Tunable Laser for Methane Sensing

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OUTLINE

ARPA-E
#1128-1549
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Houston,
TX, 77005

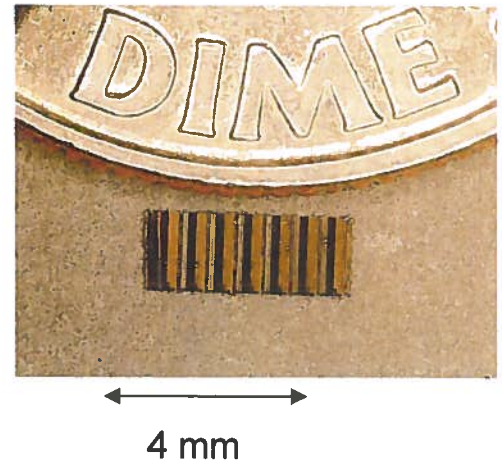
- Novel Laser-Based Trace Gas Sensor Technology
  - Mid-IR TDLAS based on a Novel Multipass Gas Cell Design
- Examples of three Mid-infrared Trace Gas Species
  - CH_4, CH4 isotopes & C_2H_6,
- Future Directions and Conclusions
  - xxxxx

Mid-IR Source Requirements for Laser based Gas Sensing

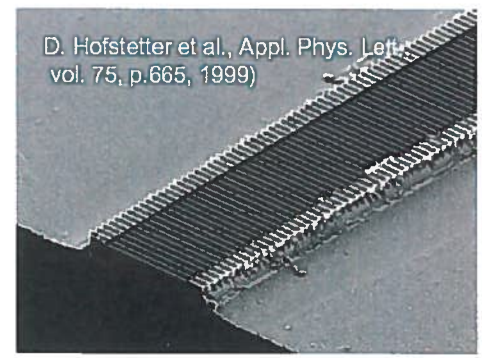
REQUIREMENTS	IR LASER SOURCE
Sensitivity (% to pptv)	Optimum Wavelength and Power
Selectivity (Spectral Resolution) or Specificity	Stable Single Mode Operation and Narrow Linewidth
Multi-gas Components, Multiple Absorption Lines, and Broadband Absorbers	Mode Hop-Free Wavelength Tunability
Directionality or Cavity Mode Matching	Beam Quality
Rapid Data Acquisition	Fast Time Response Time
Room Temperature Operation	High Wall Plug Efficiency, No Cryogenics or Cooling Water
Field Deployable in Harsh Environments	Compact and Robust

Key Characteristics of Mid-IR QCL & ICL Sources – Dec. 2015

- **Band – structure engineered devices**
  Emission wavelength is determined by layer thickness – MBE or MOCVD; QCLs operate in the 3 to 24 µm spectral region and ICLs can cover the 3 to 6 µm spectral range.
  - Compact, reliable, stable, long lived, and commercially available
  - Fabry-Perot (FP), single mode (DFB) and multi-wavelength devices

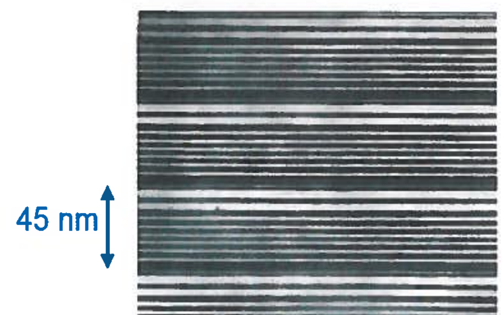


- **Wide spectral tuning ranges in the mid-IR**
  - 1.5 cm^{-1} using injection current control for DFB devices
  - 10-20 cm^{-1} using temperature control for DFB devices
  - ~100 cm^{-1} using current and temperature control for QCLs DFB Array
  - ~ 525 cm^{-1} (22% of c.w.) using an external grating element and FP chips with heterogeneous cascade active region design; also QCL DFB array & Optical Frequency Combs (OFCs) > 100 to <450 cm^{-1} with kHz to sub-kHz resolution and a comb spacing of > 10 GHz

