Low-cost trace chemical detection system *

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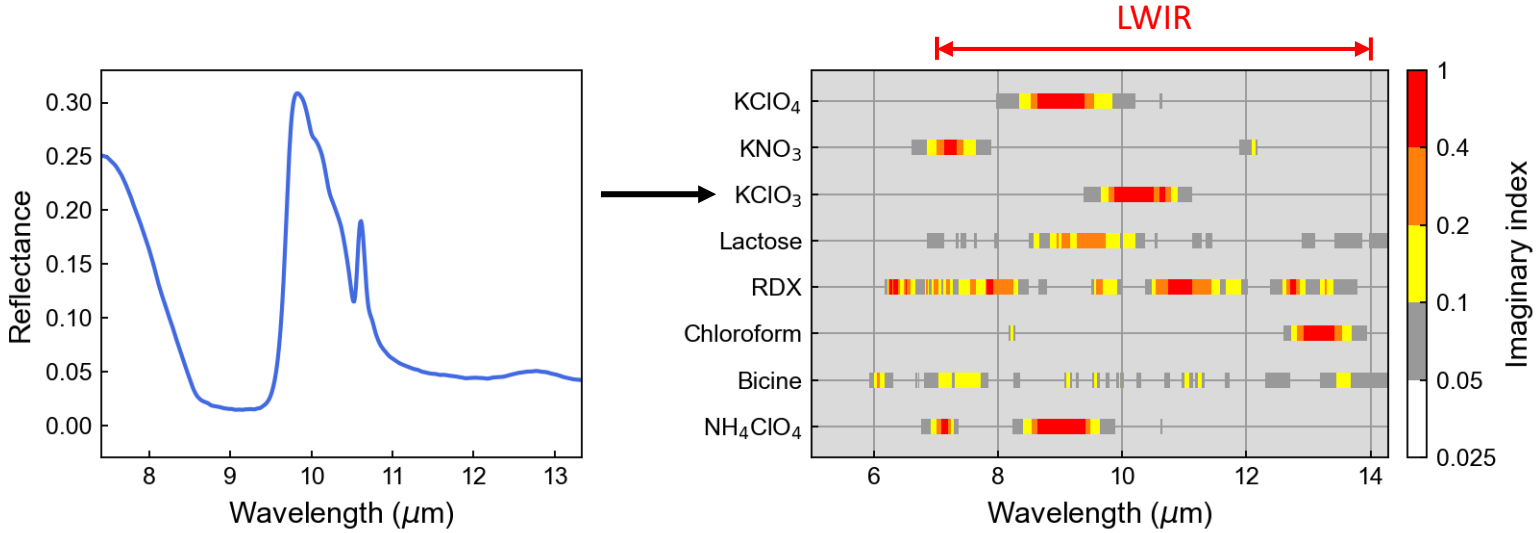
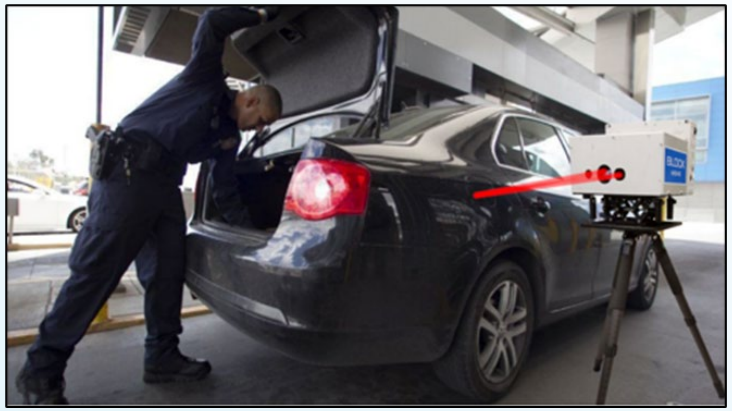
LWIR trace chemical detection

Technology: long-wavelength infrared (LWIR) optical spectroscopy

- Spans 7-14 µm
- Probes molecular vibration modes of chemicals
- Chemicals have distinct spectral features, enabling identification

