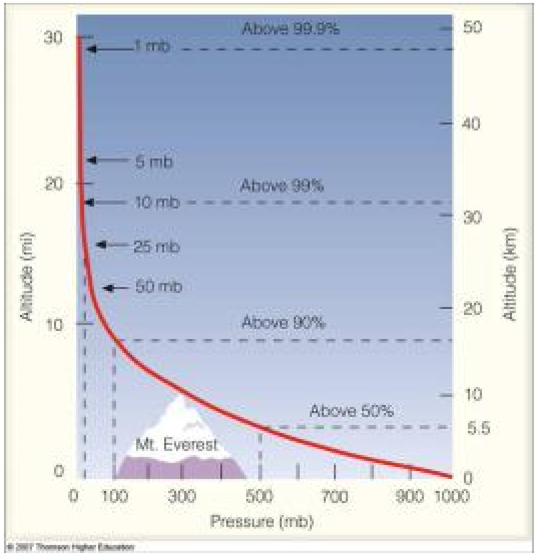
Fully integrated LHR



Trace Chemical Remote Sensing

EO vs. Terrestrial (Security & Defence)

- EO from space
  - Long paths
  - Thermal contrast



- Terrestrial S&D
  - Short plume
  - Highly localized
  - No thermal contrast
  - Low vapour pressure

Remote Sensing of Explosives

Requirements

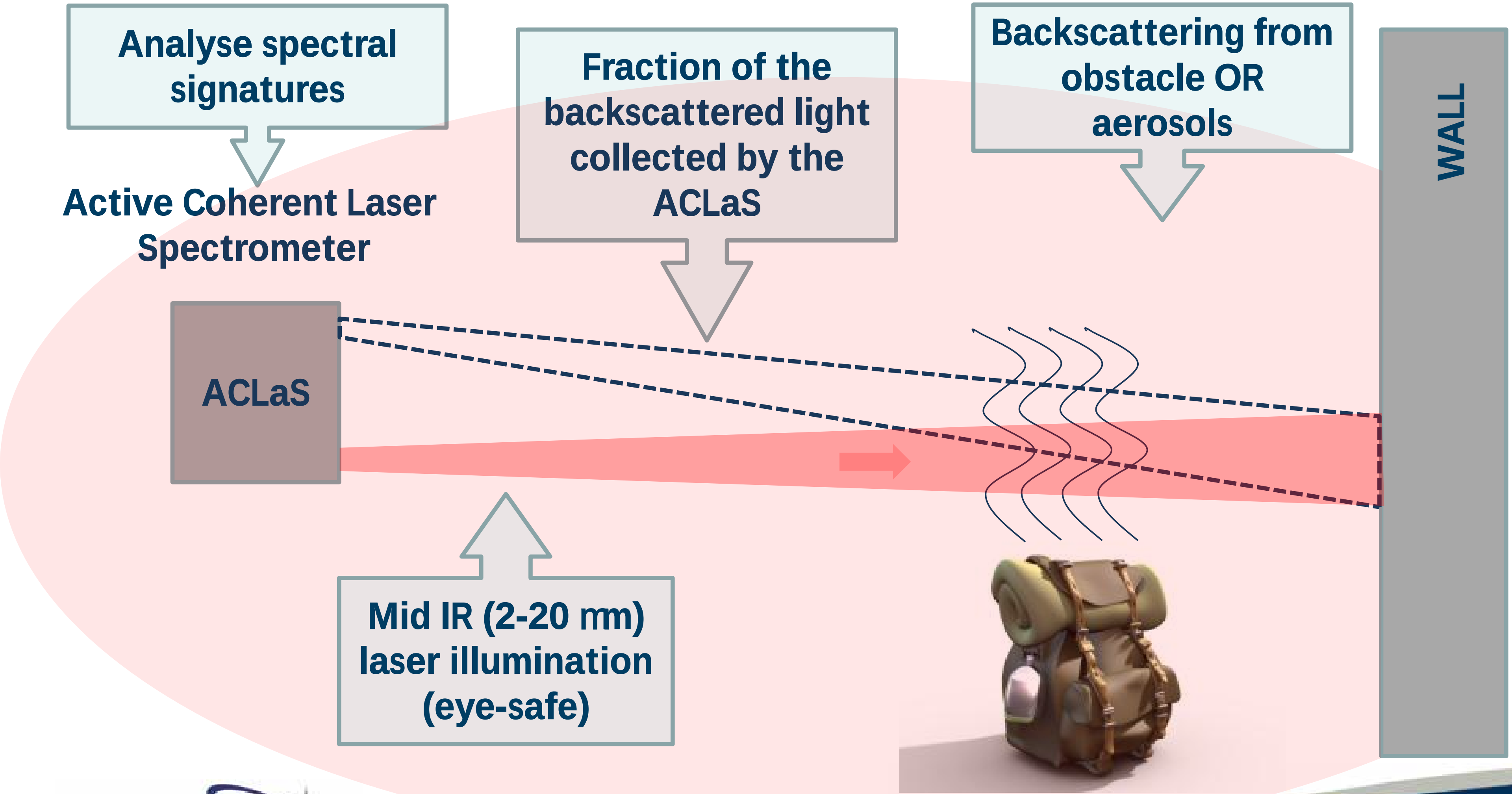
- Strict performance criteria
  - Multi-species identification and quantification
  - High sensitivity (ppb)
  - Detection ranges > 50 m
  - Rapid response times (seconds to minutes)
  - Eye-safe operation
  - Compact and portable design
  - Cost effectiveness

