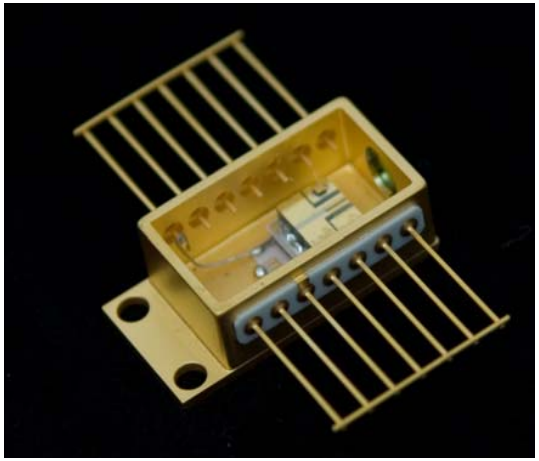
MIR Spectroscopic Sensing

IDENTIFY→MEASURE→PROTECT.

IQCLSW 19th Sept
Simon Nicholson
Sales Director – Cascade Technologies

The Company - Overview



- **Quantum cascade laser application Company**
- Operating in the field of
  - **Optoelectronic systems**
  - **Gas sensing**

  - **$12m investment received since April 2004**
  - **$6m investment in supply chain**
- **Target markets**
  - **Industrial**
    - **Emissions Monitoring**
    - **Trace Analytics**
    - **Process Control**
  - **Defence and Security**
    - **Homeland**
    - **Counter measures**
    - **Illicits**
  - **Medical**
    - **Point of Care Diagnostics**

The location

Cascade Technologies is based in Stirling, Scotland.

27 Employees and 5 Consultants

Virtual Support

Subcontractors
System design
Laser Technology
Corporate Finance
Legal

Our Expertise

Centre of Excellence- Product Dev/R&D/QCL application

- **Long Term Sustainable R&D**
  - Generate R&D collaboration/partnerships
  - Assess technology capabilities/maturity
  - **Remain at technology forefront**

- **Combined 40 years of expertise in QCL applications**
  - Exclusive supplier partnerships with the 4 major QCL manufacturers
  - Partnerships ensure quality and performance targets are met
  - **Volume manufacturer of QCL based products**

- **Create Platform Technologies/Products**
  - Develop application partnerships
  - A platform product
  - Integrate into existing applications
  - Prove product capabilities
  - Assess potential in novel applications
  - Maintain/Grow competitive advantage
  - **Concept to Demonstrator – 4 months**

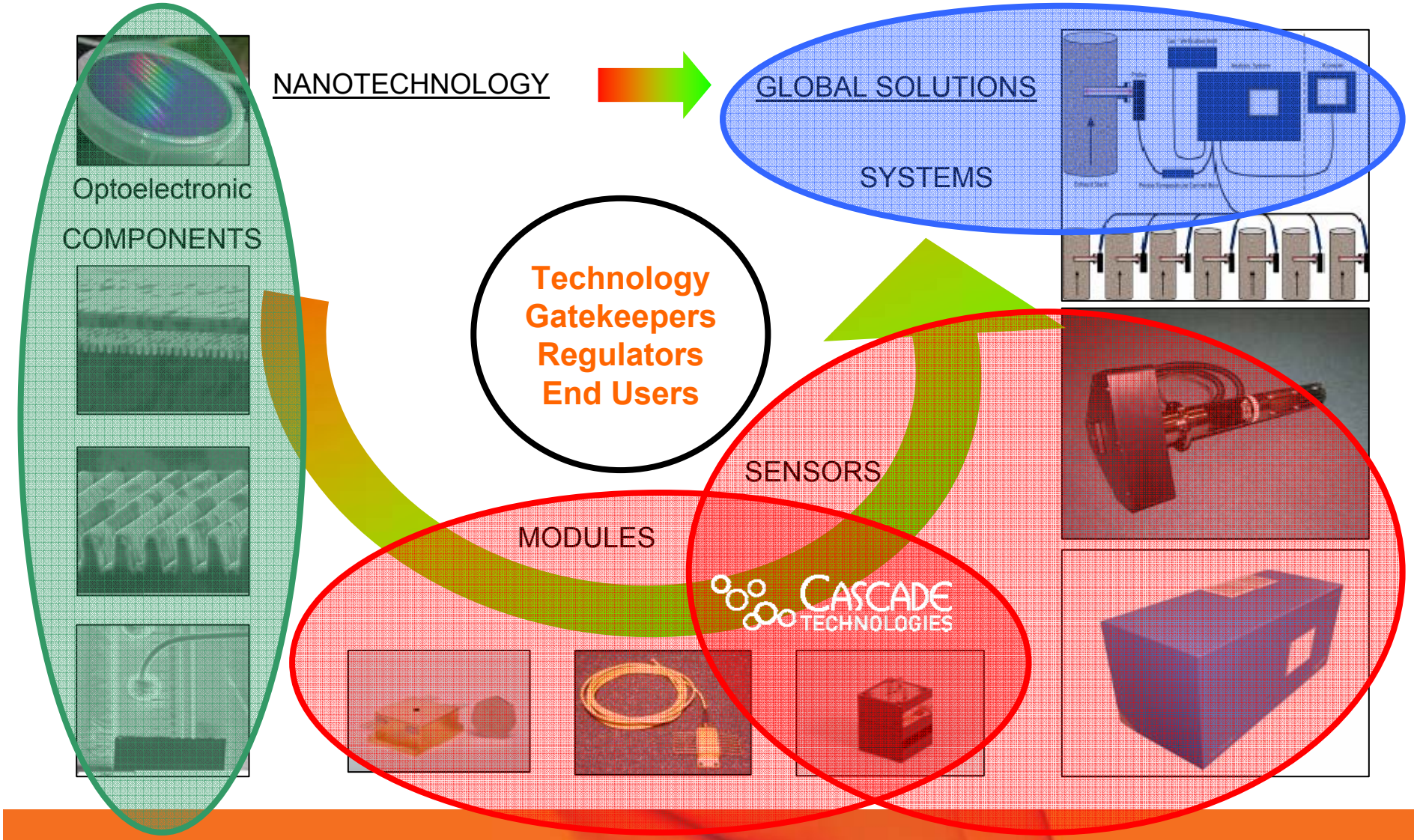
- **All IP/Expertise *"in house"***

CASCADE TECHNOLOGIES

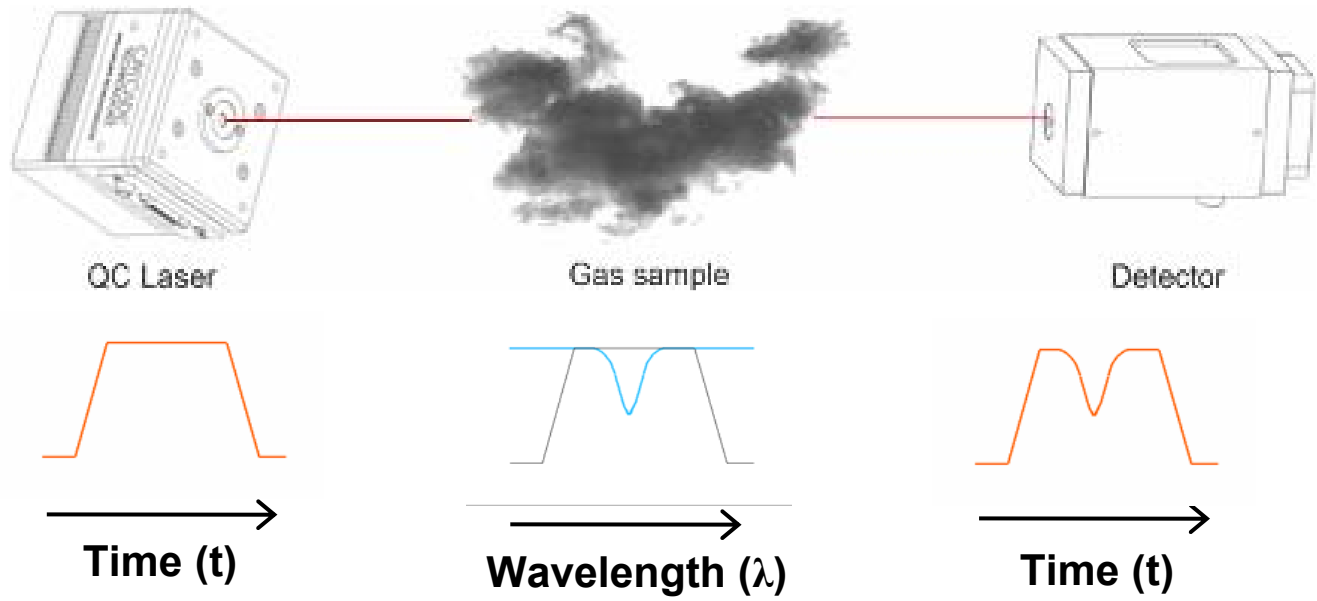
IDENTIFY→MEASURE→PROTECT.

