

# Carbon monoxide monitoring for low-power spacecraft fire detection systems using quantum cascade laser sources at 4.6 $\mu\text{m}$

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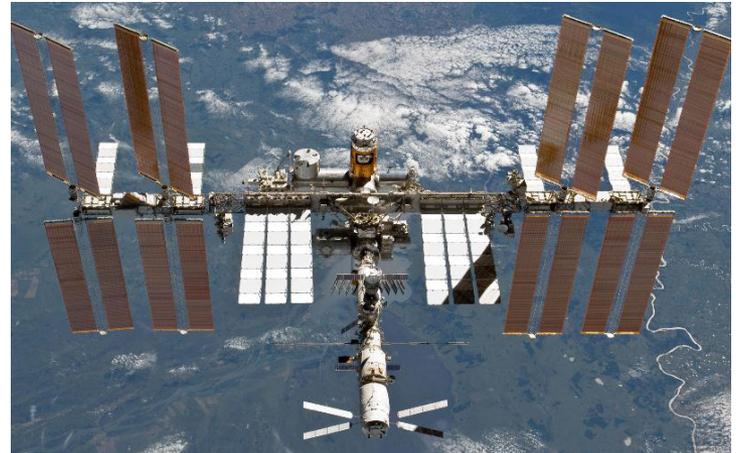


Jet Propulsion Laboratory  
California Institute of Technology

# CO detection for spacecraft fire safety

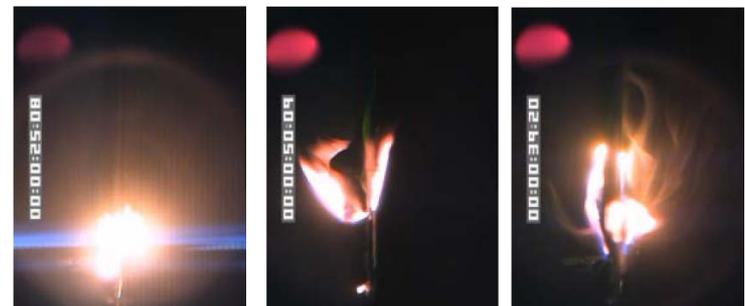
- Early detection of CO, acid gases, and other combustion products is essential to manned spaceflight safety
- Laser absorption spectrometers provide advantages over other chemical sensors:
  - **Low detection limit** – with sufficient effective interaction length
  - **Large dynamic range** – using optimized sampling
  - **Gas specificity** – with proper wavelength selection
  - **Fast response time** – limited by flow rate
  - **No consumables** – performance independent of past exposure
- Detection instruments must have excellent **reliability**, but with **minimal size, weight, and power consumption**