SOLUTION: CREATE THE CONTRAST -> MAKE THE LHR ACTIVE

LHR becomes ACLaS

Typical Detection Scenario

Active Coherent Laser Spectrometer



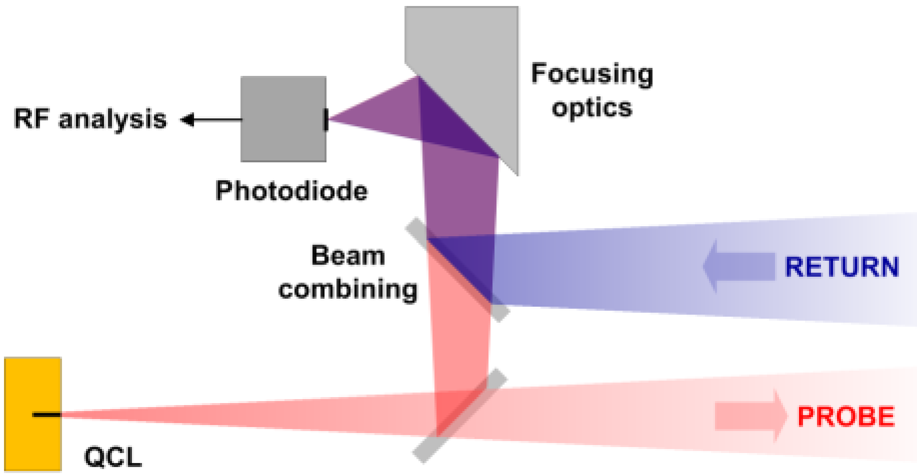
Benefits of ACLaS

Inherit advantages of LHR + new ones

High detection sensitivity (femtoWatts)

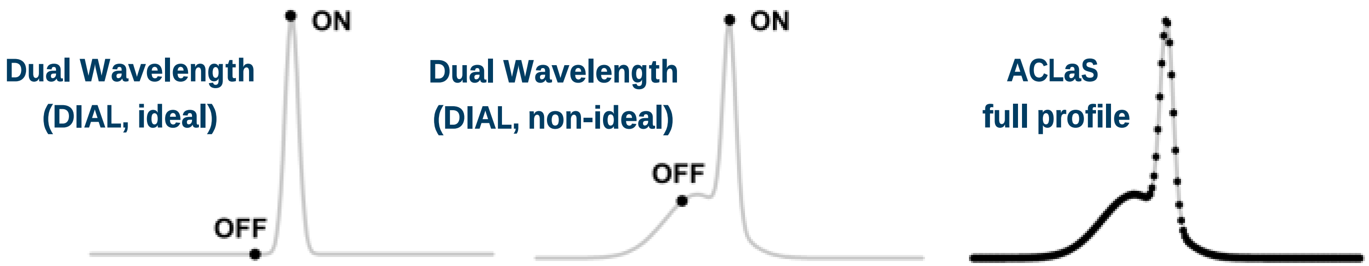
Ultra high spectral resolution: ~1MHz !!! (0.00003 cm^{-1})