Cascade's QC Laser based technology

From components to Solutions



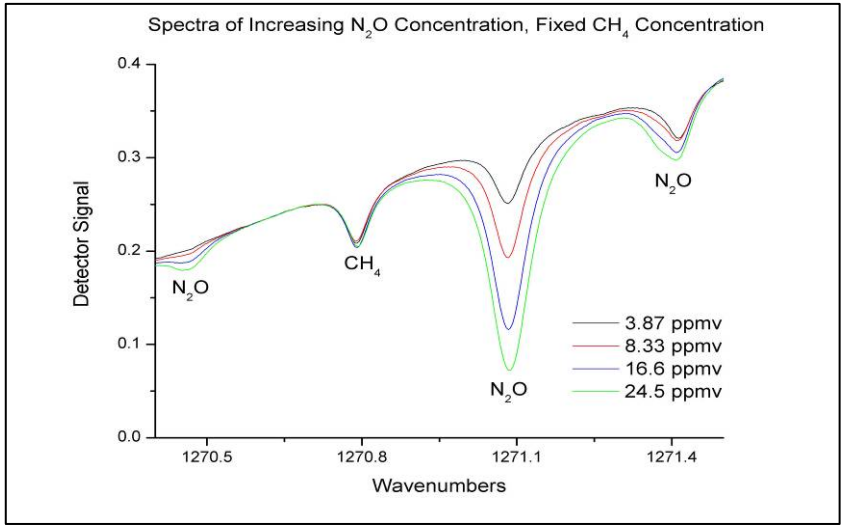
How do we use it to measure Gas?

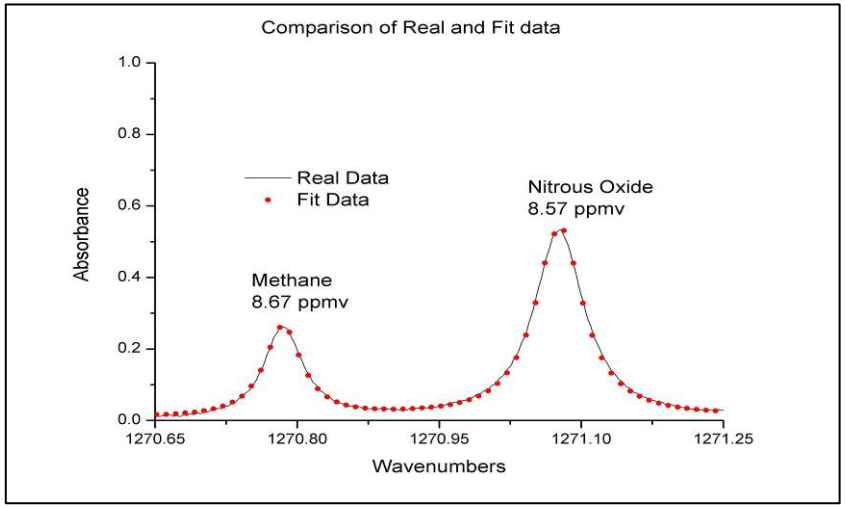


- Apply a current pulse to the QC Laser for about 1 microsecond
- Current pulse turns laser on and heats semiconductor material
- Heating causes rapid wavelength sweep - spectral fingerprint is recorded
- Uses Beer Lambert law – Theoretical physics for fitting routine
- Correction factors not required

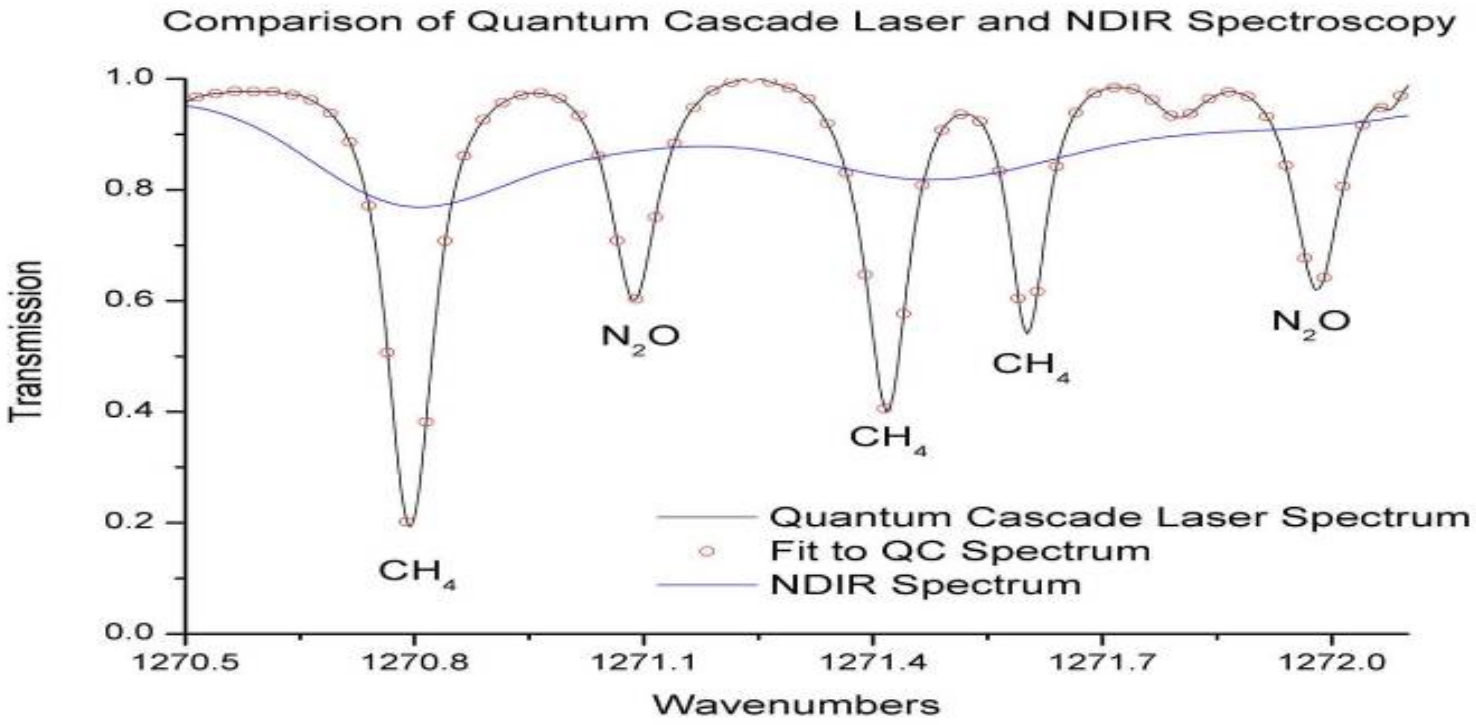
What advantages does our technique have?