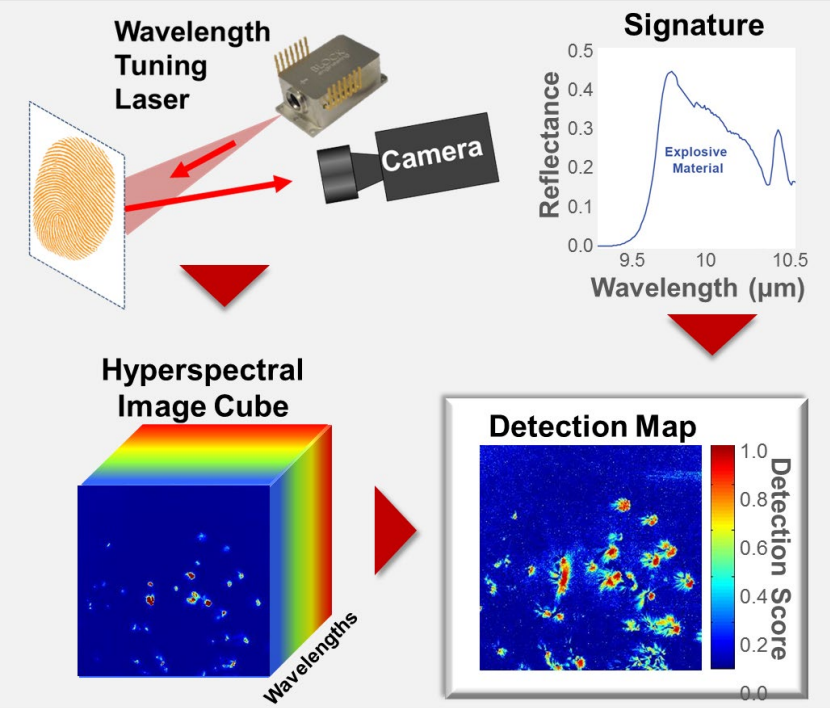




Goal: detection of trace amounts of explosives and narcotics on automobiles at vehicle checkpoints

- Non-intrusively scan handles, trunks
- Important: portability, cost
- Standoff distance up to 2 meters

Hyperspectral imaging (HSI)



1. Target is illuminated with a tunable quantum cascade laser (QCL)
2. Scattered light from particles is collected by LWIR camera
   - Specular reflection from surface is not imaged
3. QCL wavelength is tuned while the LWIR camera acquires frames

Result is a **hypercube**: a 3 dimensional snapshot of the target's spatial and spectral characteristics

- By selecting a region of interest, obtain **reflectance spectrum**

Advantages:

- Can detect trace chemicals (<1 $^{\mu g}/_{cm^2}$)
- Large standoff distances (30 m tested)

Microbolometer vs MCT detector

Previous work was conducted by Block using a mercury cadmium telluride (MCT) camera

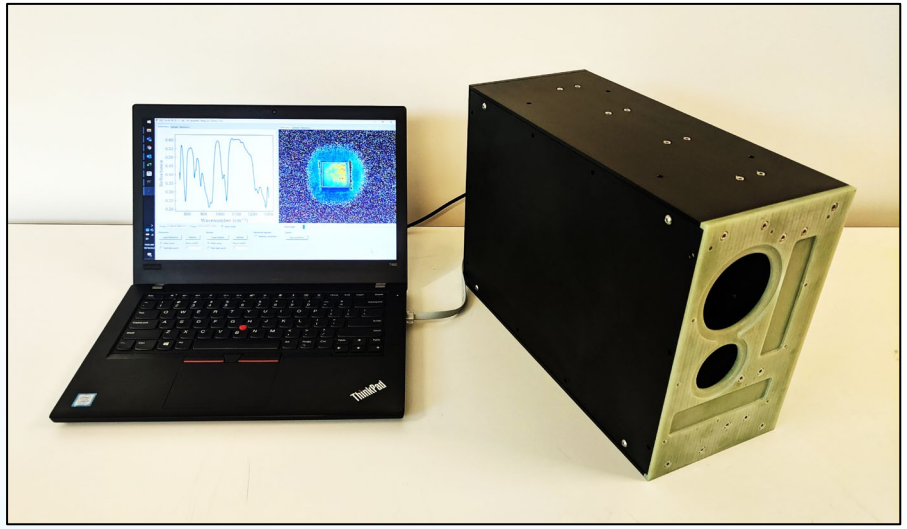
+ High signal-to-noise ratio (SNR), fast frame rate allow scanning of large areas
- Requires liquid nitrogen, not portable