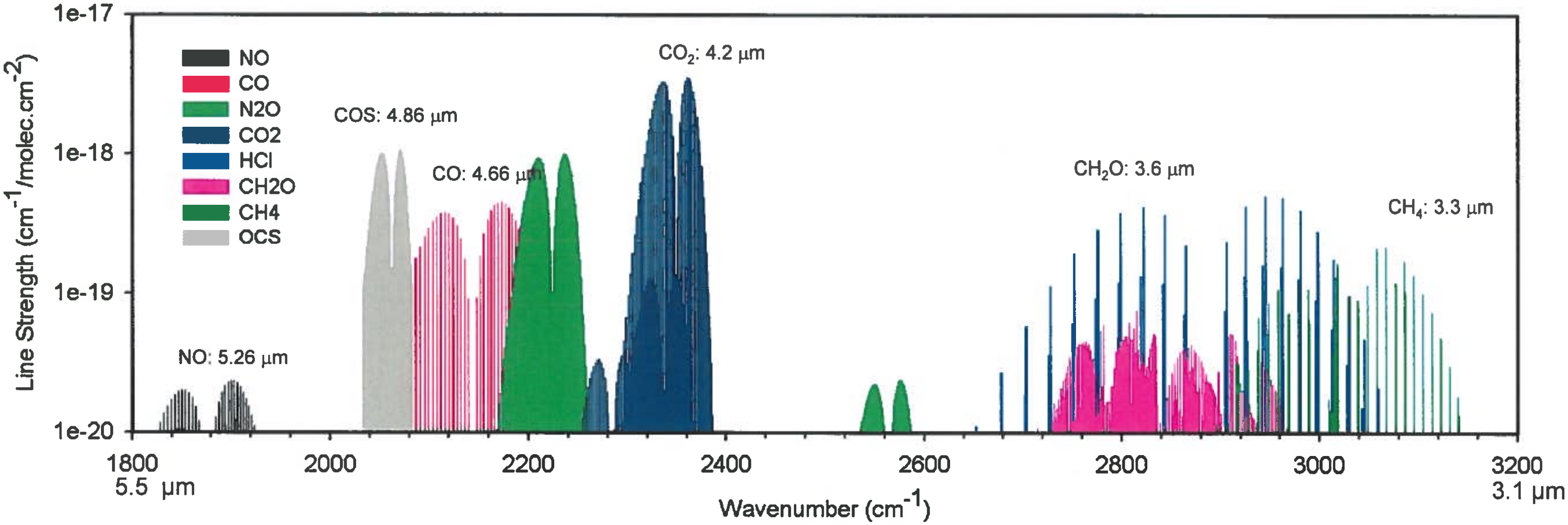


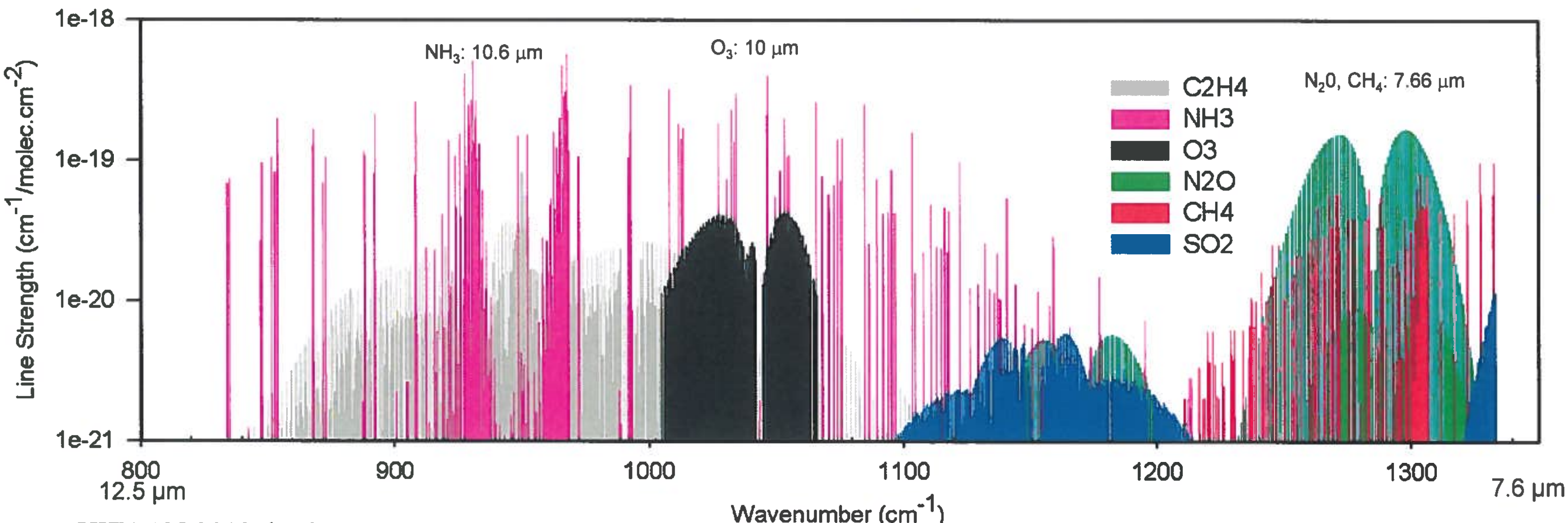
- **Narrow spectral linewidths**
  - CW: 0.1 - 3 MHz & <10kHz with frequency stabilization
  - Pulsed: ~ 300 MHz

