Mid-IR Laser Sensors for Application in Energy Systems and Environment

Aamir Farooq

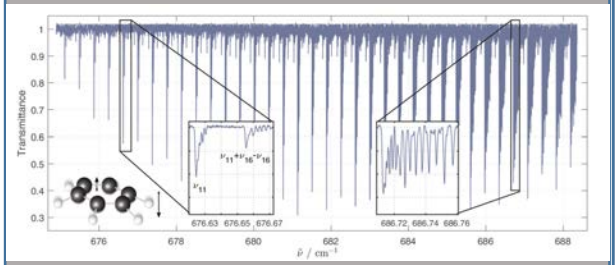
Chemical Kinetics and Laser Sensors Laboratory

King Abdullah University of Science and Technology (KAUST), Saudi Arabia

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

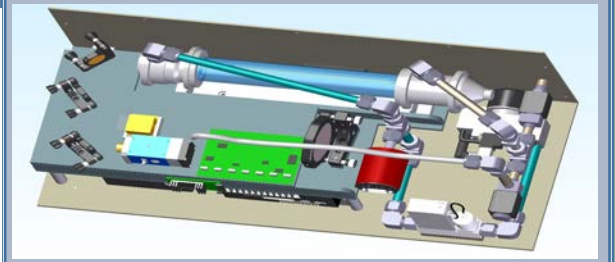
Chemical Kinetics and Laser Sensors Lab

Precision Spectroscopy



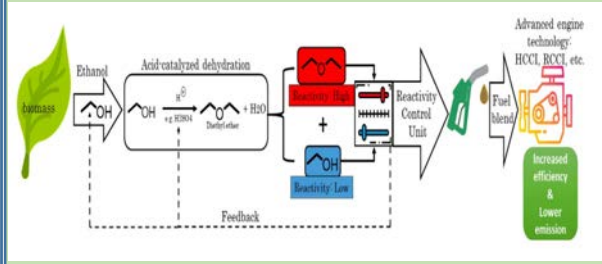
- Rotational and vibrational spectroscopy
- High-temperature and high-pressure spectra
- Collisional narrowing, line-mixing
- Spectral database of large molecules
- ML-based property prediction from spectra