Here, we use a commercially-available uncooled microbolometer

+ Very low SWaP enables low-cost, portable system
- Slow frame rate

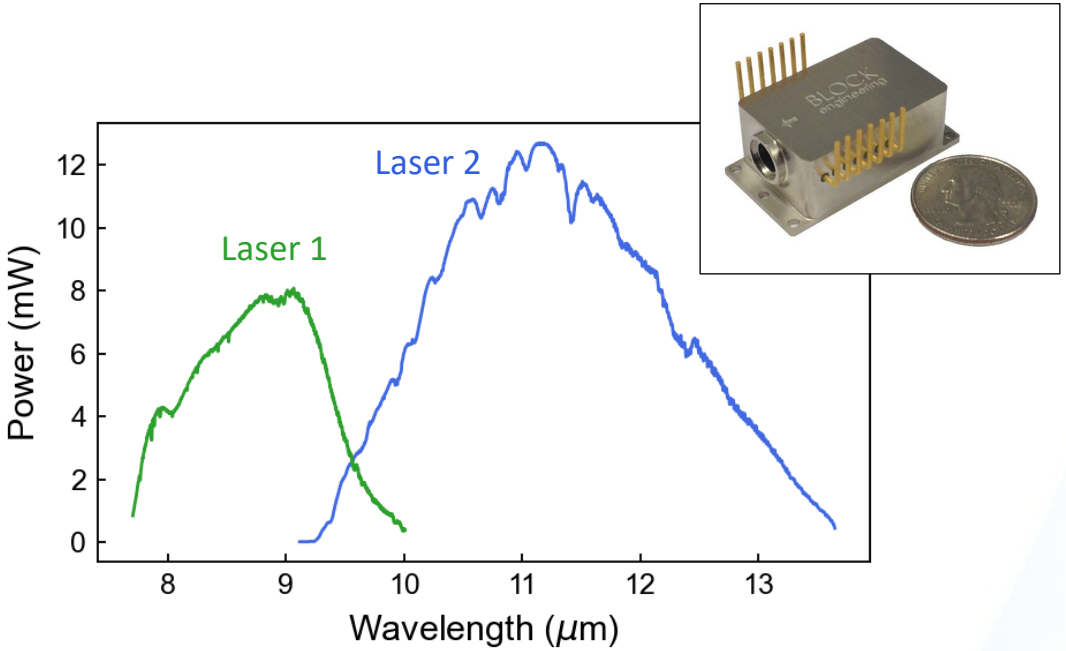
	Microbolometer	MCT camera
Frame rate	Slow, 60 Hz	Fast, > ~ 1kHz
Price	~ $1,000	~ $50,000
Size	Miniature	Moderate
Weight	Light, ~ 0.5 oz	Moderate, > 1 lb
Coolant	Uncooled	Liquid nitrogen or Stirling cycle cryocooler

System design



Gen 1 prototype

- Two tunable QCL lasers, one visible pointer laser
- 8-16 mm beam diameter (adjustable)
- X, Y galvos enable area scan
- Manual focus microbolometer lens assembly, future work will use motorized lens with distance sensing