- **CW powers of QCLs & ICLs at RT temperature**
  - CW QCL powers of ~ 5 W with 23% wall plug efficiency at 293 K
  - > 600 mW CW DFB at TEC/RT; wall plug efficiency 23% at 4.6 µm
  - **> 5mW CW, DFB ICL at TEC/RT**



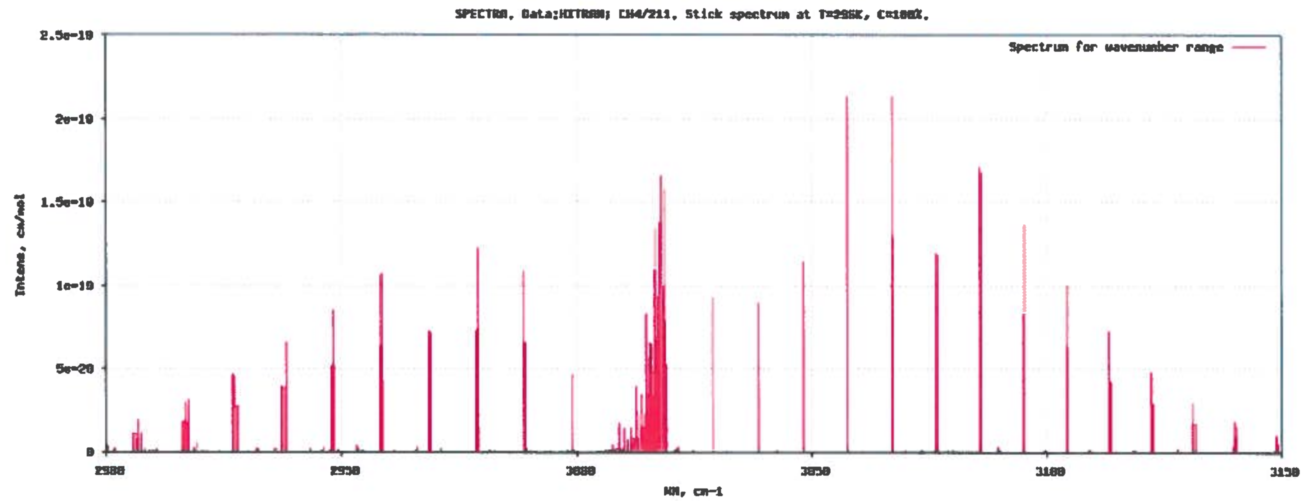
HITRAN Simulated Mid-Infrared Molecular Absorption Spectra