- Can match the 1 MHz laser linewidth
- Immune to laser frequency noise
- Full profile information

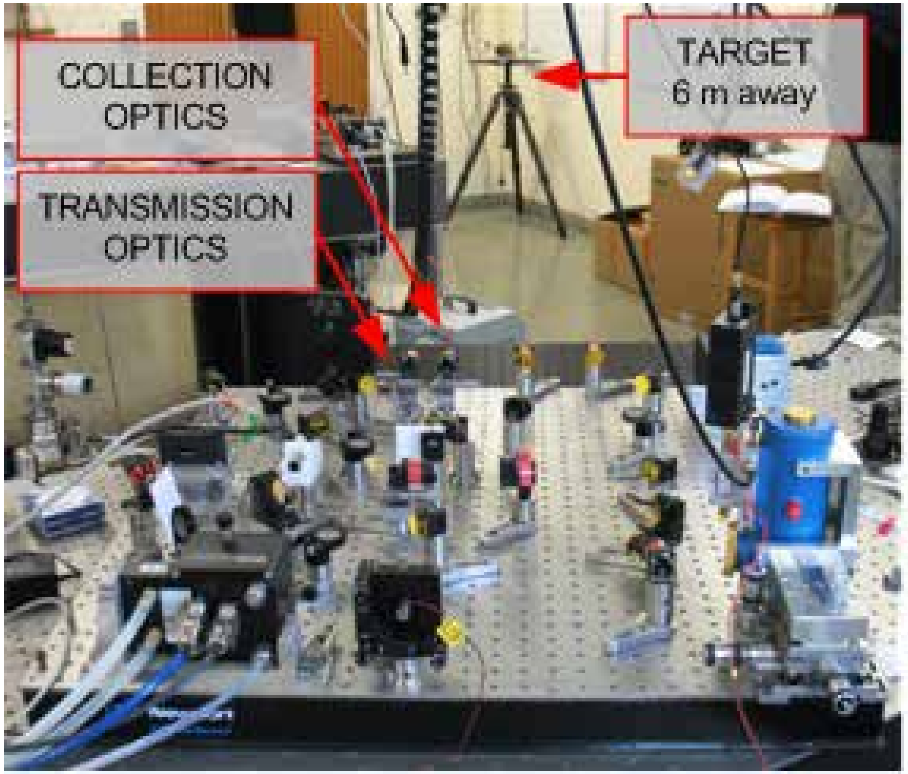


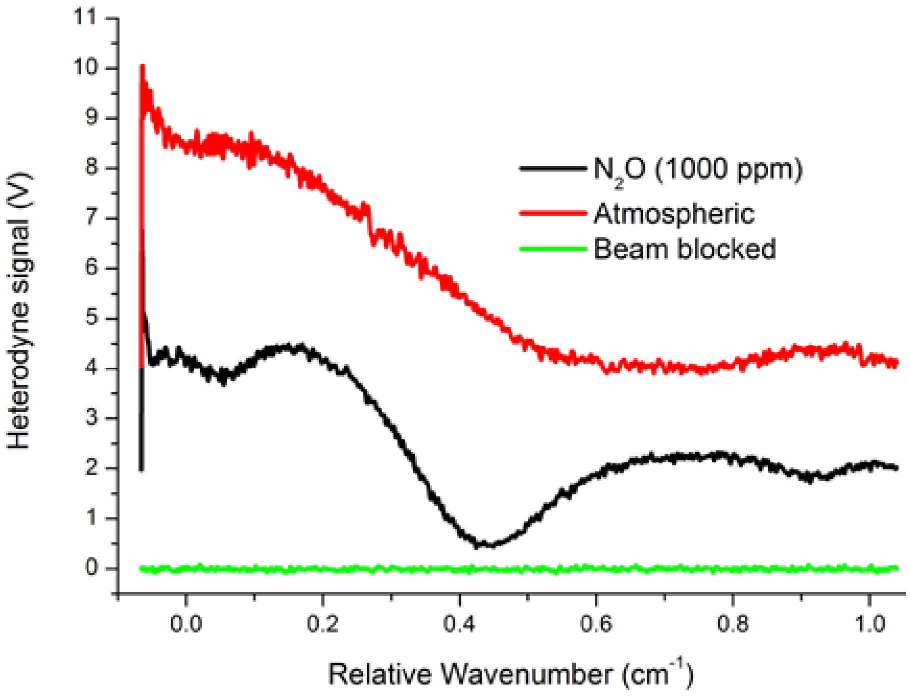
High spatial resolution (narrow FoV)