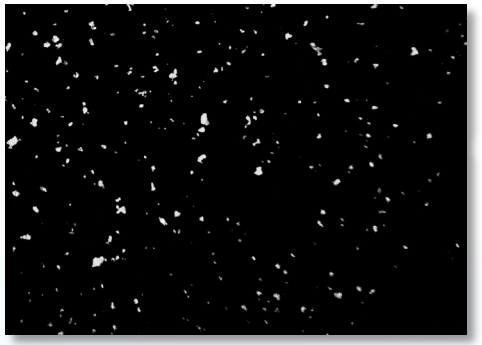


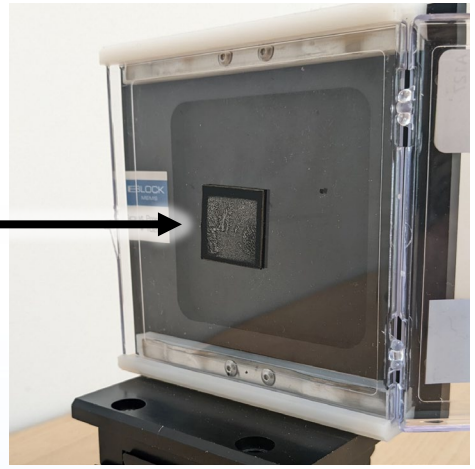
Block's miniature external cavity QCLs

- Wide tuning range
- Multiple lasers can be stitched together

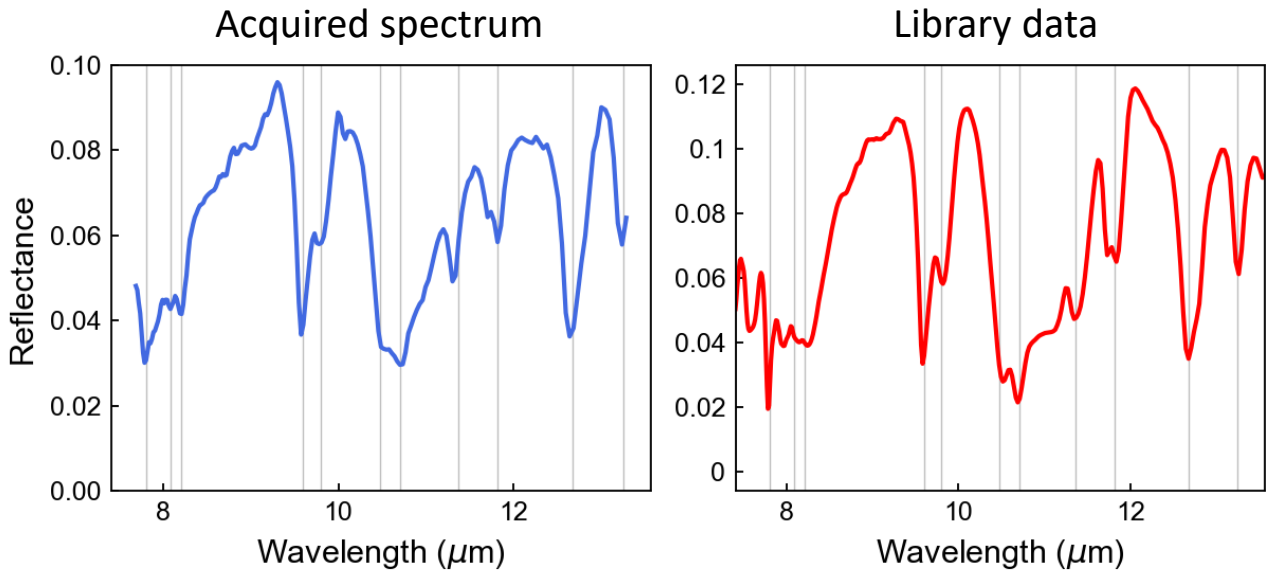
Hypercube acquisition

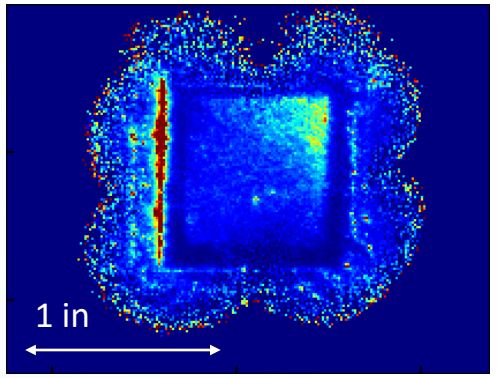
16.3 $\mu g/cm^2$ RDX on car panel





1. System is directed at target using pointer laser
2. Acquire!
   - Lasers tune from 8-13 µm while frames are collected at 60 Hz
   - Measurement time of 4-6 seconds for 205 different wavelengths (25 nm resolution)
3. Data is transferred to control computer