- **Real time (1 Micro second - 1us)**
  - **Insensitive to turbulence**
  - **Insensitive to vibration**
  - **Multiple measurements "simultaneously"**
- **Large dynamic range**
  - **Linear response from PPB up to Tens of %**
- **Fixed Calibration**
  - **Concentration derived from first principles**
  - **Spectral database traceable to primary gas standard**
  - **Fundamental physics of the gas absorption spectra do not change with time**
  - **No requirement for calibration gases or any other consumables**
  - **Every Gas sensor will be the same**
- **Excellent Immunity to cross interference**
  - **Can accurately measure target gas in complex gas mixture**



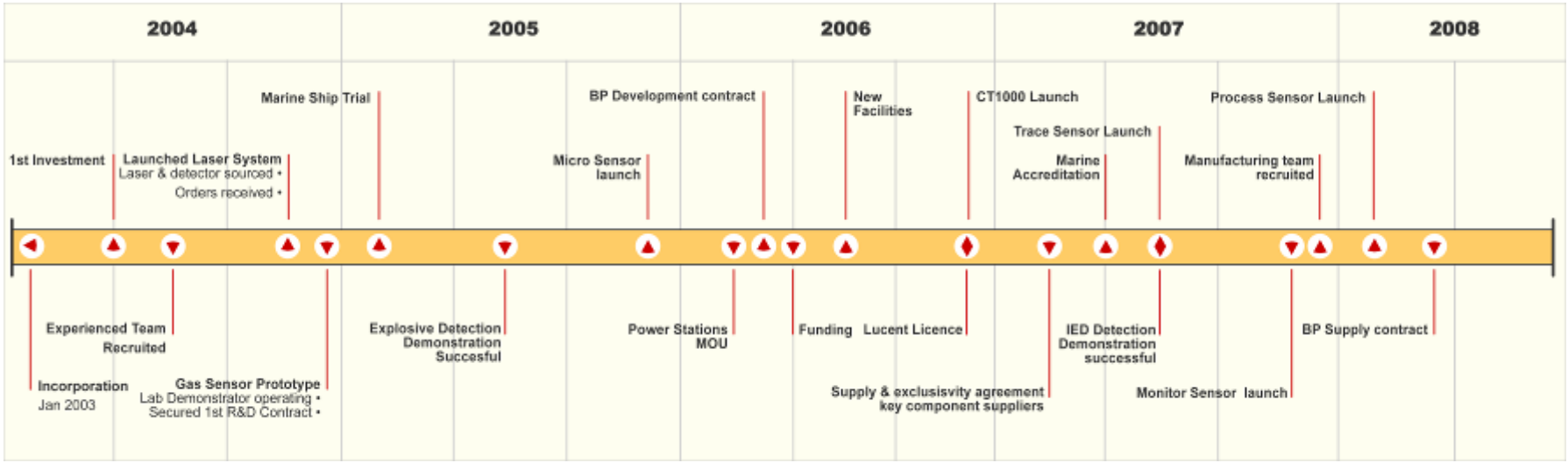


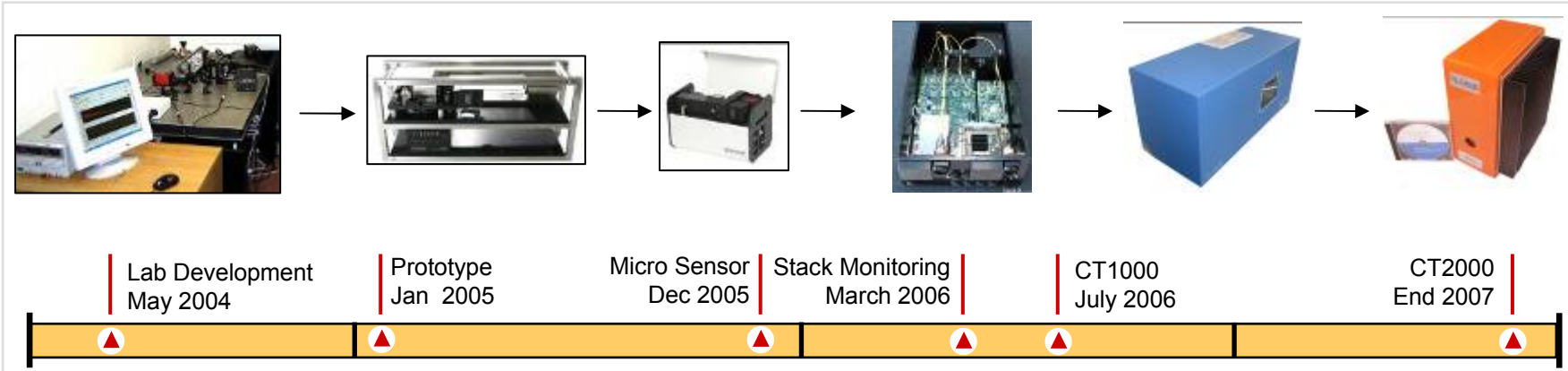
How is this different from other technologies?



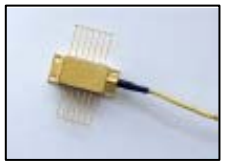
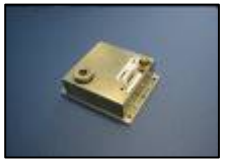
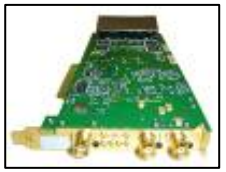
- **No need for correction curves for concentration, pressure, temperature, gas**
- **No need for zero/span**
- **Unambiguous Fingerprinting**
- **Simultaneous measurement of multiple compounds**

Technology Timeline

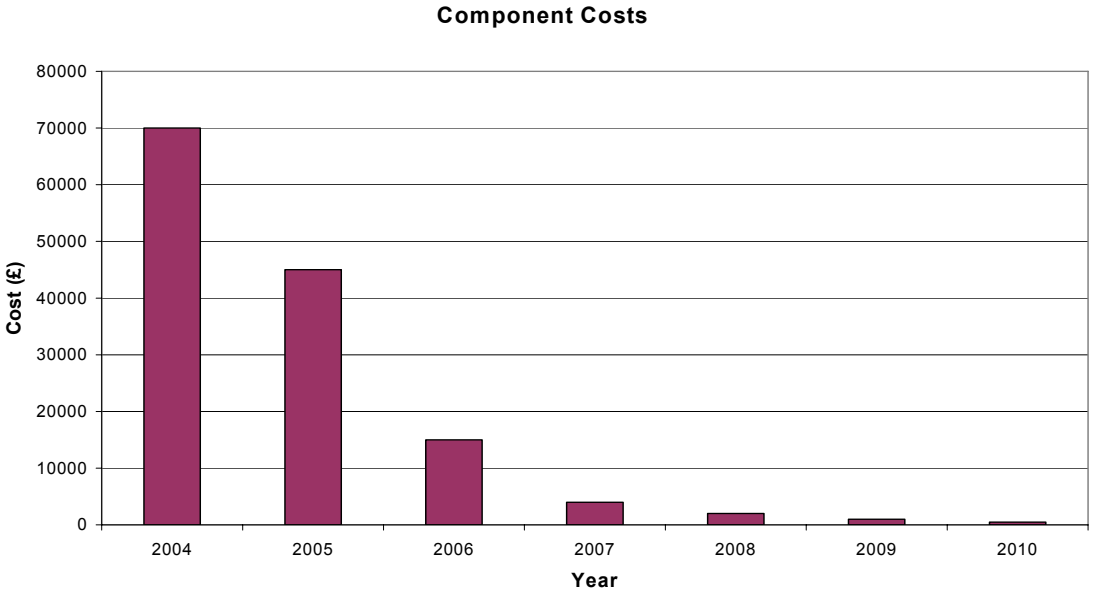




The Technology – Cost Down

Laser			Detector			Control Electronics			Hi Speed Digitiser		
											
2005	2007	2008	2005	2007	2008	2005	2007	2008	2005	2007	2008
$14 000	$1400	$600	$6000	$2200	$800	$44000	$1000	$600	$24000	£1000	$400