Laser Sensors

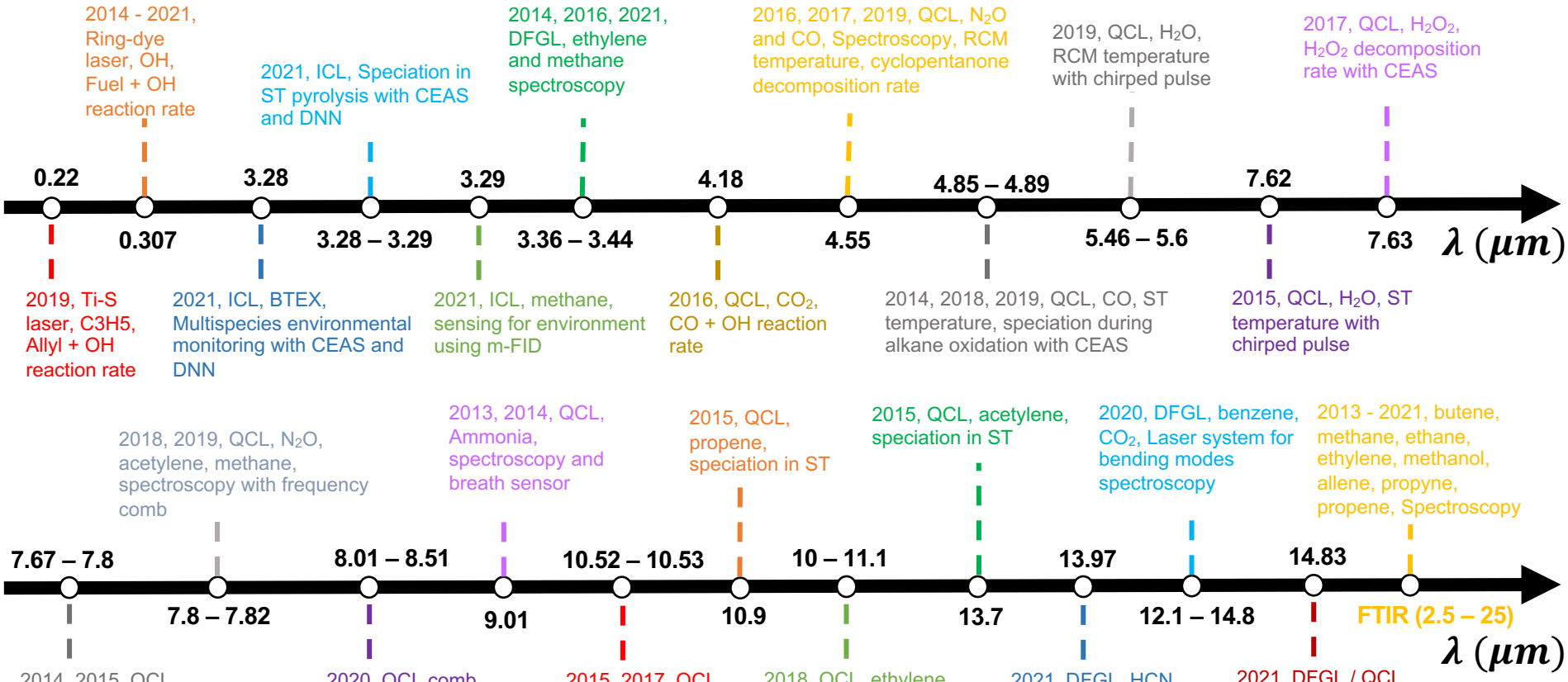


- Compact, portable, selective, sensitive sensors
- Direct absorption and wavelength modulation
- Chirped-pulse and cavity-enhanced techniques
- Application to chemical kinetics, environment-monitoring & biomedical