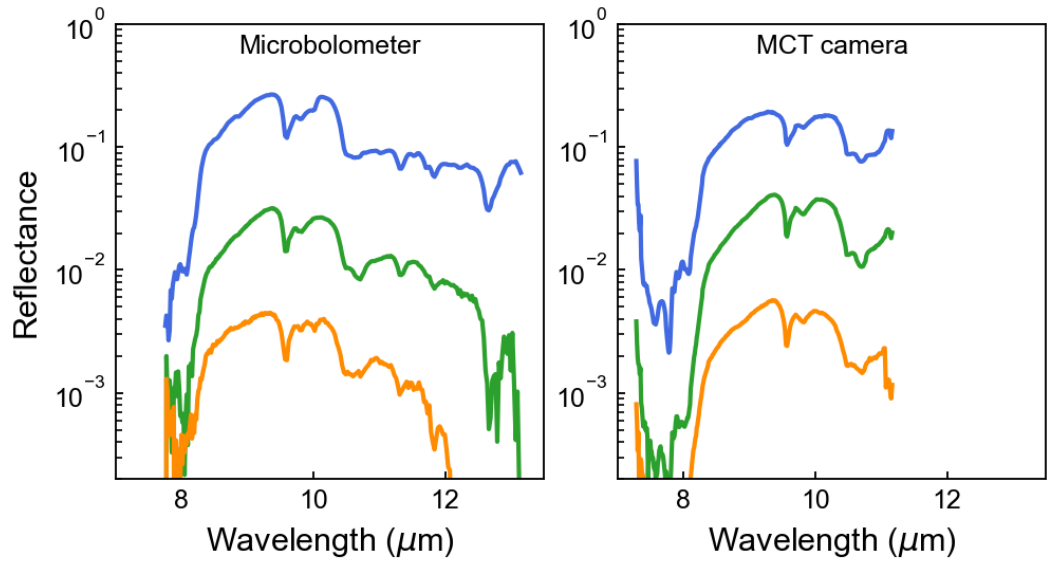




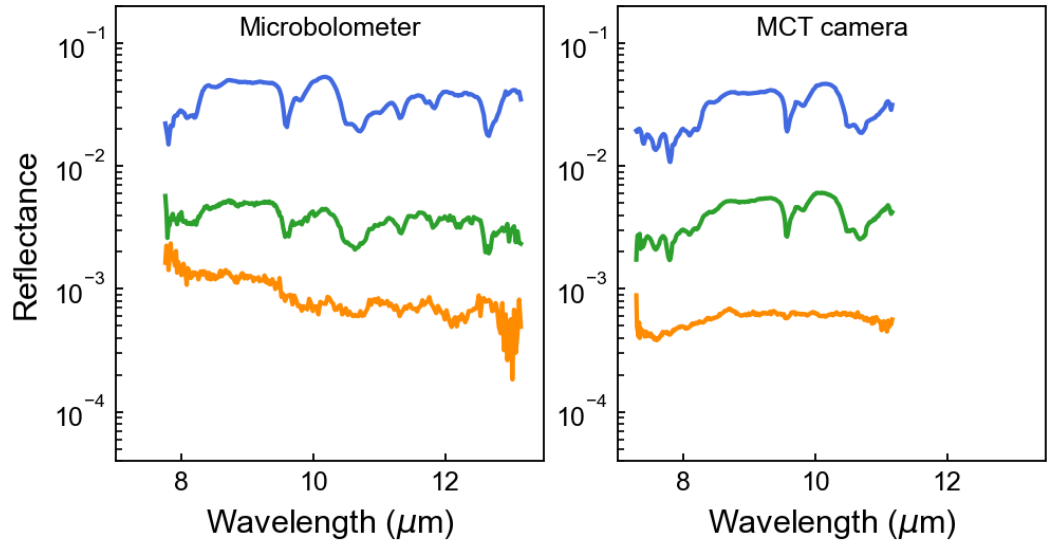
Hyperspectral image (wavelength-averaged)

Comparison of MB and MCT systems

RDX on glass



RDX on car panel



Three concentrations:

- ~ 100 $^{\mu g}/_{cm^2}$
- ~ 10 $^{\mu g}/_{cm^2}$
- ~ 1 $^{\mu g}/_{cm^2}$

Excellent agreement between single-point measurements with microbolometer system and "gold standard" MCT data

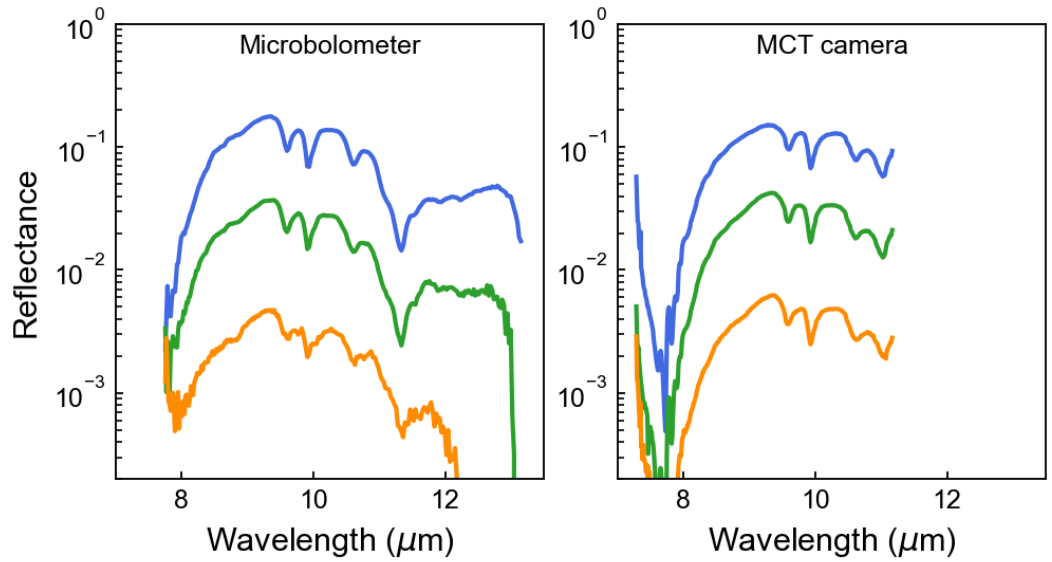
Can detect down to

- 1 $^{\mu g}/_{cm^2}$ on moderately reflective surfaces (glass, aluminum)
- 10 $^{\mu g}/_{cm^2}$ on car panels