- All components designed in-house – manufacture out sourced
- Final assembly and test in-house
- Lasers/Detectors optimised by suppliers to Cascade specifications
- Costs include all key components (lasers, detectors, electronics, optics) and are based on volume supply 1000+




CASCADE
TECHNOLOGIES
IDENTIFY→MEASURE→PROTECT.
Markets and Applications

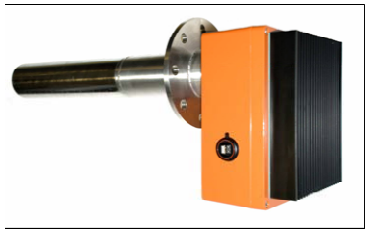
Our Products and Applications

CASCADE TECHNOLOGIES

Industrial

MONITOR

- PPM detection capability
- In Situ or Extractive
- Platform Development Completed



Marine

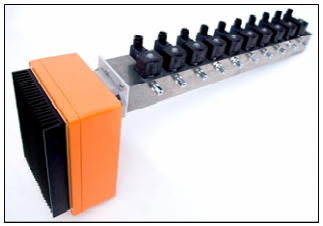
Power Station

Air pollution

Industrial

PROCESS

- Sub PPM detection capability
- In Situ or Extractive – Fast Response
- Platform Development completed Q3 2008



Automotive

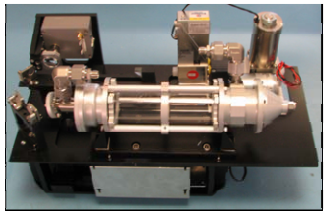
Aerosols

Boiler setting

Industrial

TRACE

- PPB detection capability
- Extractive
- Platform Development completed Q3 2008



Cigarette Manufacture

Gas turbine

Gas purity

Defence and Security

SECURITY

- PPB detection capability
- In Situ/ Extractive – Fast Response
- Trial Platform Development completed Q1 2008

IED Detection

Illicit Movement

Counter Measure

Core detection technology

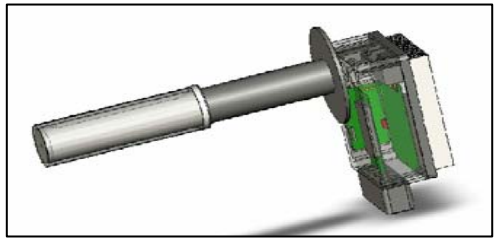
Quad laser system allowing multiple gas detection.

Contains control electronics, detector, digitizer, PC and power supply.

Base unit that can attach to a number of interfaces.

- Sample probe (optical Cell: cm to km)
- Mid Infrared Fibre (up to 20m)
- Hollow waveguide (small volume cell)
- Free space

Compact, robust and cost effective.

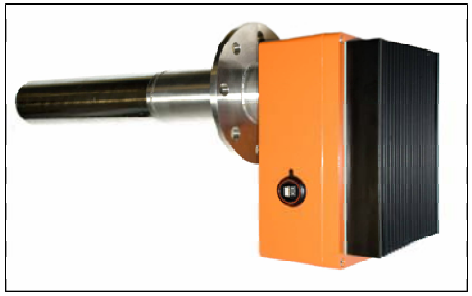


Marine Market - Typical Ferry Exhaust Stack Output – UK/France – Multiple gases

Industrial

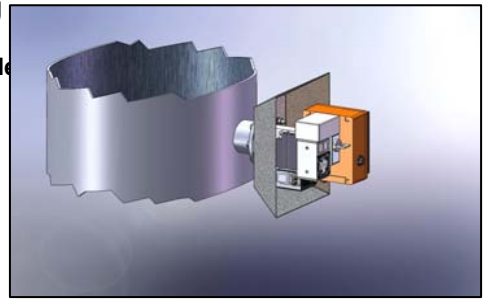
MONITOR

- **PPM detection capability**
- **In Situ or Extractive**
- **Platform Development Completed**



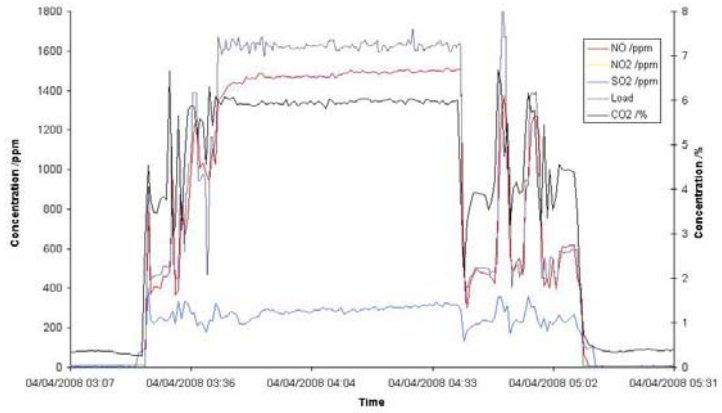
Solutions for marine emission monitoring

◀P&O Pride

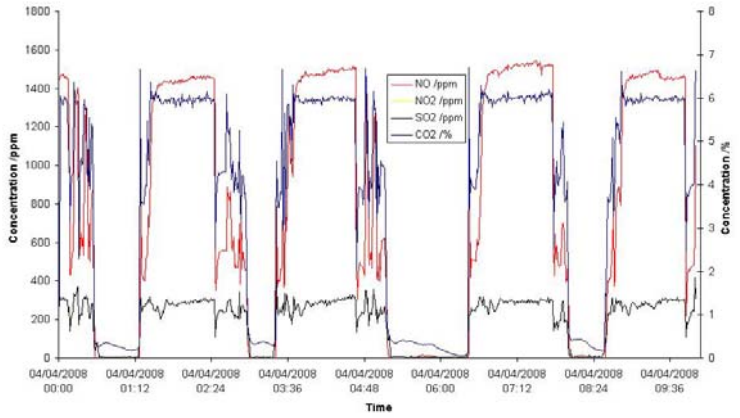


- **The Technology**
  - **In – situ is the most representative measurement**
  - **CO_2, SO_2, NO and NO_2**
- **Features**
  - **Ease of installation - plug and play**
  - **Internet connectivity**
  - **No consumables – low cost of ownership**
  - **12 month maintenance interval**
  - **Low through-life cost**
- **User Benefits**
  - **Corporate reporting of emissions**
  - **Compliance with regulations**
  - **Diagnostics in real time**
  - **Improved efficiency – fuel**