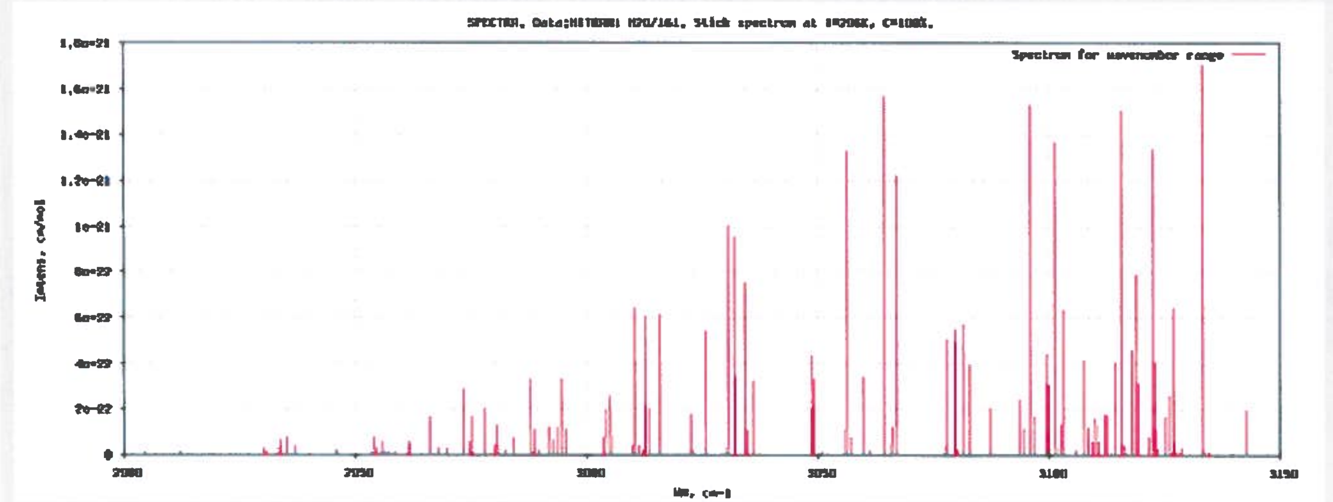


Source: HITRAN 2012 database

Methane and Water Spectra around 3.3 μm (based on HITRAN database)



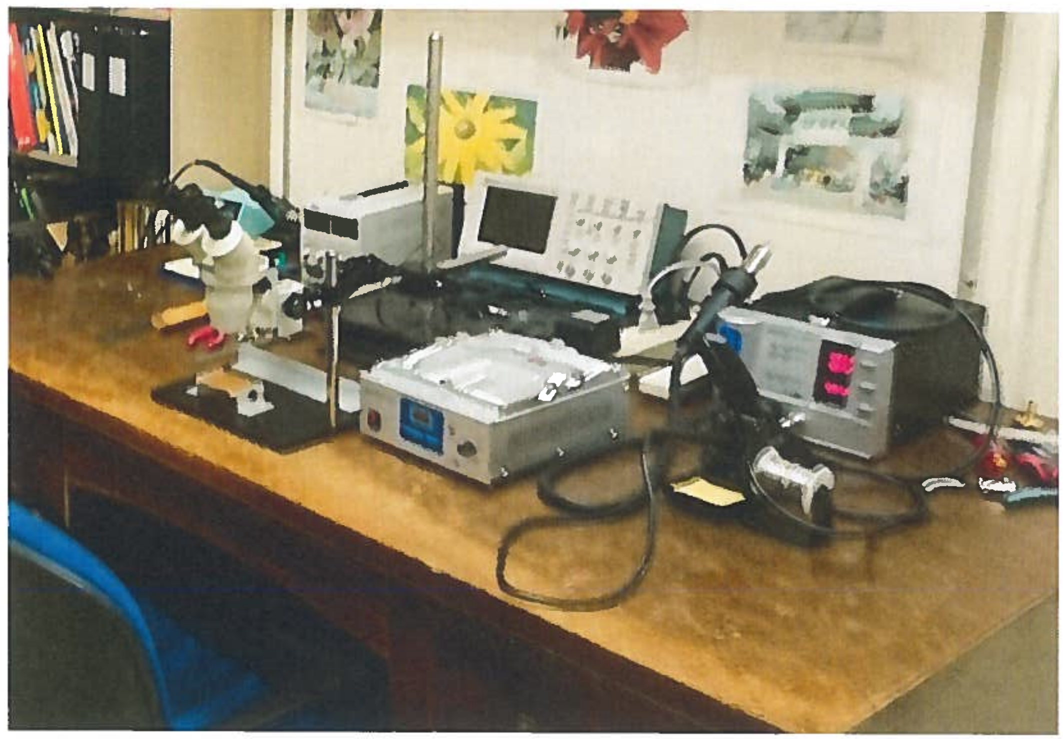
Synthetic spectrum for isotopic species $H^{16}OH$ from HITRAN.



R branch has the stronger line strength with the interference from congested water lines, while P branch has the weaker line strength with few interference from water lines.