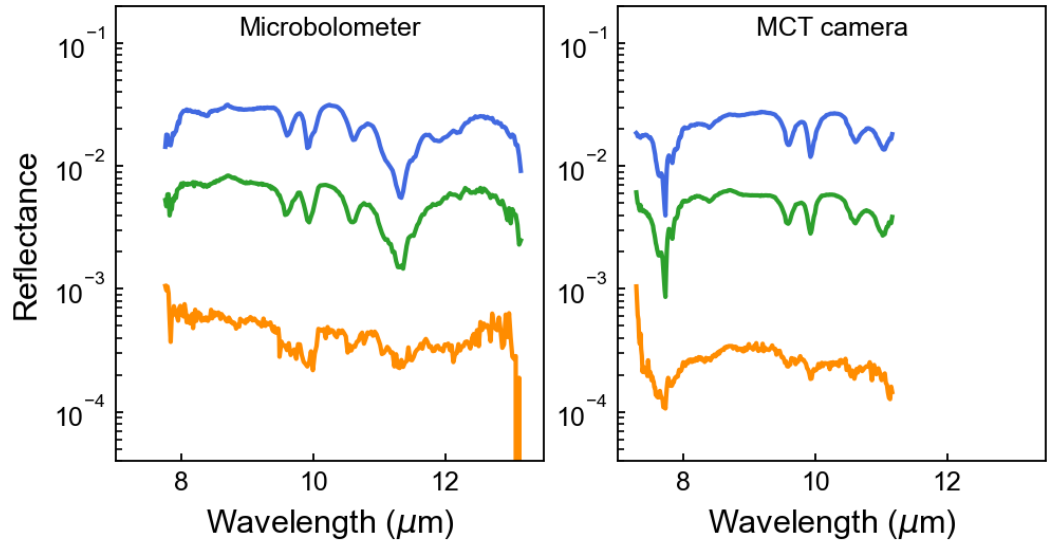
Data quality can be further increased with longer scan times

Comparison of MB and MCT systems

PETN on glass



PETN on car panel



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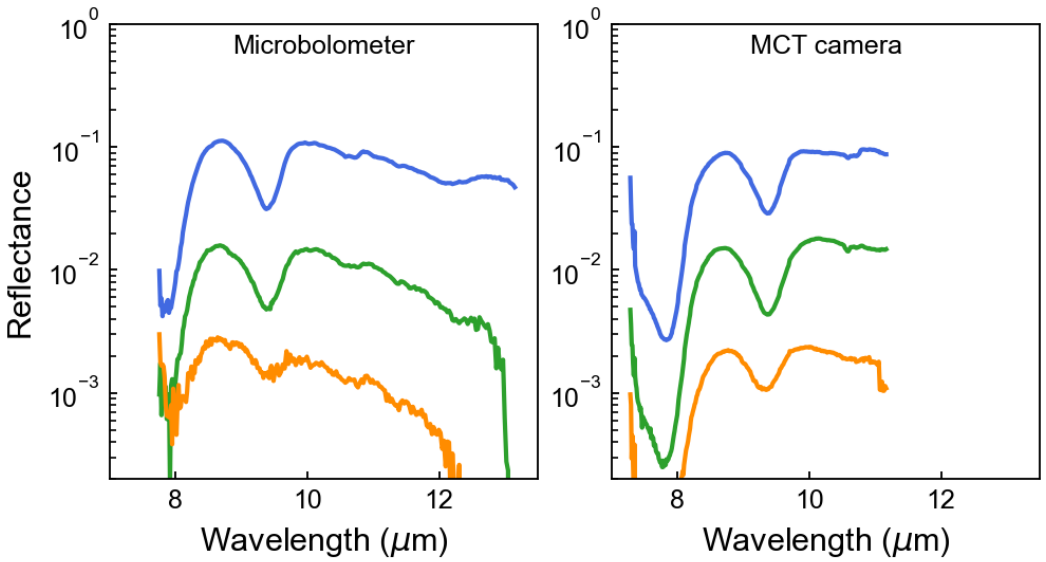
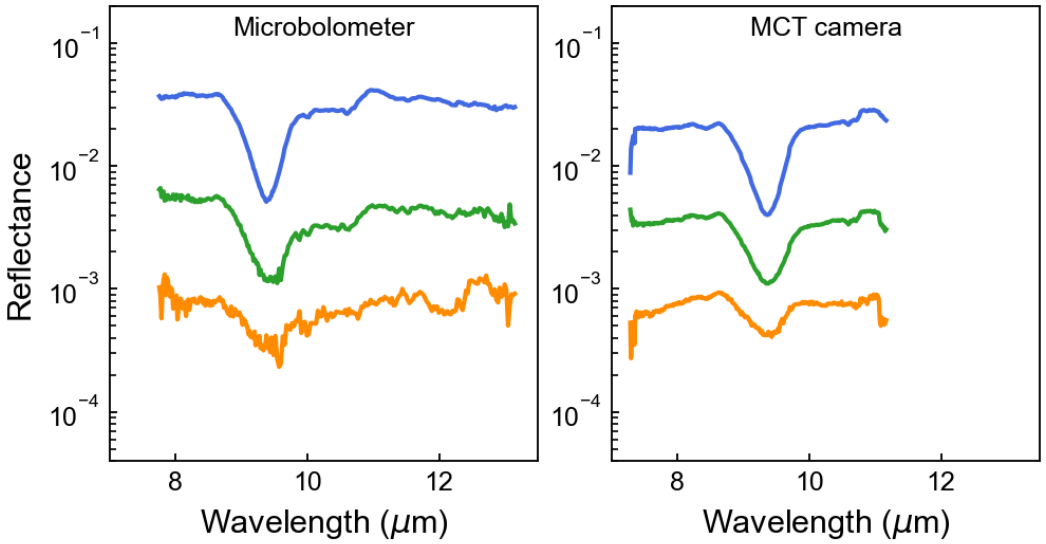
Comparison of MB and MCT systems