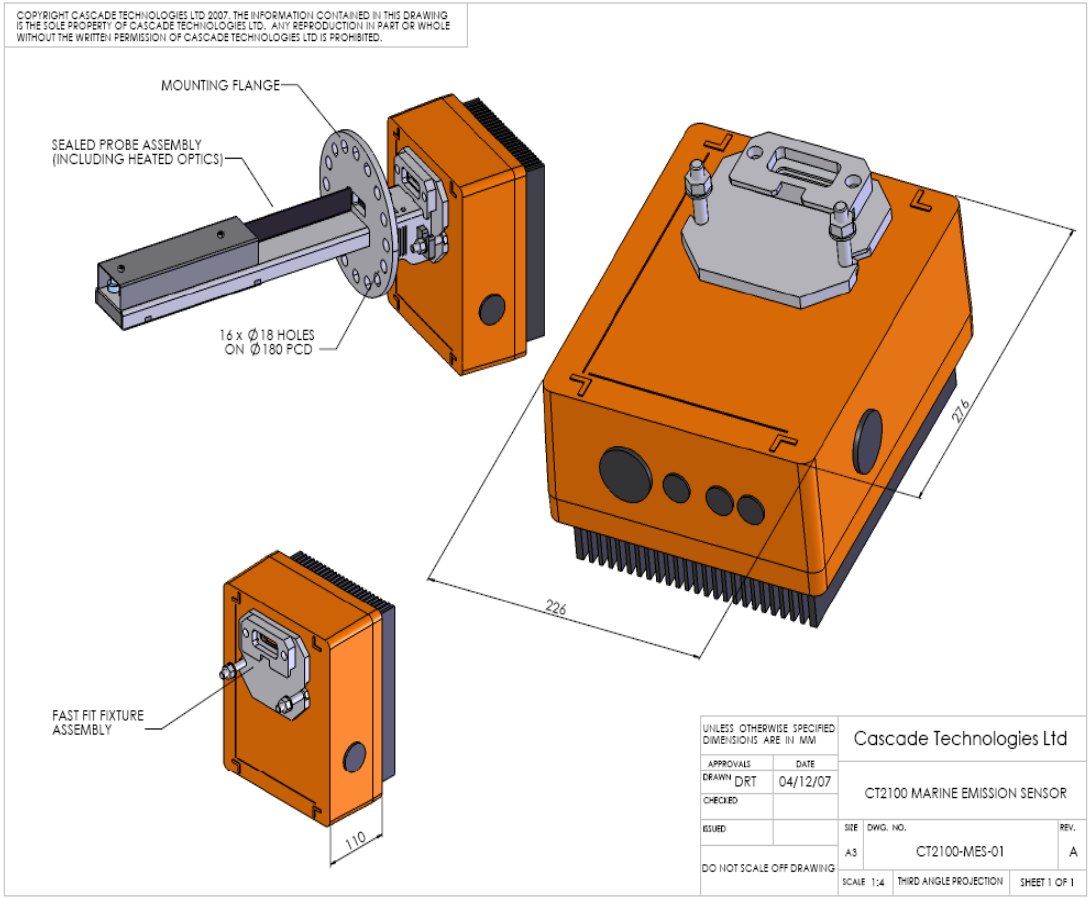
Marine Sensor - Multiple gases, One trip with engine load (4th April 2008)

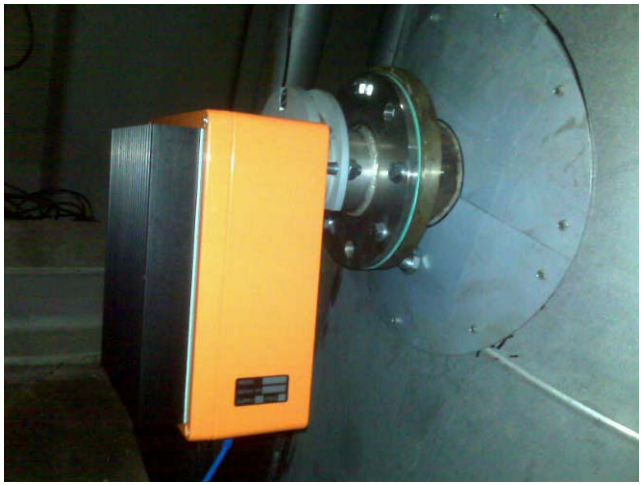


Marine Sensor - Multiple gases, Multiple trips (4th April 2008)