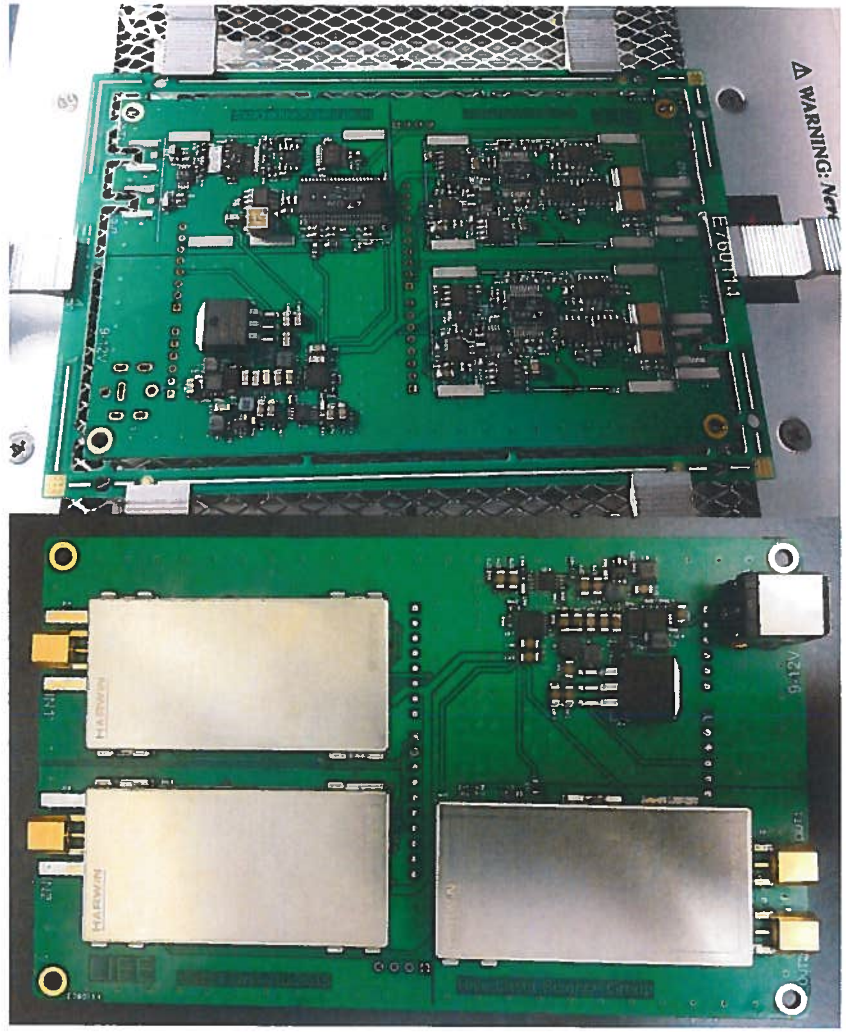
Completion of SMD rework station

- Soldering station
- Hot-Air gun
- Pre-heater station
- Microscope
- Set of hand tools
- Power supply
- Oscilloscope
- Arbitrary generator



