European Automotive Congress
EAEC-ESFA 2015

University “Politehnica” of Bucharest

NEW TECHNOLOGIES FOR HIGH ACCURATE EXHAUST MEASUREMENT

Ernst Kargl
November 27th, 2015
HORIBA Business Segments

**ATS Automotive Test Systems**
From Emission measurement, Driveline testing, virtual Battery simulation, Test Automation Systems, Wind Tunnel Balances and Brake Testing systems, we offer total solutions that are indispensable for overall Vehicle development.

**Process & Environmental**
Air, water, soil. HORIBA contributes to global environmental safety with measurement technology that complies with environmental regulations throughout the world.

**Scientific**
HORIBA's analytical and measurement equipment offers broad-ranging support for R&D and quality control in every kind of industry and is contributing to pioneering scientific research such as micro analysis at the nano level.

**Medical**
From the medical frontline (Point of Care Treatment) to testing centers. HORIBA's hematology analysers and clinical chemistry analysers help to construct the ideal diagnostic system.

**Semiconductor**
Providing advanced solutions for the control and monitoring of semiconductor manufacturing processes and for quality control inspections of semiconductors and LCD devices.
Automotive Test Systems Products and Services

TAS Test Automation Systems
Automation systems, STARS & VETS

MCT Mechatronic Systems
Engine-, Vehicle-, Driveline Test Systems, Brake and Component Test Stand, Wind Tunnel Balances

Services
Installation, Commissioning, Training, Service & Maintenance

PMD Project Management Department
Project Management & Coordination, Turnkey

EMS Emission Measurement Systems
Exhaust Measurement Technology
HORIBA In-House-Technologies

- A long history of experience and partnership with industry, academia and regulatory bodies.
HORIBA In-House-Technologies

- All core parts and analyzers are manufactured by HORIBA.
  - Quality, Know-How, Availability, Service, Flexibility
Contents

1. Regulation Situation
2. CO₂ Low Emission Measurement
3. Quantum Cascade Laser Infrared Spectroscopy for NO, NO₂, NH₃, N₂O Measurement
4. Fast Response EGR Measurement
5. PEMS Portable Emission Measurement Systems
First Exhaust Regulation from 1661

“Till more effectual methods can take place, it would be of great service to oblige all those Trades who make use of larger Fires to carry their Chimneys much higher into the air than they are at present; this expedient would frequently help to convey the Smoak away above the buildings, and in a great measure disperse it into distant parts without its falling on the houses below.”

“Workmen should be consulted, and encouraged to make experiments, whether a particular construction of the Chimneys would not assist in conveying off the Smoak, and sending it higher into the air before it is dispersed….and Premiums should be given to those that were successful in it”
Regulation Situation

- **European vehicle penalty for car makers**
  - When CO\(_2\) fleet emission average of new cars will be exceeded.

- **EURO VI for HDV**
  - Limit value NH\(_3\) = 10 ppm

- **U.S. EPA 40 CFR PART 86 subpart B for LDV**
  - Limit value N\(_2\)O = 10 mg / mile

- **Real Driving Emissions Legislation**
  - Emission under normal life and conditions of use
CO$_2$ Low Emission Measurement

Mass Emission (g) = Gas Concentration (%, ppm) * Gas Density (g/m$^3$) * Exhaust Volume (m$^3$)

Gas Concentration = Gas Conc. Exhaust Sample Bag – Gas Conc. Dilution Air Sample Bag
CO$_2$ Low Emission Measurement

- NDIR Non-Dispersive Infrared Detector

![Absorbance vs. Wavenumbers (cm$^{-1}$)]

- H2O 15%
- CO2 20%
- CO 200ppm
- NO 200ppm
- CH4 500ppm
- C7H8 500ppm
CO₂ Low Emission Measurement

- **Higher accuracy – CO₂(L) Analyzer**
  - Water interference correction with compensation detector
  - No measurement error when different H₂O concentration is in sample- and ambient bag.
  - Measuring ranges: 0 - 1000 ppm to 6 vol%
  - FYI CO₂ ambient concentration: approx. 400 ppm
  - Noise: < 3 ppm