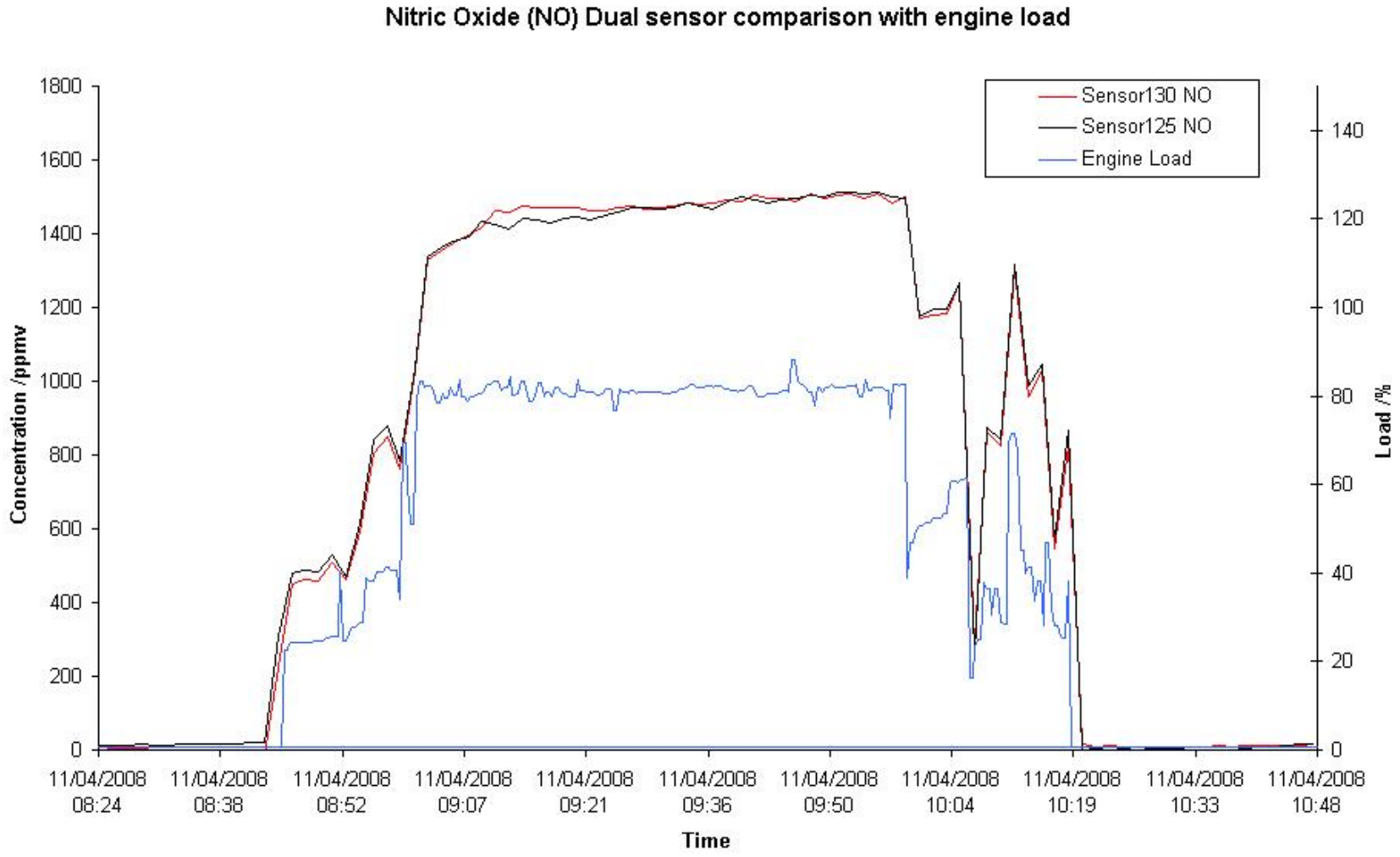


CT 2000 sensor – Schematic and Installation

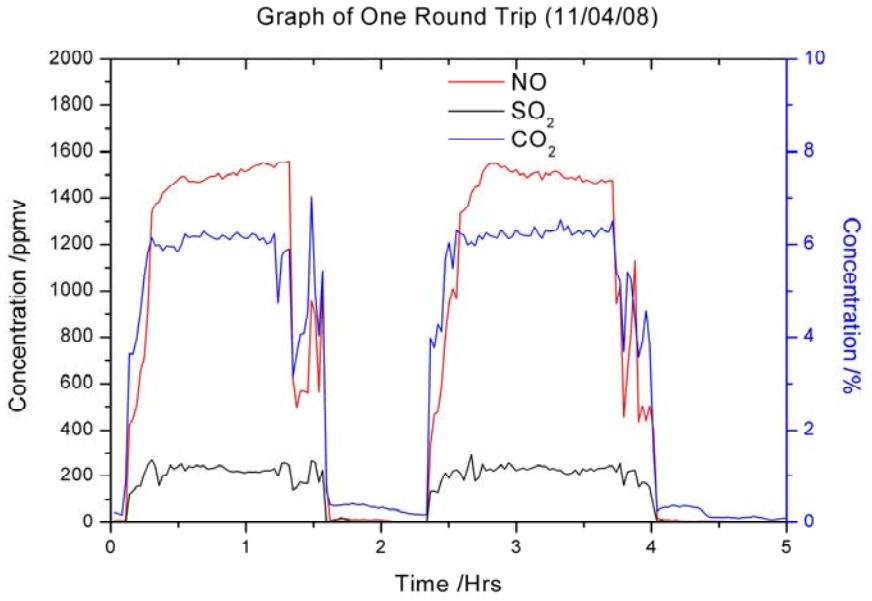




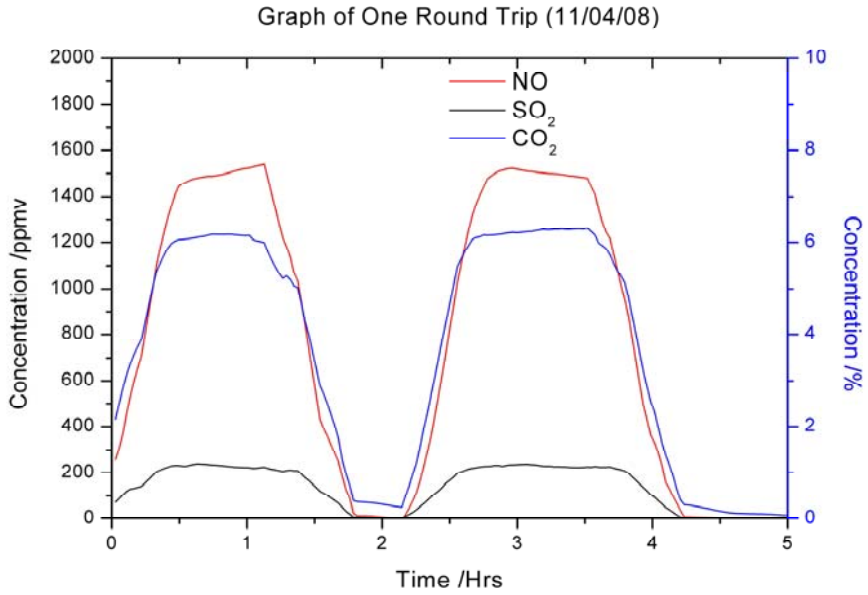
Comparison of NO data from two independent sensors



Comparison between In Situ and Extractive output



In-situ 15 second response time
Most Accurate measurement



Simulated extractive – 15 minute averaging
Data significantly reduced

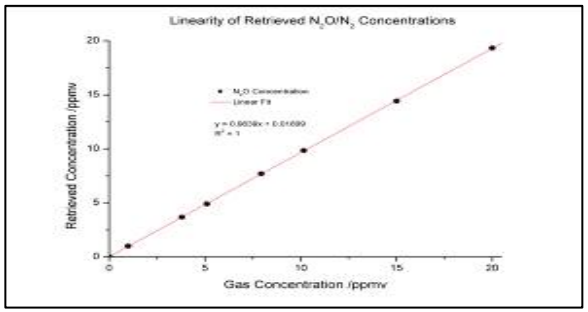
Key benefits of additional data

- Instantaneous tuning and diagnostics
- Potential for process control with real time feedback loops

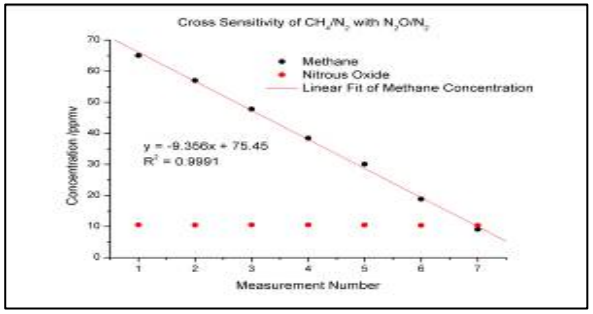
MCERTS Accreditation and Type Approval

- **Performance**
  - Linearity
  - Cross Interference
  - Temperature
  - Pressure
  - Noise
  - Drift

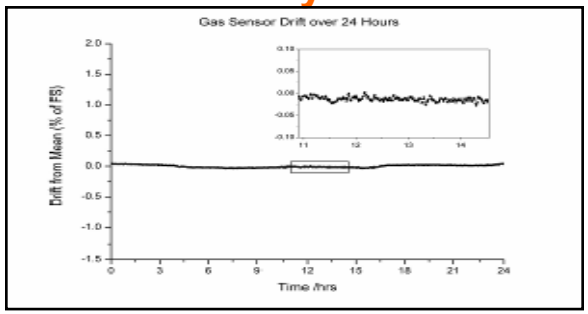
- **Environmental**
  - Humidity
  - Vibration
  - Electrical



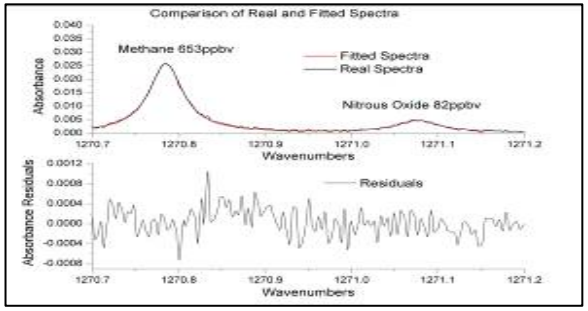
Linearity $R^2 = 1$



Cross Sensitivity < 0.02% FS



Drift (24 hrs) < 2 ppb



Noise < 1 PPB

- **First QCL technology accredited to MCERTS and Type Approval requirements without any zero, span or cross interference correction**
- **Gas database now extended beyond NOx, SOx, CO2 and now includes NH3, H2O, CO and N2O.**

- **Accreditation has proven to be a major milestone in demonstrating technology maturity**

Butane Leak detection for Aerosols filling lines

- **Industrial**

PROCESS

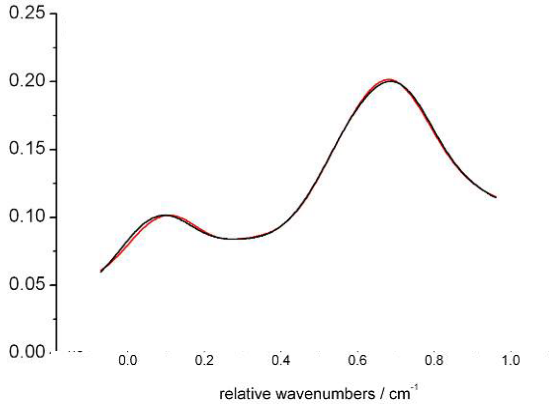
- **Aerosol Leak Detection**
  - **>20 cans per second**
  - **Real time analysis**
  - **High sensitivity (tens of ppb)**
  - **Low false negative (<2.10^{-5})**
  - **Low false positive (<2.10^{-4})**
  - **Hardware must be outside exclusion zone**
  - **Formal acceptance received from customer (5x more sensitive at 2x the speed)**