International Space Station, March 2011



Credit: NASA

Low-gravity combustion tests of common spacecraft plastics



Mylar

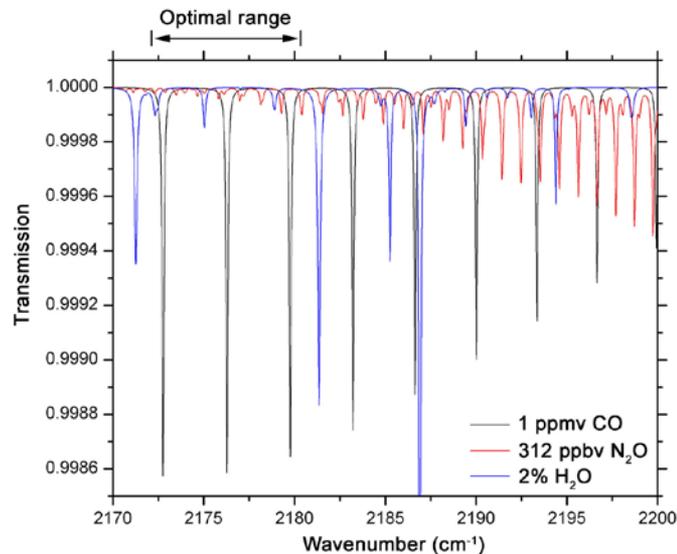
Ultem 1000

Nomex

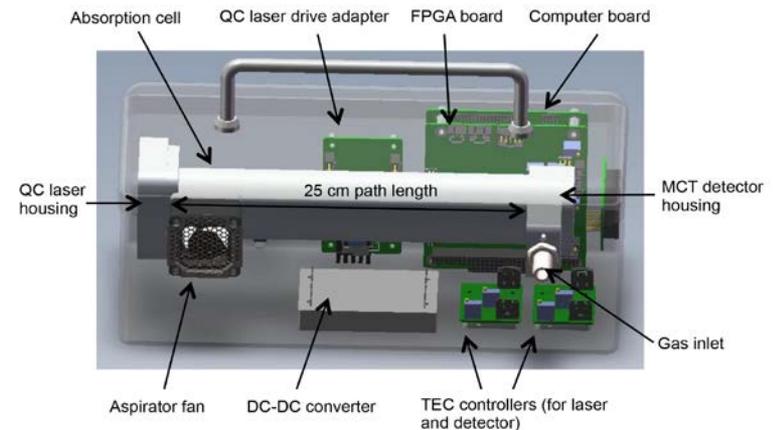
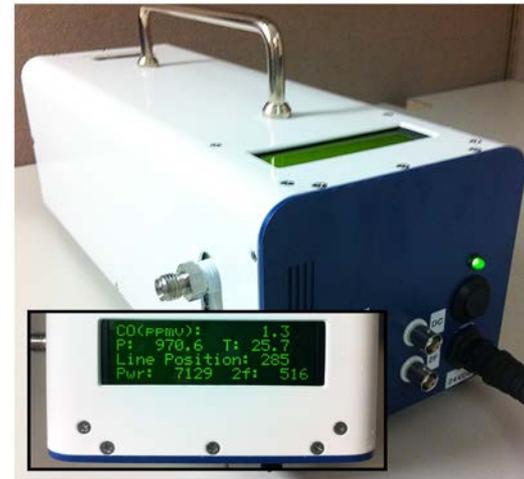


# Portable laser absorption spectrometer for CO monitoring

- Strength of fundamental ro-vibrational CO lines near  $4.6\ \mu\text{m}$  allow for minimal interaction length in the absorption cell
- Instrument designed for 0.1 to 500 ppmv CO detection and refresh rate below 1 s:
  - 25 cm single-pass absorption cell with single-mode QC laser source and commercial MCT detector
  - Simultaneous collection of raw absorption and second-harmonic spectra
- Commercial QC lasers not suitable for low power consumption



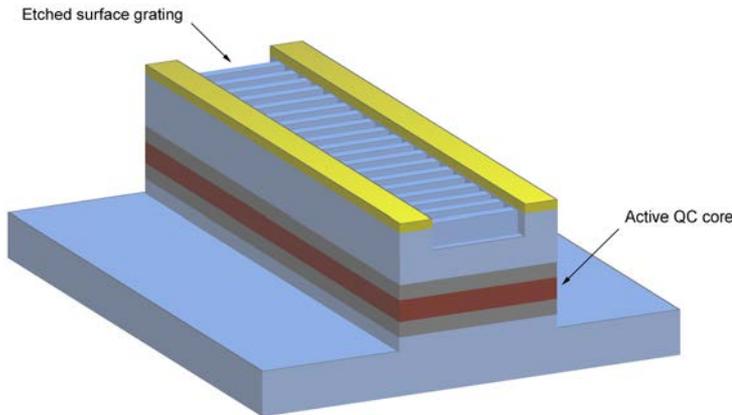
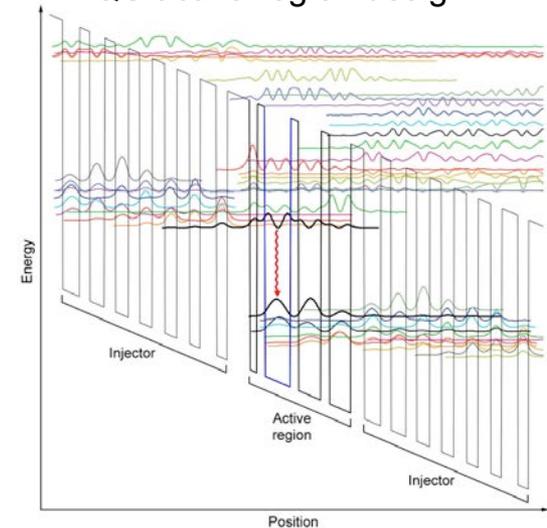
Prototype CO detection instrument