$KClO_4$ on glass



$KClO_4$ on car panel



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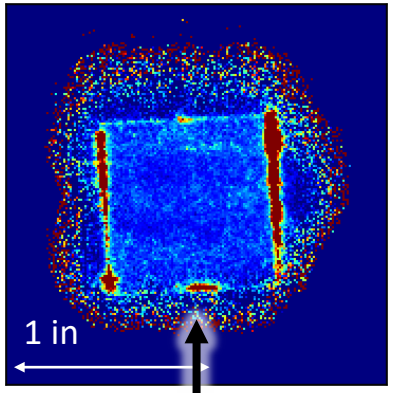
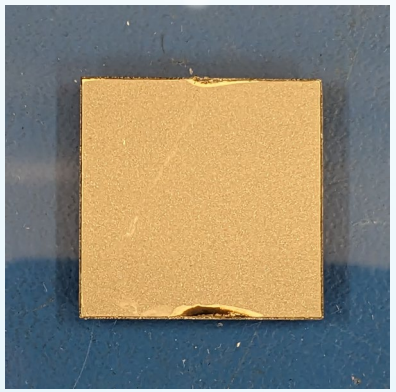
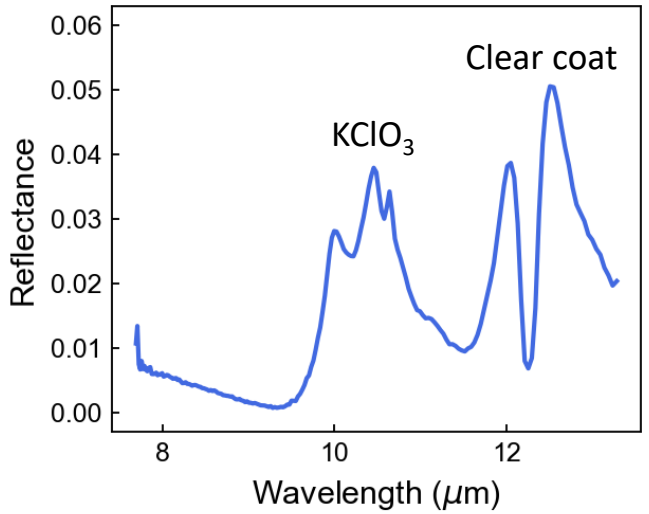
Long standoff distance operation

1.5 meters

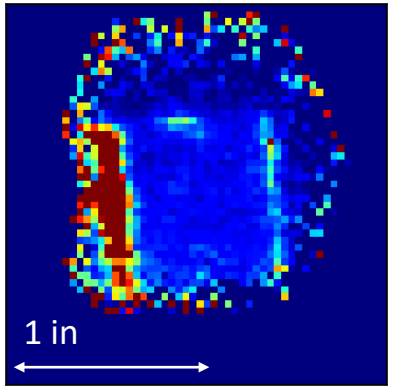


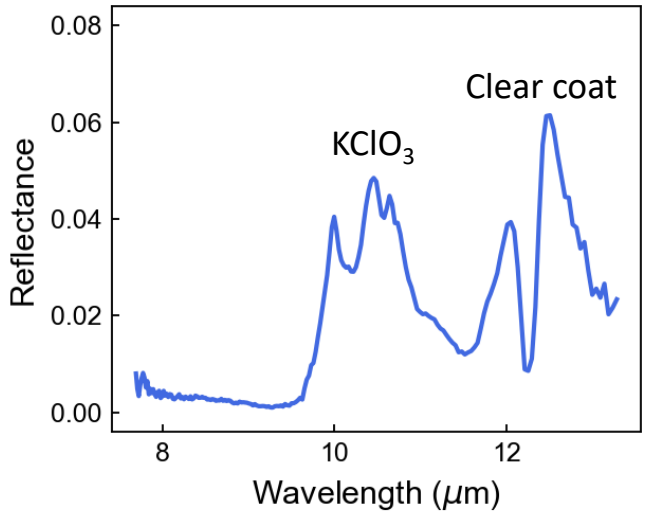




18.6 $^{\mu g}/_{cm^2}$ $KClO_3$
on painted car panel

5 meters





System has been tested with standoff distances up to 5 meters

- Can still clearly see spectral features of chemicals with 10 $^{\mu g}/_{cm^2}$ concentration (< 60 s acquisition time)