Main + Compensation Detector
CO$_2$ Low Emission Measurement

- Water interference comparison and noise

![Graph showing water interference comparison and noise](image)

- MEXA-7k AIA-722 CO$_2$
- MEXA-ONE AIA-22 CO$_2$(L)
Quantum Cascade Laser Technology

- For NO, NO₂, NH₃, N₂O Measurement
- No operation gases
- Low concentration measurement with high power laser
- High resolution spectrum ⇒ minimum interference from other gases

Very high absorption coefficients

Ammonia
QCL region
MEXA-ONE-QL-NX

low absorption coefficients
NDIR regime

wavenumbers
Quantum Cascade Laser Technology

Temperature of QCL vs. Time

- ~ 200-1000 ns
- ~ 100 kHz

Wavelength vs. Time
Quantum Cascade Laser Technology

Detector Signal NH$_3$

\[ C = \frac{-\ln(I/I_0)}{K \times L} \]

Detector Signal [a.u.]

Time [ns]
Incorrect NH$_3$ measurement when analyzer sample temp. is >133°C

- Comparison measurement with QCL and FTIR at pre SCR catalyst

Sample temperature >133°C: Thermolysis to isocyanic acid and ammonia (NH$_2$)$_2$CO → NH$_3$ + HNCO

Sample temperature >160°C: Hydrolysis of isocyanic acid to ammonia HNCO + H$_2$O → NH$_3$ + CO$_2$
# Quantum Cascade Laser Technology

<table>
<thead>
<tr>
<th>Model</th>
<th>MEXA-ONE-QL-NX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling</td>
<td>Direct exhaust measurement</td>
</tr>
<tr>
<td>Measuring ranges</td>
<td>NO: (Low) 0-10/100 ppm</td>
</tr>
<tr>
<td></td>
<td>NO$_2$: (Low) 0-5/50 ppm</td>
</tr>
<tr>
<td></td>
<td>N$_2$O: (Low) 0-10/100 ppm</td>
</tr>
<tr>
<td></td>
<td>NH$_3$: (Low) 0-5/50 ppm</td>
</tr>
<tr>
<td></td>
<td>(High) 0-500/5000 ppm</td>
</tr>
<tr>
<td></td>
<td>(High) 0-200/2000 ppm</td>
</tr>
<tr>
<td></td>
<td>(High) 0-500/1000 ppm</td>
</tr>
<tr>
<td></td>
<td>(High) 0-200/1000 ppm</td>
</tr>
<tr>
<td>Noise (2x STDEV)</td>
<td>NO: (Low) &lt;0.4 ppm</td>
</tr>
<tr>
<td></td>
<td>NO$_2$: (Low) &lt;0.2 ppm</td>
</tr>
<tr>
<td></td>
<td>N$_2$O: (Low) &lt;0.4 ppm</td>
</tr>
<tr>
<td></td>
<td>NH$_3$: (Low) 0.2 ppm</td>
</tr>
<tr>
<td></td>
<td>(High) &lt;20 ppm</td>
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<tr>
<td></td>
<td>(High) &lt;8 ppm</td>
</tr>
<tr>
<td></td>
<td>(High) &lt;20 ppm</td>
</tr>
<tr>
<td>Sample temperature</td>
<td>113 ± 6°C</td>
</tr>
<tr>
<td>Response time $T_{10-90}$</td>
<td>NO, NO$_2$, N$_2$O: &lt; 2 s; NH$_3$: &lt; 2.5 s</td>
</tr>
<tr>
<td>Dimensions</td>
<td>Main unit: W440 × D660 × H877 mm</td>
</tr>
</tbody>
</table>
Quantum Cascade Laser Technology

- Multi-Line CAT-Measurement
  - With MEXA-ONE, OVN-25A & MEXA-ONE-QL-NX
Quantum Cascade Laser Technology

- Block Diagram MEXA-ONE-QL-N2O

**Sample flow rate:** 4 l/min

**Cell volume:** 300 ml

**Optical path length:** 80 m

**Cell temp:** 40 °C

**Cell pressure:** 20 kPa

**Range:** 0 – 0.5/200 ppm

**N₂O Ambient:** approx. 0.32 ppm

**CFO:** Orifice

**DET:** Detector

**REG:** Regulator

**PS:** Pressure Sensor

**TS:** Temperature Sensor

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Explore the future

Automotive Test Systems | Process & Environmental | Medical | Semiconductor | Scientific
Quantum Cascade Laser Technology