Trace IED Detection Portal

Defence and Security

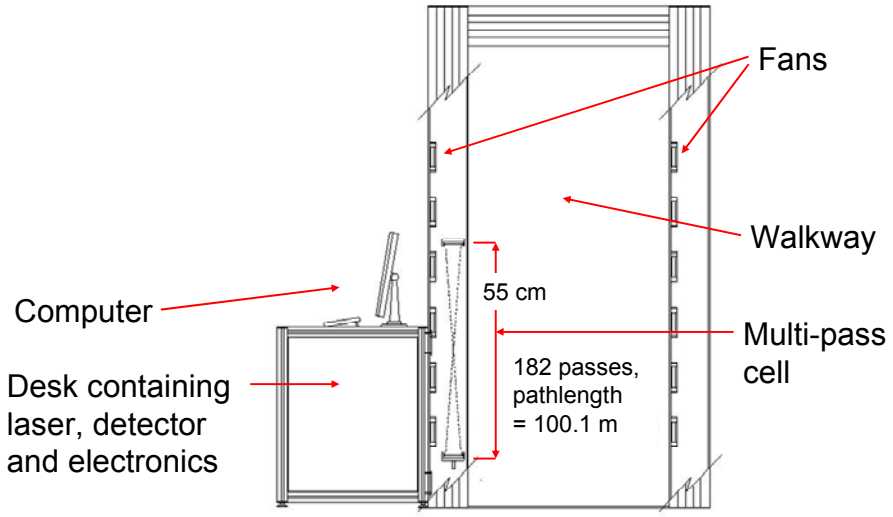
SECURITY

- **PPB detection capability**
- **In Situ/ Extractive – Fast Response**
- **Trial Platform Development completed Q1 2008**



The IED precursor H_2O_2 portal performances

- Minimum detection level: 5ppb
- Fingerprint acquisition: <50 ms
- Recognition/detection/concentration retrieval: <50ms
- Detection rate: >10Hz
- Interferant free: >40 tested
- Detection capability:
  1. Compound H_2O_2 in liquid/solid (dried)
  2. Compound H_2O_2 mixed with flour
  3. Simulated IED based on H_2O_2

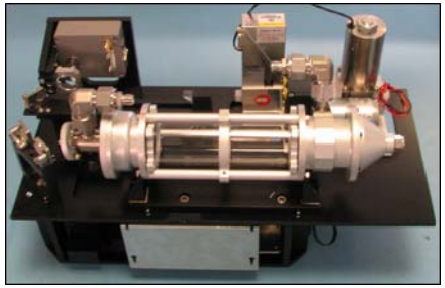


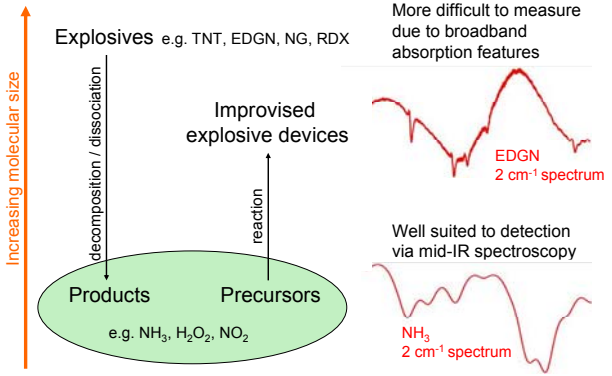
Bulk explosive detection

Defence and Security

SECURITY

- **PPB detection capability**
- **In Situ/ Extractive – Fast Response**
- **Trial Platform Development completed Q1 2008**
- **Existing Applications:**

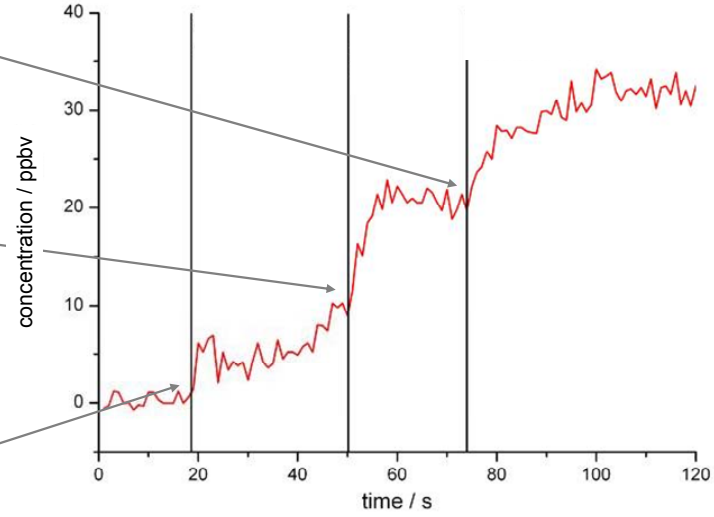




Ammonium nitrate in dish placed at cell entrance

Ammonium nitrate transferred to dish and placed near cell entrance

Ammonium nitrate container opened

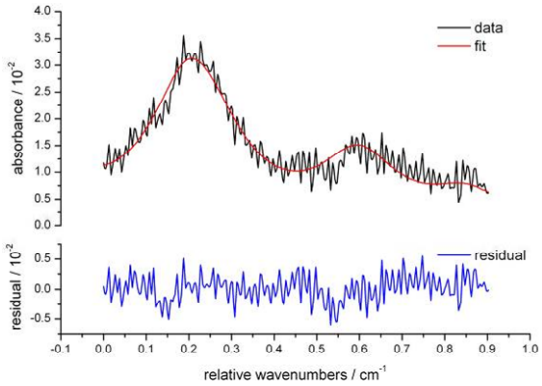


Decomposition

T>170C: NH_4NO_3 (s) ↔ N_2O (g) + H_2O (g)

Dissociation

T<170C , NH_4NO_3 (s) ↔ NH_3 (g) + HNO_3 (g)



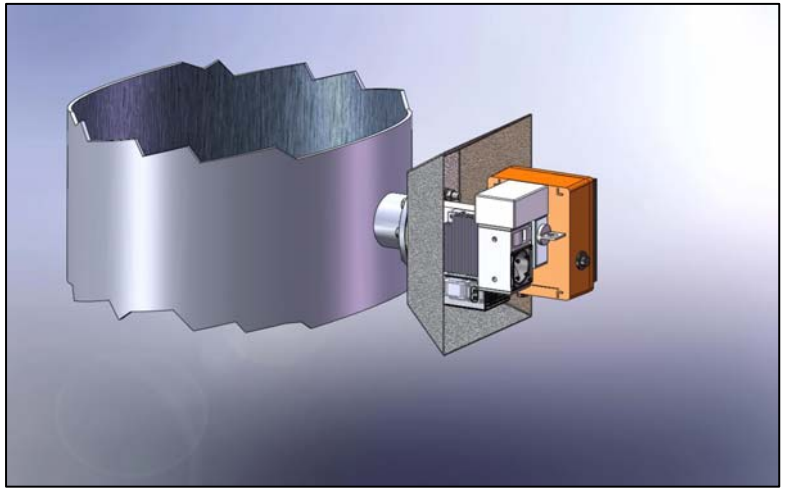
NH_3 Concentration calculated from fit = 32.8 ppbv

Detection limit = 4.5 ppbv .Eq. concentration of NH3: 2-6ppb (RH 95-0%)