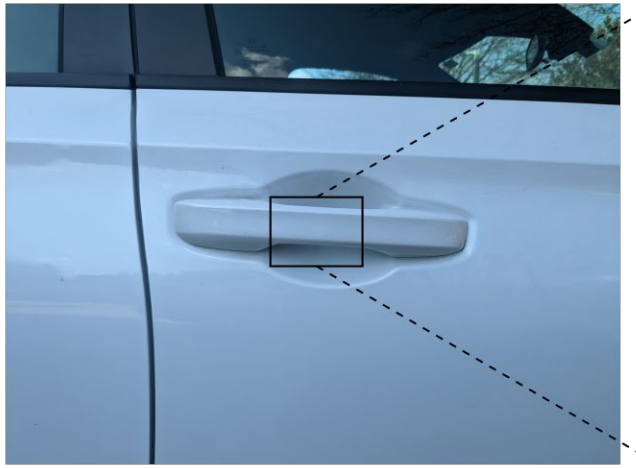
Detection of trace explosives on automobiles

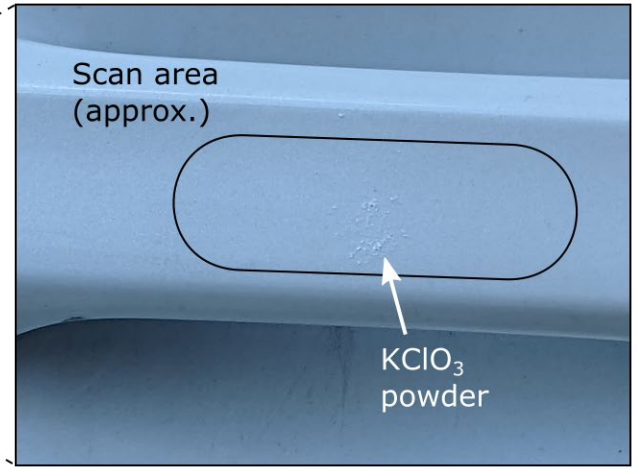
System was used to detect trace amounts of explosive powder on a car handle

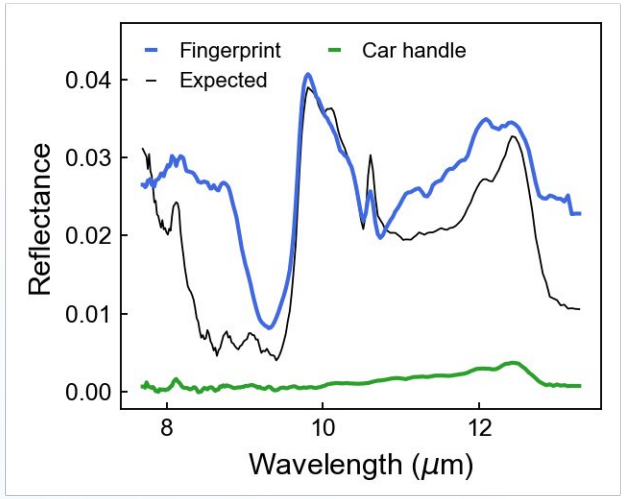
- Fingerprint of $KClO_3$

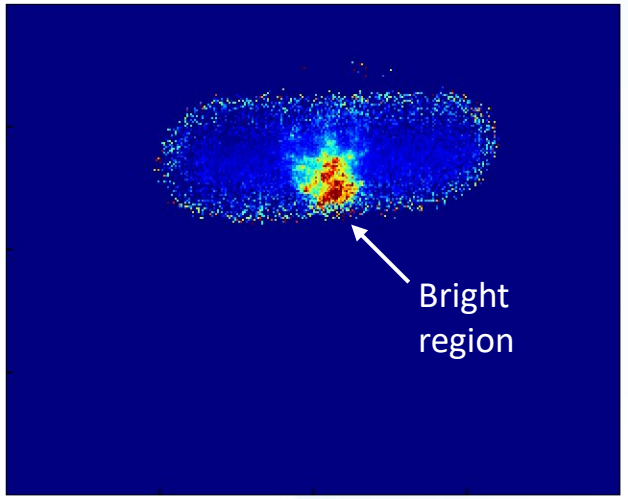
Features of $KClO_3$ can clearly be observed!

- Car handle is relatively spectrally neutral









Summary

We have demonstrated hyperspectral imaging of trace chemicals using a microbolometer-based system

+ Lower SWaP-C than previous high-performance MCT camera system
+ Signal quality approaches level of MCT camera system
- Slower scan speeds (4-6 seconds per beam spot)

The application of detecting trace chemicals on car panels is favorable for detection

- Limit of detection down to…
  - ~ 1 $\mu g/cm^2$ on metal and glass
  - 10 $\mu g/cm^2$ car panels and smooth painted surfaces
- We have demonstrated functionality up to 5 meters

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- **Ali Fadel** (PM), **Patrick LaFontant**