- Identification of highly localized releases before dispersion
- Potential for high resolution imaging



First System – First Spectrum
Nitrous Oxide





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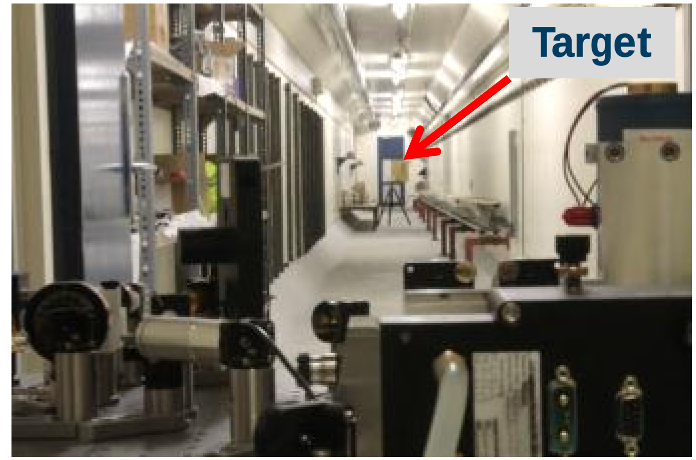
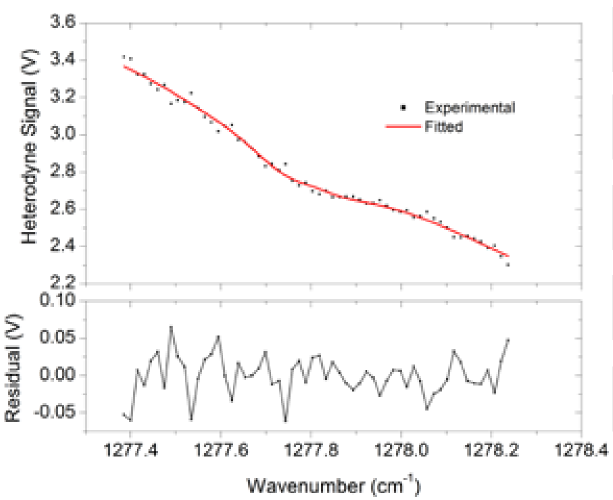
Long Range Tests (up to 50 m)