Fuel Kinetics

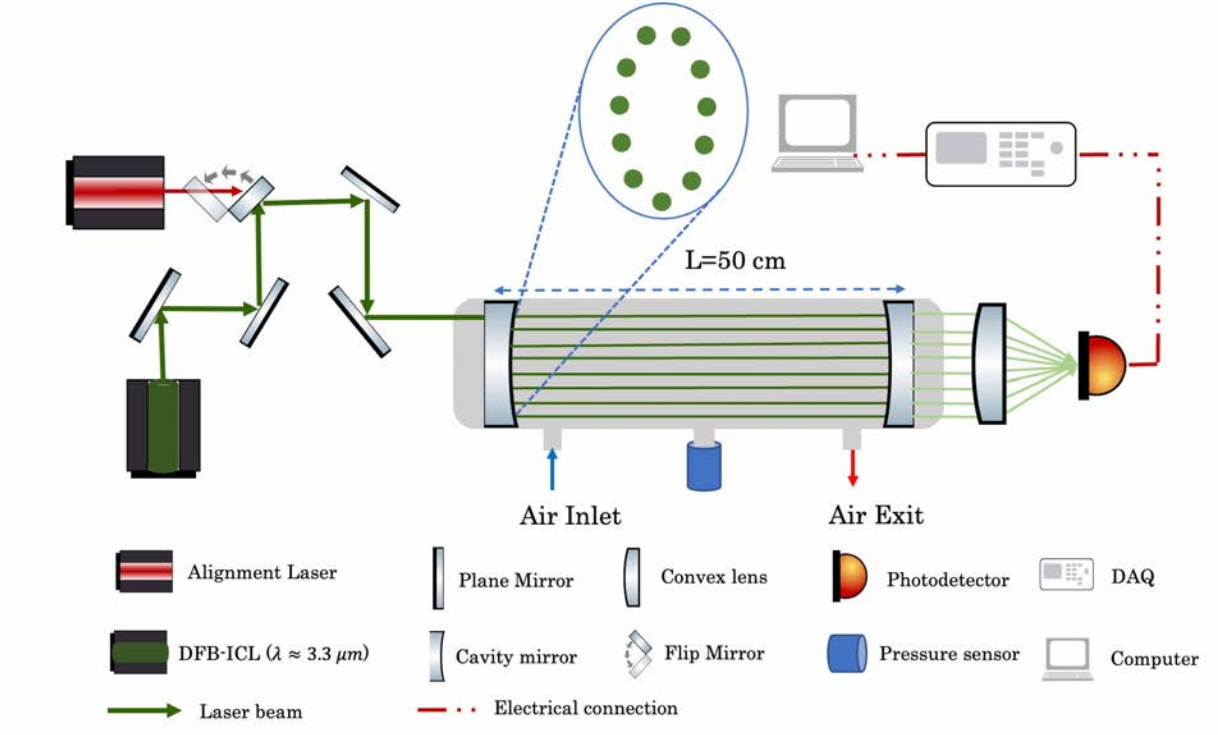


- Low-carbon, zero-carbon and e-fuels
- Efficiency and emission
- Elementary reaction rate measurements
- Ab-initio theoretical calculations
- Data-science based kinetic modelling
- Heterogenous chemistry



جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

Benzene emission sensor



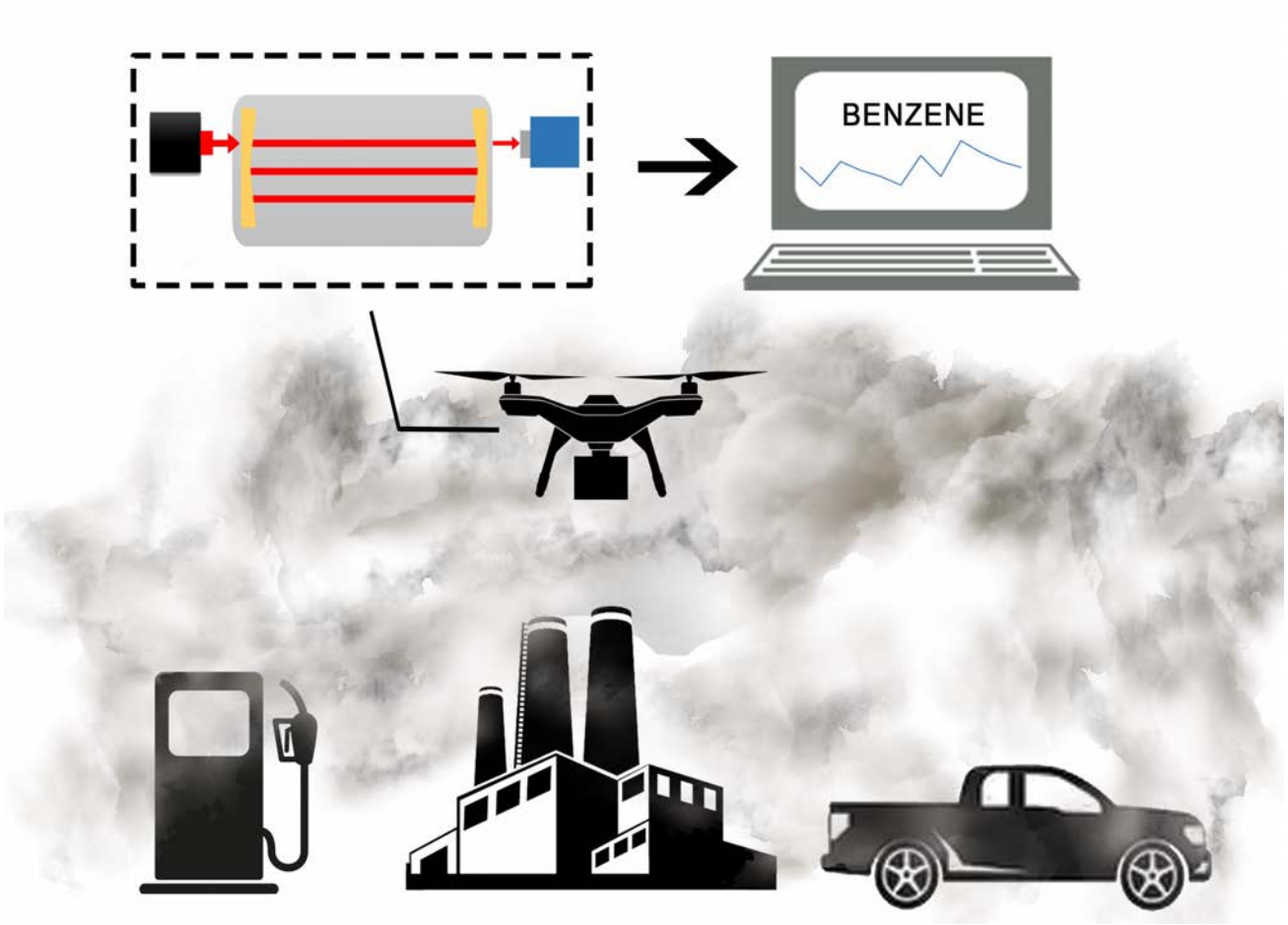
Environmental Protection Department

US Patent pending 17/299,888 (2020)

Mhanna et al., IEEE Express (2021)

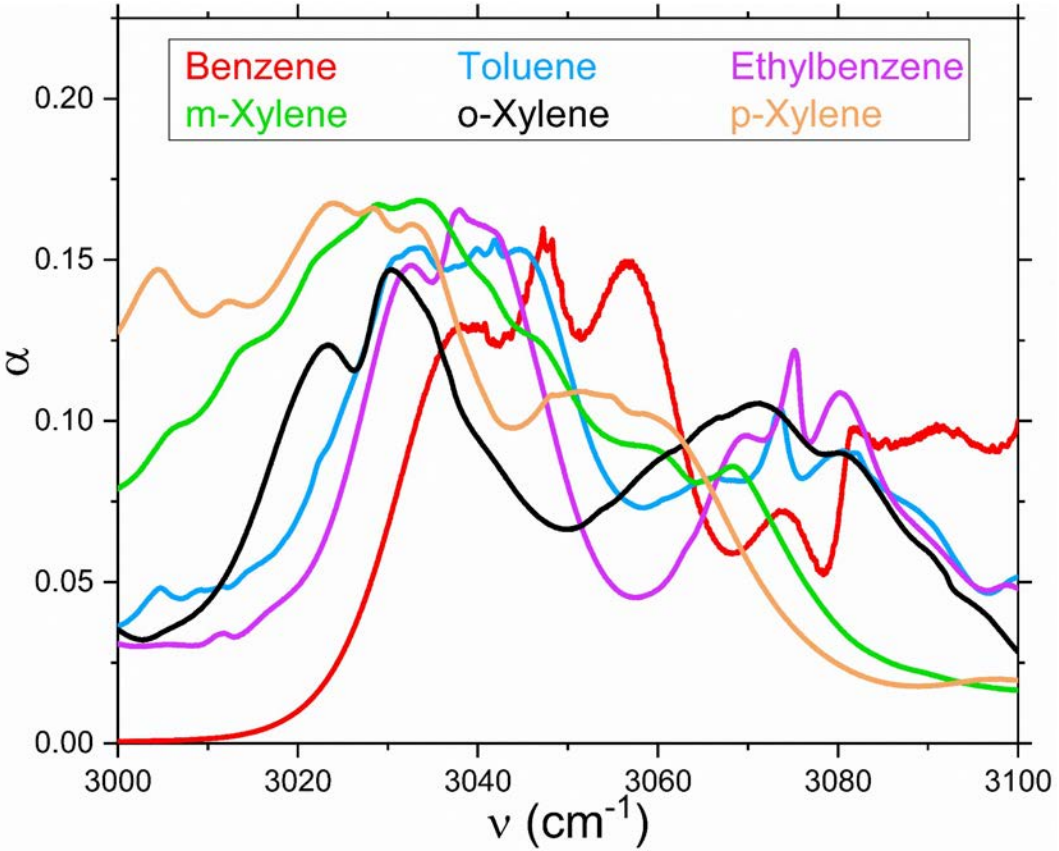
- Non-intrusive, highly sensitive and selective detection of **benzene**
- Cavity-enhanced strategy provides > 1000 increase in sensitivity
- Detection limit of **2 ppb**