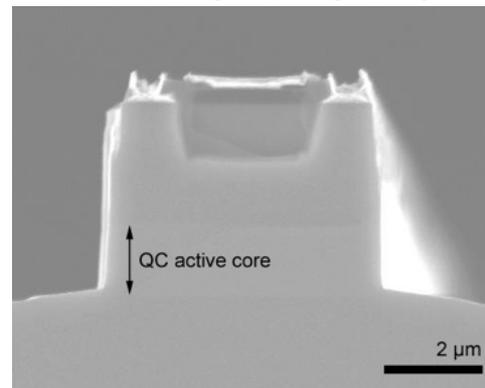
# Single-mode QC laser fabrication

- Active region grown by MBE with InGaAs/AlInAs strain-balanced design adapted from Evans, *et al.* *APL* **91**, 071101 (2007)
- Deep-etched surface gratings for distributed feedback (no epitaxial regrowth required)
- Narrow dry-etched ridge minimizes active area to reduce power consumption

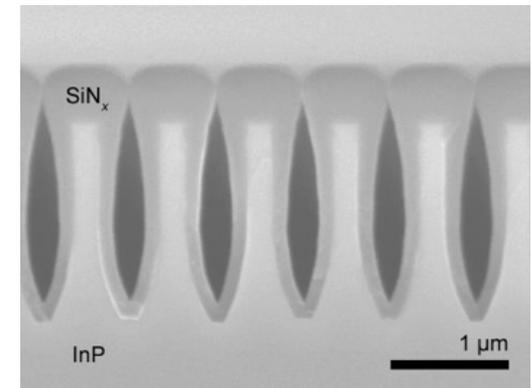
QC active-region design



Laser ridge with grating



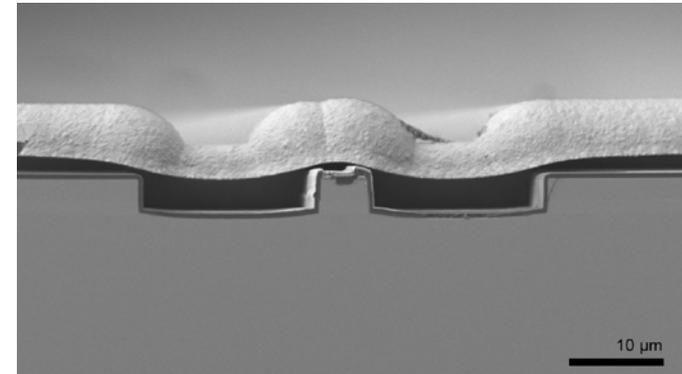
Grating cross section



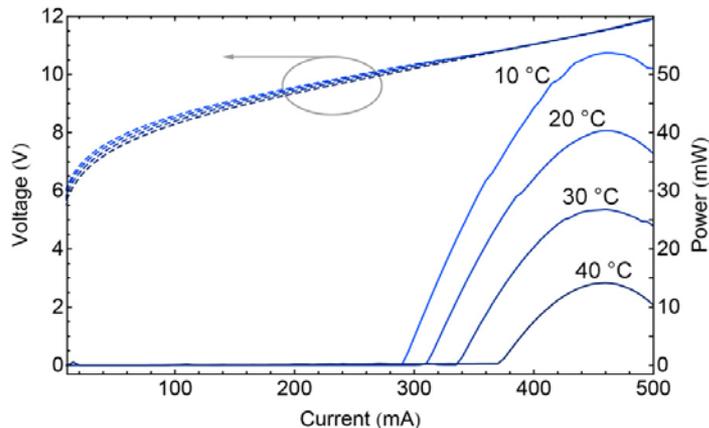
# QC laser performance

- CW laser operation near room temperature with 3 - 4 W power consumption
- Optimal emission wavelength near 4.8  $\mu\text{m}$  for first-generation devices – redesigned active region currently being grown

QC laser with etched surface grating and electroplated Au contact



CW light-current-voltage performance (epi-down mounted)



Emission spectra and thermal wavelength tuning