2 channels analog Front End

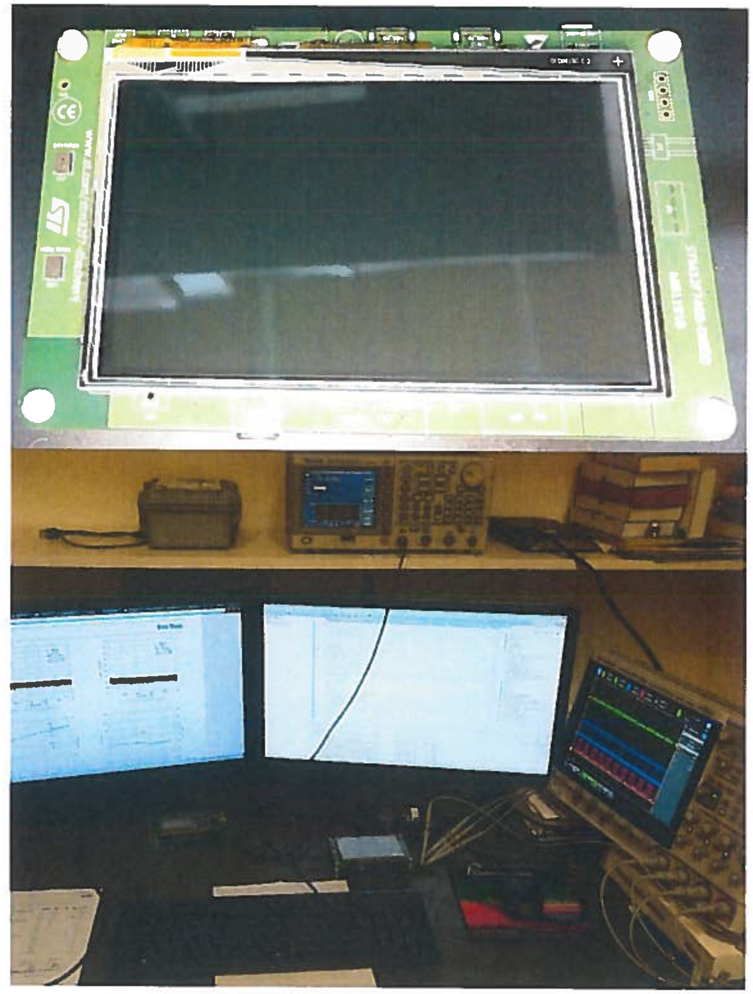
- Making PCB
  - 4 layers PCB
  - Soldering elements
  - Running PCB components
  - Connecting to STM32F7 discovery