Benzene emission sensor



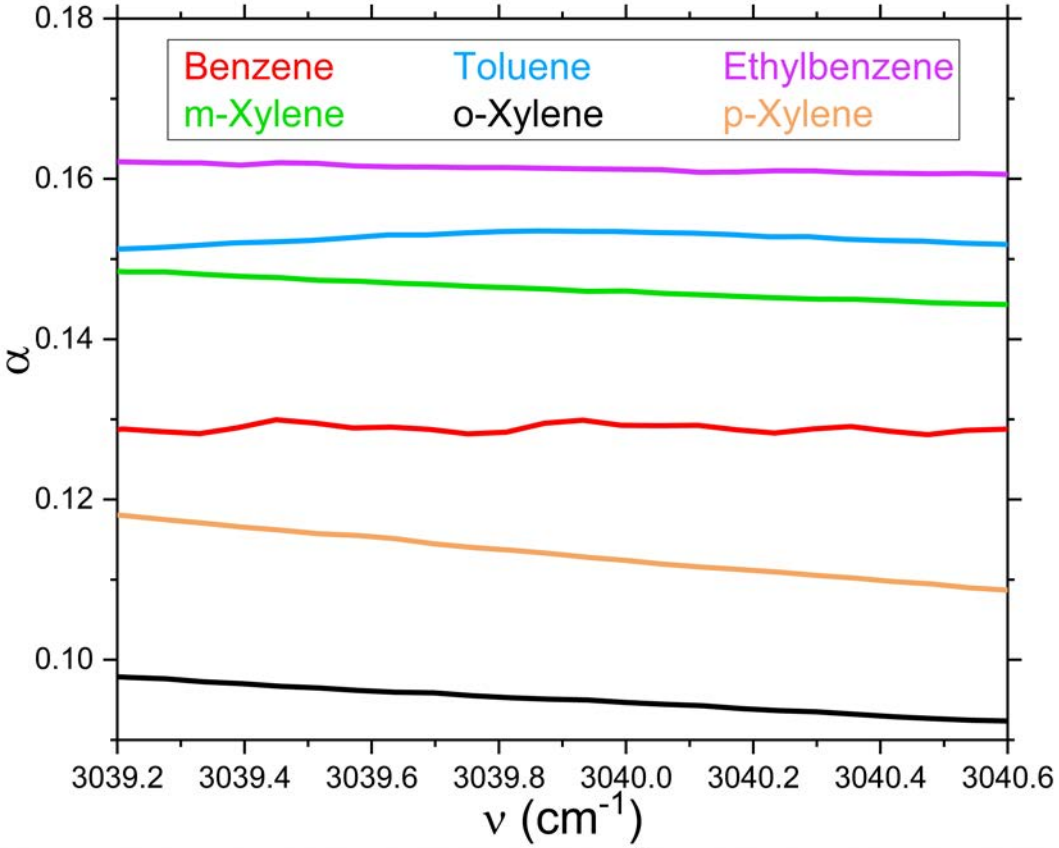
Environmental Protection Department

BTEX emission sensor



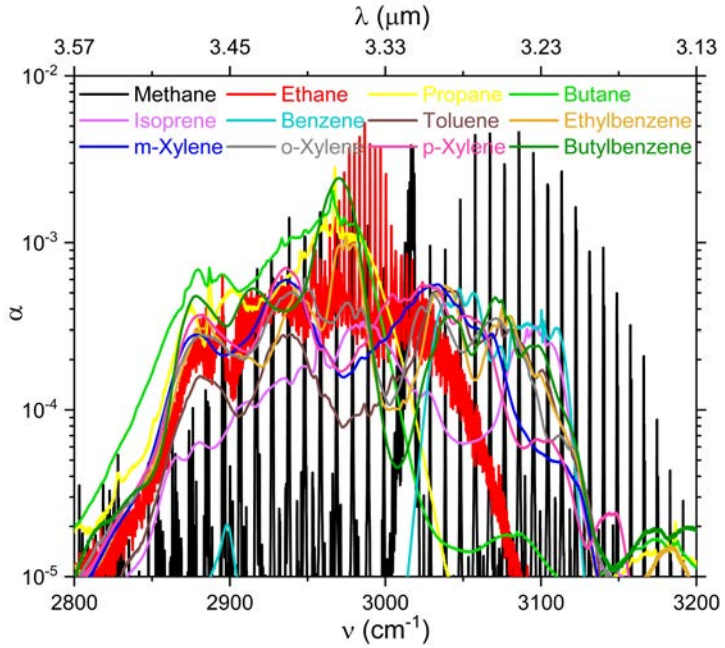
- The spectra are very similar, making it difficult to do selective detection
- Machine learning algorithms for spectral differentiation