Hydrogen Peroxide and Nitrous Oxide





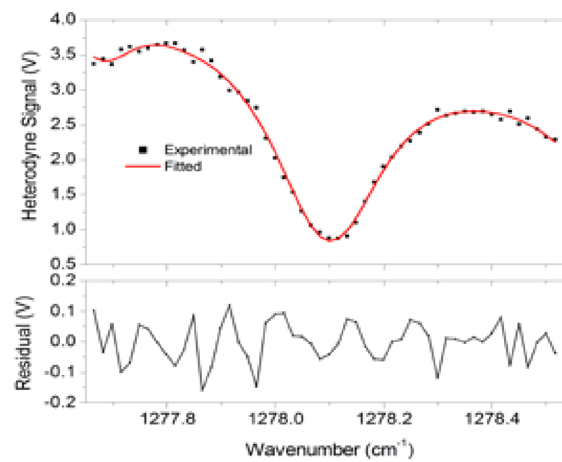
H_2O_2

20 cm plume

252 ± 17 ppm

10 seconds

10 meters



N_2O

20 cm plume

3588 ± 29 ppm

8 seconds

40 meters

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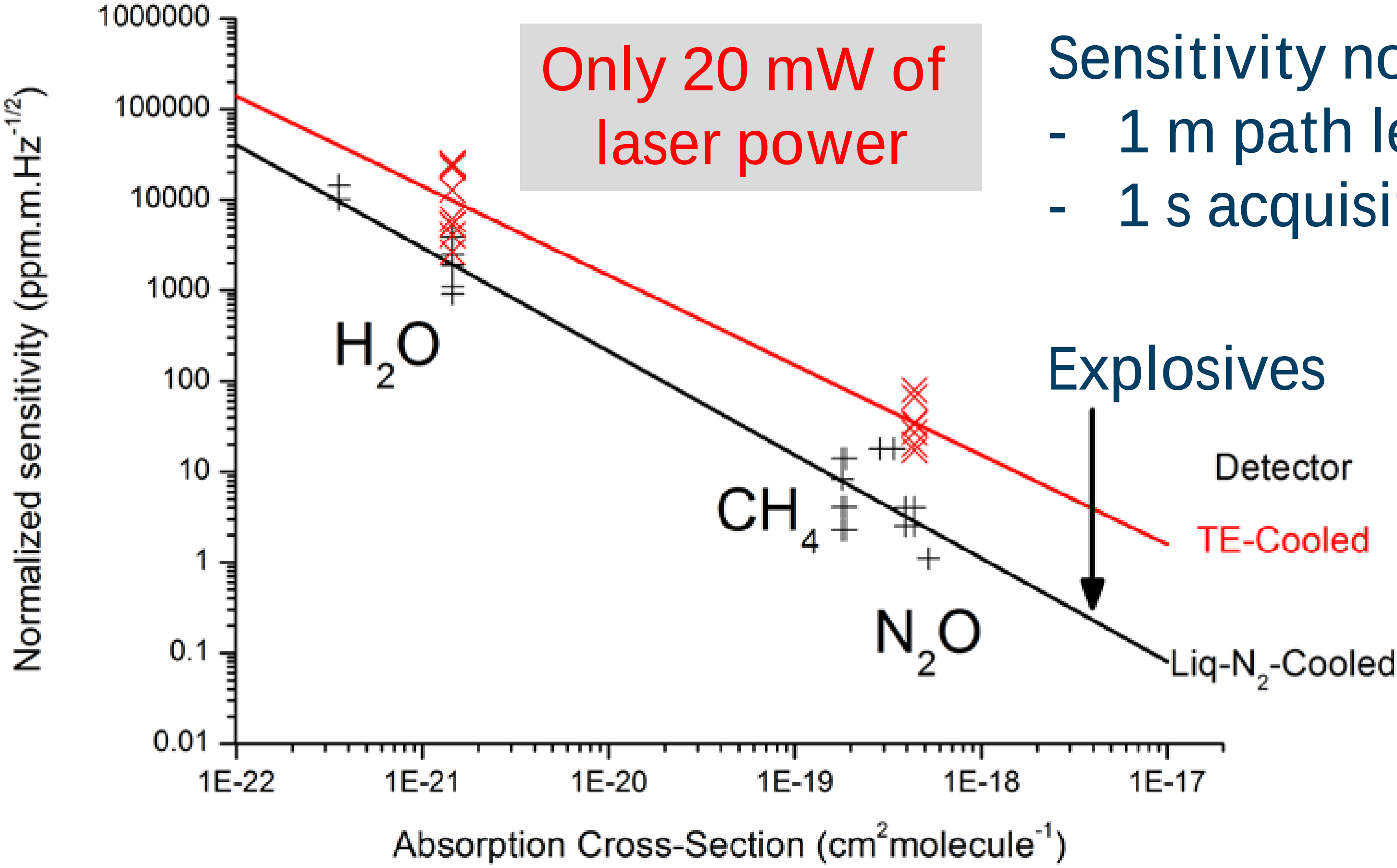
Current Normalised Detection Limits

Only 20 mW of laser power

Sensitivity normalised to
- 1 m path length
- 1 s acquisition time



STILL ~10^4 above ultimate noise limit

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Conclusions & Prospects

Ø Adapting EO oriented instrumental development into terrestrial sector for standoff detection

Ø Most sensitive Standoff detection/identification system fulfilling operational requirements

- Several orders of magnitudes to gain in sensitivity
- Miniaturization under way (field deployment)
  - Direct benefits from CEOI programme
- Increased spectral agility
- Range resolution

Ø Further spinning out in environmental monitoring

- What and how much is getting out of this chimney stack?
- Urban tomography

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Acknowledgements

- Mike Jenkins
- Neil Macleod
- Rebecca Rose

Scottish Enterprise

Science & Technology Facilities Council

Centre for eo Instrumentation