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<tr>
<th>Model</th>
<th>MEXA-ONE-QL-N2O</th>
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<tbody>
<tr>
<td>Sampling</td>
<td>CVS diluted exhaust gas measurement</td>
</tr>
<tr>
<td>Measuring ranges</td>
<td>N$_2$O: (Low) 0-0.5/5 ppm (High) 0-20/200 ppm</td>
</tr>
<tr>
<td>Noise (2x STDEV)</td>
<td>(Low) &lt;0.01 ppm (High) &lt;0.4 ppm</td>
</tr>
<tr>
<td>Sample temperature</td>
<td>Room temperature: 15 to 35°C</td>
</tr>
<tr>
<td>Response time T$_{10-90}$</td>
<td>&lt; 4.5 s</td>
</tr>
<tr>
<td>Dimensions</td>
<td>Main unit: W430 × D590 × H262 mm</td>
</tr>
</tbody>
</table>
Quantum Cascade Laser Technology

- CVS diluted exhaust gas measurement
  - With MEXA/CVS-ONE, DLS, MEXA-2000SPCS & MEXA-1100QL-N2O
Fast Response EGR Measurement

- **General Specifications**
  - EGR ratio measurement by CO₂ trace method
  - Heated NDIR: *Intake CO₂, Exhaust CO₂*

- **Key Features**
  - Accurate EGR measurement
    - Heated NDIR method (HORIBA patented technology)
      - ✓ No water extraction with cooler
      - ✓ Dry-to-Wet compensation is not required
  - Transient EGR Measurement
    - Analysers and sample handling in one unit
      - ✓ Installation close to the sample point of test engine
    - Minimized influence of sample pressure on the transient error
    - Sample flow rate is only 2.5 l/min

EGR ratio = \( \frac{\text{CO}_2 \text{ Intake} - \text{CO}_2 \text{ Ambient}}{\text{CO}_2 \text{ Exhaust} - \text{CO}_2 \text{ Ambient}} \)
Fast Response EGR Measurement

- Comparison tests with conventional EGR-system (MEXA-7100DEGR):
  - R-EGR analyzer follows EGR valve operation very well under transient condition.
  - Correct analysis at engine cold start because of the wet measurement capability.
  - R-EGR shows smaller transient errors under high pressure condition at sample inlet.
  - Good correlation with conventional system with dry/wet conversion under steady state

(SAE paper 2012)
Fast Response EGR Measurement

- Multi-point measurement: Easy addition of second unit for complicated measurement-setups
“Wet” Based Heated Measurement

Direct emissions without dry to wet correction

- **Heated FID for THC**
  - Sample temp. 191°C, no THC Hang-up

- **Heated Dual-CLD for NO, NO₂, NOₓ**
  - No hydrolyses => no reduction of concentration

- **Heated NDIR for CO, CO₂**
  - No cooler/dehumidifier for sample gas

- **CPC Condensation Particle Counter for PN**
  - Real particle counting, no particle size dependency like DCS Diffusion Charging Sensor

- **Filter Batch Sampling for PM**
  - Partial flow gravimetric sampling method
Portable Emission Measurement Systems

OBS-ONE Series

- OBS-ONE-GAS
- OBS-ONE-PM (Particle Matter)
- OBS-ONE-PN (Particle Number)

GPS antenna unit
Weather station unit

Main unit
Emergency button

Battery unit
Exhaust flow calculation unit
Exhaust flow meter unit

CO Monitor

Operation PC

Control Software of OBS based on HORIBA Platform

Regulatory Post-Processing

Cylinder gas for zero span calibration

Environmental Case for outside installation

Videocamera

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Thank you

감사합니다
Cảm ơn

ありがとう
dziękuję

谢谢
Merci

謝谢
Grazie

谢谢
Děkuji

谢谢
Obrigado

谢谢
Σας ευχαριστούμε

谢谢
Đánh giá

谢谢
Tack ska ni ha

谢谢
Danke

谢谢
Большое спасибо