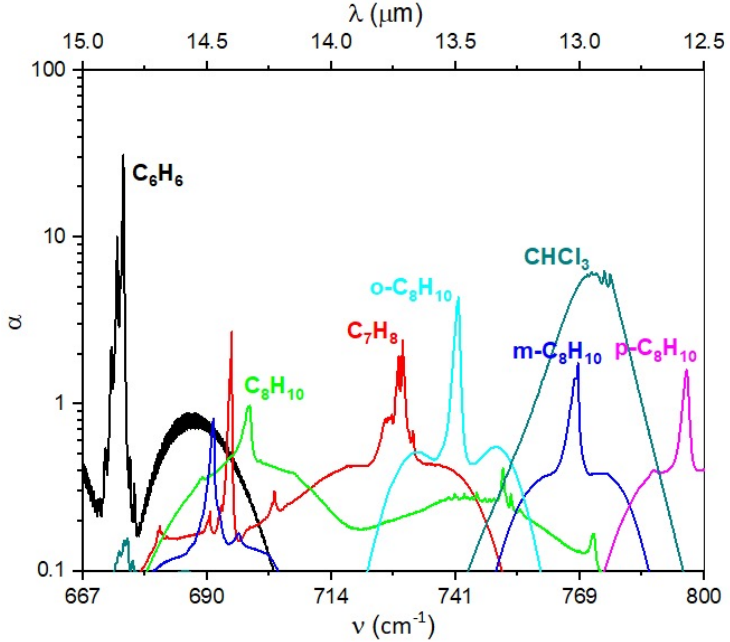
BTEX emission sensor



- The spectra are very similar, making it difficult to do selective detection
- Machine learning algorithms for spectral differentiation

Long-wavelength Mid-IR





C-H Stretch

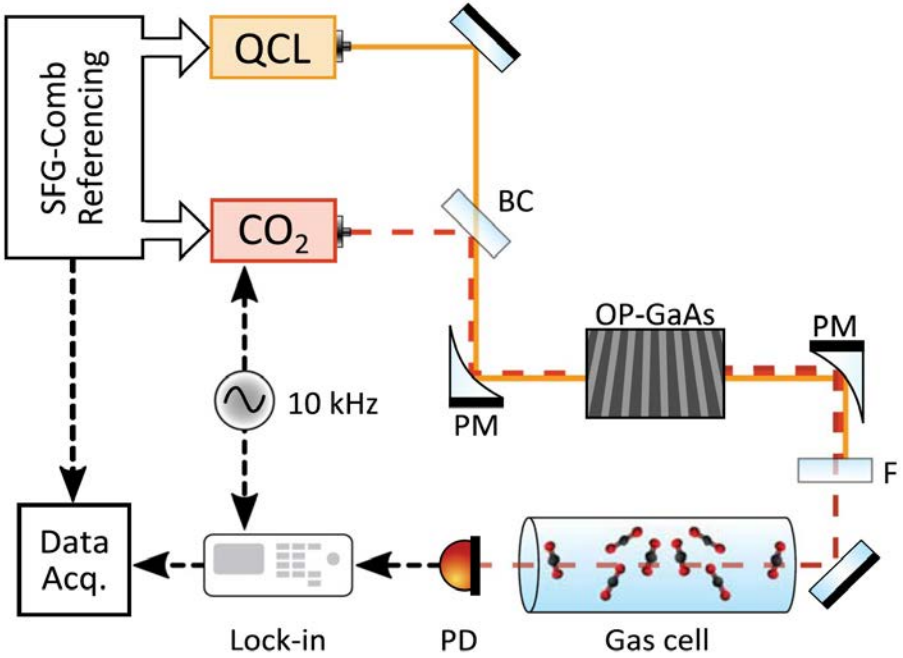
- ✅ Laser availability
- ✅ Multi-species detection
- ❌ Spectral interference