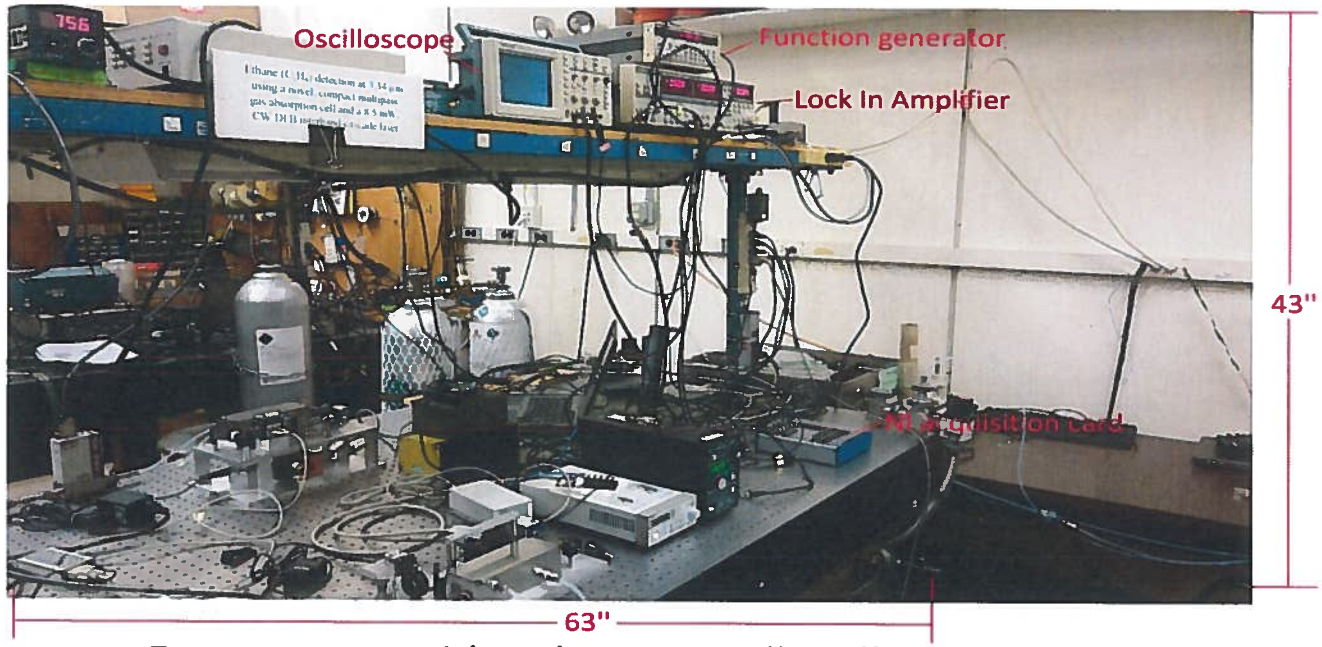
2 channels analog Front End

- Communication with STM32F7 Discovery

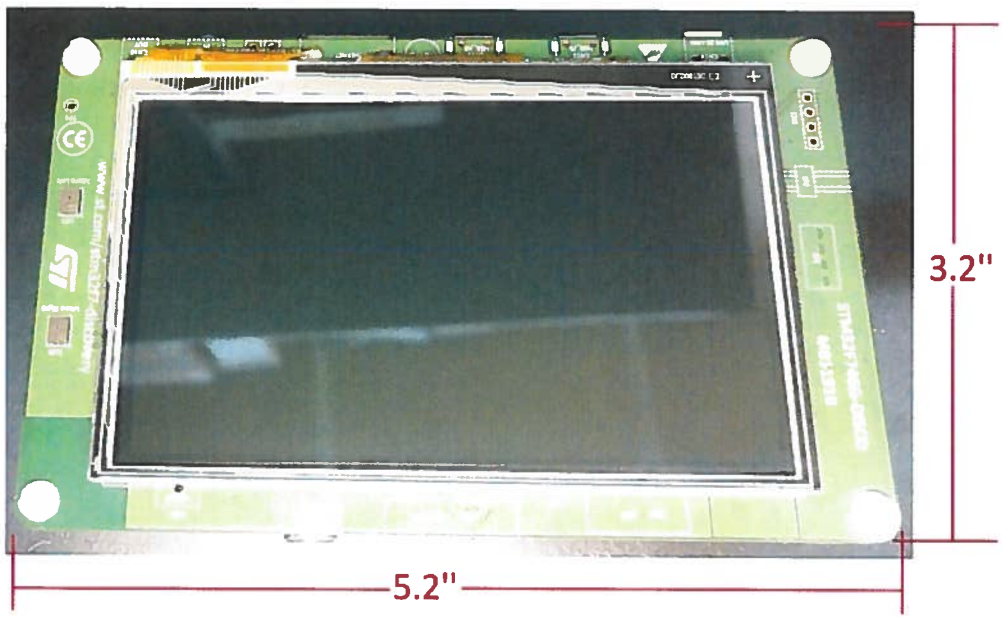
- Connectinng boards
- Running ADC's
- Running DAC's
- Running configuration components



Current setup with many equipment



Future setup with only one small 5.2'' x 3.2'' device



Gaussian Dispersion Calculation* plume C from e (inverse of e from C)

Equation 1 Environ.Sci. Technol. 2015, 49, 7889-7895 (Aerodyne)

Goal: Autonomously locate and quantify leaks on the wellpad with higher precision and accuracy. 95% reduction in fugitive leaks

Technical approach:

Meteeorology at Site-wind speed and solar insolation

Multipoint sampling system

Sonic anemometer for wind velocity

Inverse modeling to locating leaks based at multiple locations plus wind velocity

Standard deviations of Mass distribution in a Gausian Plume *

*Chemical Fate and Transport in the Environment (sec Edition) H.F Hemond & E.J.Fechner-Levy Academic Press, 2000 Chapter 4, page 30

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Single, fixed Rice methane/ ethane gas sensor

Multipoint sampling system

Sonic anemometer for wind velocity

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Natural Gas Leak Detection

Leak quantification and location:

- Wellpads
- Processing, Compression
- Distribution
- End use
- CH_4, H_2O, C_2H_6
  - H_2O required for dry mole fraction: accurate background levels
  - C_2H_6 (1-5% Natural Gas) enabled immediate discrimination of thermo vs. biogenic sources

Potential Embodiments

- Fixed, in-situ
- Portable
- Mobile
- Airborne/ UAV/Drones

Autonomous Natural Gas Leak Detection System

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Account Activity

View transactions by term: Fall 2015 Credit: $0.00 Select

Fall 2015 Credit Account Activity

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Description	Code	Date	Amount($)
VISA WEB REGISTRATION 3506	VSAW	12-AUG-2015	-674 00
TUITION OUT OF DIST SOUTH	TOD3	30-JUL-2015	267 00
TUITION OUT OF DIST SOUTH	TOD3	30-JUL-2015	267 00
GENERAL SERVICE FEE	GSF	30-JUL-2015	140 00
		Term Balance:	**0.00**

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