New Developments

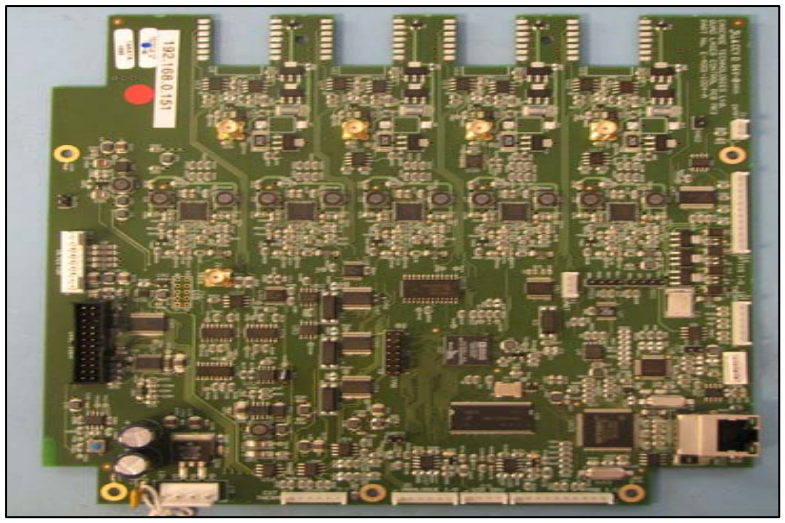
Cascade On Stack$_{TM}$ Sensor

- On stack system with sensor directly mounted onto stack,
- No sample lines or sample manifold
- No sample conditioning
- No pump option
- Fast response time
- Simplified zero/span (where required)
- Launch October 2008



Cascade Uni-Drive $_{TM}$ Control Electronics

- Hybrid electronics for CW and Pulsed N-IR and QCL laser drive.
- Extended gas capability (HCl, HF, O_2)
- Revised detection algorithms for ultra trace detection (ppt)
- On board DSP gas analysis for autonomous operation
- 1Khz data output for process applications
- Launch Spring 2009

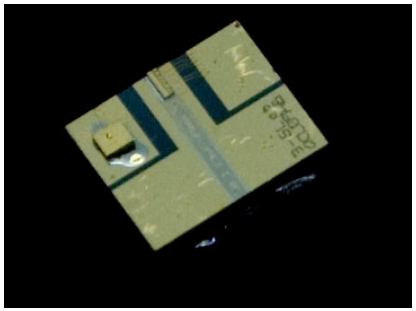


CASCADE TECHNOLOGIES

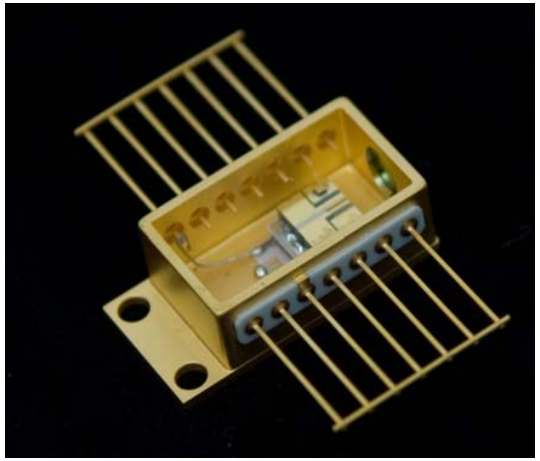
IDENTIFY→MEASURE→PROTECT.

Performance of QC Laser technology

QC Laser template specification example



- **Nominal Reciprocal Wavelengths between T1 (15C) and T2 (35C):**
  - ũ1 = 1345cm-1
  - ũ2 = 1631cm-1
  - ũ3 = 1904cm-1
  - ũ4 = 2230cm-1
  - ũ(T2) =< ũn =< ũ(T1)
- **Current and voltage compliances:**
  - Pulse current compliance (Ic): =< 4 Amps
  - Pulse voltage compliance (Vc): =< 20 Volts
  - Product current threshold (Ith): =< 1 Amps
- **Duty cycle, repetition frequency, temperature tuning rate and reciprocal wavelength scan:**
  - Operating duty cycle (DCc): =< 5%
  - Useful pulse duration (tpulse): 333ns =< tpulse =< 1000ns
  - Pulse repetition frequency (PRF): =<150 KHz
  - Useful reciprocal wavelength scan during tpulse (ũs): >= 2cm-1
  - Temperature tuning rate (Γ'): 0.15 cm-1/oC >= Γ' >= 0.05 cm-1/oC
  - RMS (middle of pulse) : =< 0.1% of full pulse amplitude
- **Operating and environmental temperature:**
  - Product sub-mount temperature (T): 15C =< T =< 35C
  - Product package environmental temperature (Tenv): -20C =< Tenv =< 85C
- **Beam divergence at emitting facet of the Product:**
  - Mean optical output power (Pm) guaranteed in a full solid angle of 60°.
- **Single mode suppression ratio:**
  - SMSR of the Product over the laser gain spectrum of the Product: >= 30dB
- **Mean optical output power:**
  - Mean optical output power (Pm) during tpulse >= 50 mW
  - Optical output power decay (Pdecay) from start to end of tpulse: =< 30%
- **Chirp rate:**
  - At any given time during tpulse the chirp rate (Ғ): 0.002 cm-1/ns =< Ғ =< 0.006 cm-1/ns



Production QC Laser test platform

Figure 1. Quad Laser test production platform

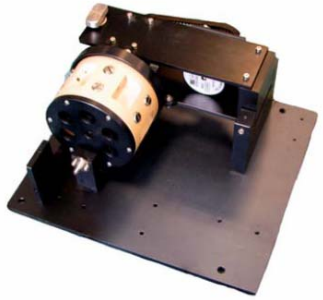
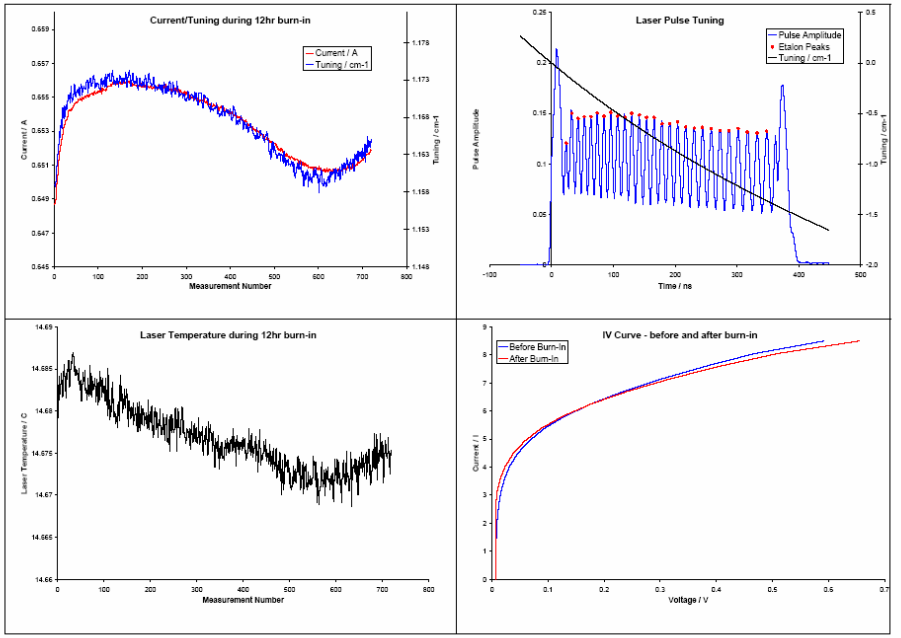


Figure 2. Gas Calibration carousel



- Testing of 4 lasers simultaneously (unlimited number of platforms can be networked: N x 4 lasers)
- Perform FAT, burn in and long term reliability test while monitoring
  - Light
  - Current
  - Voltage
  - TEC temperature,
  - Ambient temperature
  - Real time tuning rate of pulsed lasers, etc...
- Typical measurements and functionalities are:
  - Current , voltage threshold and compliance of laser via L-I-V curve measurement
  - Relative tuning of laser during pulse via included Ge Etalon
  - Programmatically generate Laser spec sheets
  - Scripting of custom routines via LabVIEW drivers
  - Built in software allows recorded data to be plotted and analyzed or exported to MS Excel format

Laser capacity (12 lasers illustration):

Reliability -	50 lasers/year	2 000hours per laser MTTF
Burn in -	2 400 lasers/year	12hours per laser
FAT -	20 000 lasers/year	1hour per laser (extended FAT: stress, condition of use and datasheet)