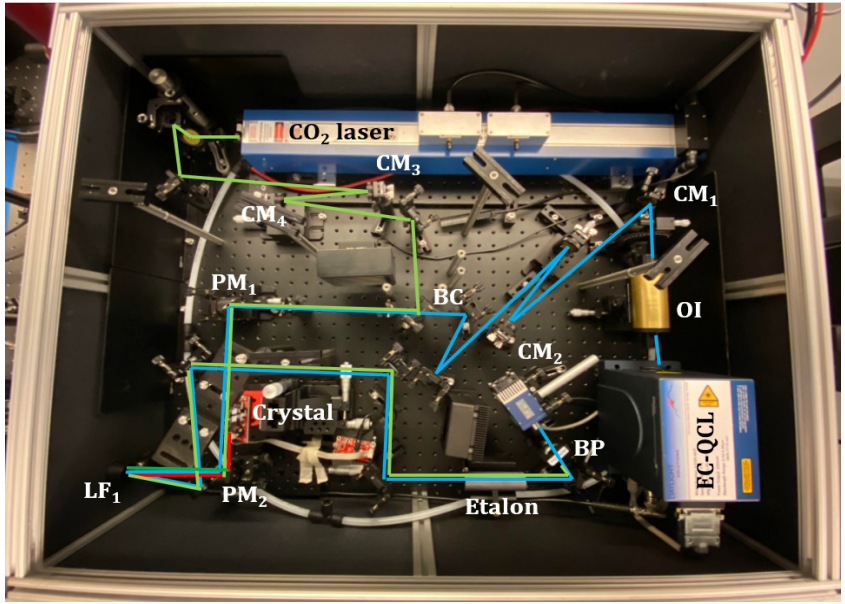
C-H Bend

- ✅ Spectral separation
- ✅ Larger absorption
- ❌ Laser availability

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

Long-wavelength Mid-IR laser

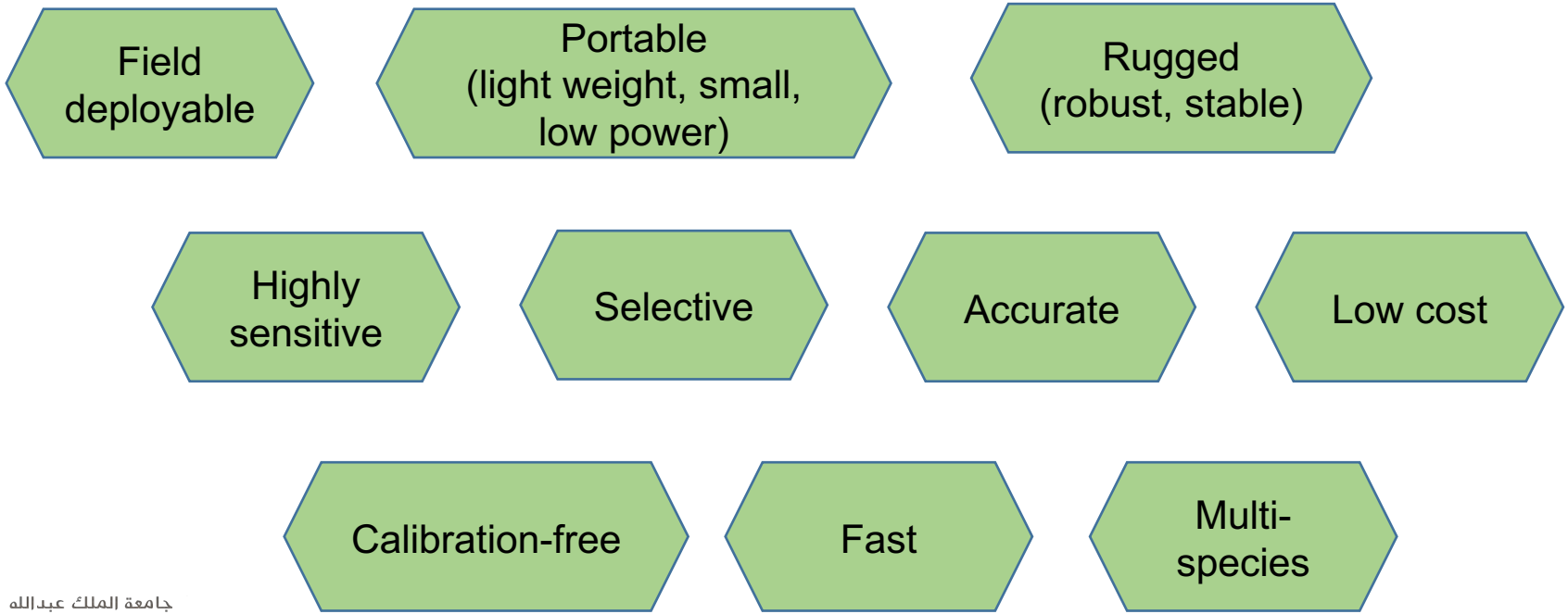




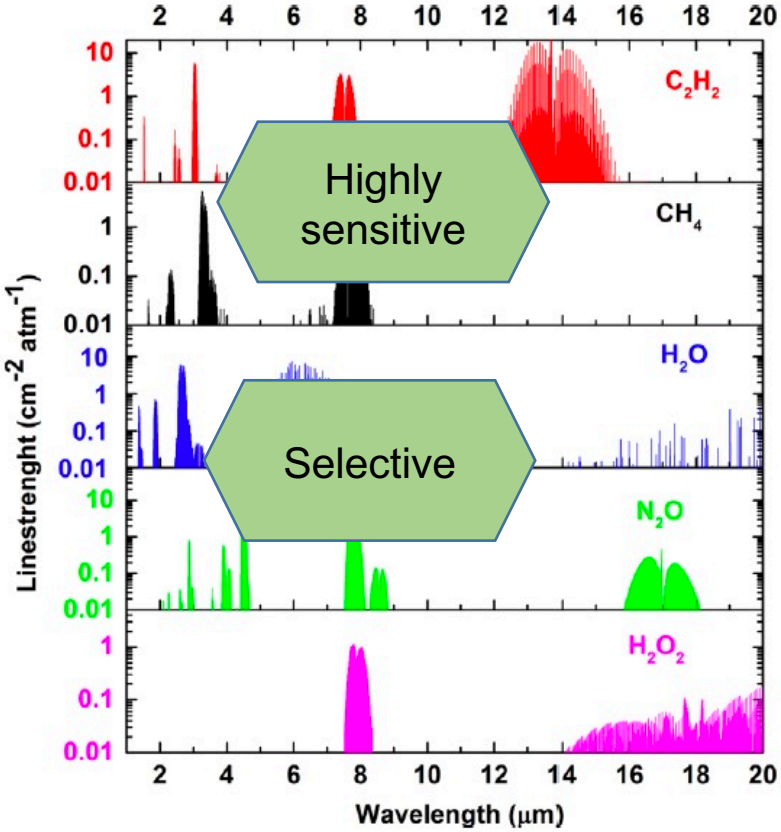
Lamperti et al., Communication Physics (2020)
Shakfa, Jin, Mhanna, Marangoni, Farooq, PROCI (2021)

What does the industry need?

Sense everything, everywhere, all the time!



Why Mid-IR?



Why not Mid-IR?

- Field deployable
- Portable (light weight, small, low power)
- Rugged (robust, stable)
- Low cost

What do we need in mid-IR technology?

Better Lasers

- ✓ Widely tunable
- ✓ Fiber-coupled
- ✓ Low-power consumption
- ✓ Room-T operation
  (with only TE cooling)
- ✓ Low-cost

Better Detectors

- ✓ High sensitivity
- ✓ Fiber-coupled
- ✓ Low-power operation
- ✓ Fast time response
- ✓ Large area
- ✓ Balanced detection

Optical Components

- ✓ Single-mode fibers
- ✓ Fabry-Perot etalons
- ✓ High-reflectivity cavity mirrors
- ✓ Compact laser controllers

شكراً

THANK YOU!