Introduction
Ammonia or NH₃ has widespread use in many industrial sectors and is one of the most highly produced chemicals in the world. Main uses are in industrial refrigeration systems, as well as in fertilizer, explosives and chemicals production. Ammonia also evolves in agriculture and livestock farming and is generated in catalyzed combustion processes in heat & power generation. Natural ammonia levels in the atmosphere are in the low ppb range. Ammonia is toxic to humans at low ppm levels and needs an effective detection solution in most industrial environments. Traditional technologies (e.g. electrochemical and semiconductor detectors) have serious drawbacks in terms of selectivity, lifetime, functional safety and cost-of-ownership. ®IR Microsystems’ optical gas sensing technology based on tunable diode lasers overcomes these disadvantages, while providing a performance of Sigma = 0.8 ppm ammonia. It thus represents an excellent sensor alternative for the applications discussed below, which are partly not even accessible with previous detection solutions.

Toxicity of Ammonia
Ammonia is a toxic gas and a severe irritant to the respiratory tract. Several international standards exist that define the level of toxicity for humans. Generally, short-term exposure over 15 minutes needs to be limited to 25-35 ppm and the Time-Weighed-Average (TWA) over a 8-hour period should not exceed 25 ppm. Values for Immediate Danger to Life & Health (IDLH) are at 300 ppm. Concentrations of 1'500 ppm and more can cause fatal pulmonary oedema and ammonia becomes irritating to moist skin at about 10'000 ppm. The Lower Explosive Limit (LEL) for ammonia is 15 %. Depending on conditions and sensibility, humans can first notice the smell of ammonia anywhere between a few and 50 ppm. Accidental ammonia releases are far from being rare. A survey has shown that over a 5-year period in the 90ies a total of 40'000 people were evacuated as a result of roughly 600 incidents, whereas 250 led to a total of 1'400 injuries. This shows the critical need of reliable and effective ammonia monitoring in the industry sectors mentioned below.

Applications
Industrial Applications
Refrigeration: Due to its interesting thermodynamic properties ammonia has been used for decades in industrial style refrigeration. Apart from its toxic properties in case of an accidental release, it is considered to be efficient, economical and environmentally friendly because it does not deplete the ozone layer or contribute to global warming, which is not the case for most other refrigerants. Applications include:
- Cold storage
- Food manufacturing, processing and preservation
- Beverage production
- Ice rinks

Chemical Industry:
Today’s ammonia production of more than 100 million tons per year principally uses hydrocarbons as an educt in a catalyzed process. Applications include:
- Fertilizer production (more than 80% of the produced ammonia)
- Explosives production
- Plastic manufacturing
- Pharmaceutical products

Agriculture and Livestock Farming
Most ammonia emissions result from metabolic activities related to bacteria in livestock farming of poultry, cattle and pigs. Ventilation in the stables must be managed in order to avoid long-term over-critical exposure of the animals to ammonia, causing stress, poor health and reduced productivity. In poorly ventilated stables the health of the personnel also can be endangered. At the same time, ventilation and heating must be minimized/optimized to safe energy while keeping temperatures at an
adequate level, especially when young livestock is present. Fertilization in intensive agriculture is another source of ammonia.

**Emission Control**

While NO\textsubscript{x} reduction by 3-way catalysts has found a lot of attention in environmental protection, there is a growing awareness to reduce significant NH\textsubscript{3} emission from fuel-rich operated thermal engines. Ammonia contributes to poor air quality by fostering the formation of noxious dust-size airborne particles.

**Heat & Power Generation:** Gas and oil power & heat plants, as well as stationary diesel engines for power generation use selective catalytic reduction (SCR) to reduce NO\textsubscript{x} emissions. In this process an aqueous urea solution is injected to react with the exhaust gas. Ammonia slip occurs when over-stoichiometric amounts of urea are present. NH\textsubscript{3} detection in mobile diagnostics and engine management can be used to optimize the catalytic process, reduce NO\textsubscript{x} and NH\textsubscript{3} emission, increase catalyst life span and reduce urea injection.

**Truck Emission Control:** Compliance with 2005 (Euro IV) and 2008 (Euro V) emission standards for heavy-duty trucks will require exhaust after-treatment. Selective Catalytic Reduction (SCR) to reduce NO\textsubscript{x} emission has been adopted for mid- and heavy-duty trucks by several major manufacturers. In order to optimize performance and to reduce cost, the ammonia slip related to the necessary urea solution injection may need to be monitored, as NH\textsubscript{3} levels in transient regimes reach up to 50 ppm.

**Medical Applications**

Ammonia is produced in small quantities by the human body. The normal level can be altered as a result of kidney disorder or ulcer, where urea conversion leads to presence of ammonia in exhaled air. A measurement of ammonia on the 50-100 ppb level would allow fast and non-invasive diagnostics.

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**IR Microsystems**

**Laser Gas Detection**

IR Microsystems' microLGD gas sensors are stand-alone or ready-to-use OEM subsystems for selective detection and monitoring of gases. The sensor is based on a technology called "TDLS" – or Tunable Diode Laser Spectrometry, which has proven its validity in high-end laboratory and process control applications. It uses a laser to scan the specific absorption lines of a target gas with an extremely high resolution, which enables a precise measurement of the gas concentration without any cross-sensitivity. IR Microsystems proprietary approach to TDLS leverages this technology to low-cost, high-volume gas detection & monitoring applications: The use of low-cost telecom-type laser diodes as light source, combined with IR Microsystems intellectual property of reference channel-free devices, reduces the gas sensor to a set of generic components and enables significant cost synergies across applications.

The microLGD gas sensor technology brings a competitive solution to most of the drawbacks of current sensors:

- Extremely high selectivity to the target gas
- Functional safety, continuous status reporting
- Long lifetime (10+ years)
- Fast response times
- Low power consumption possible
- Very low cost-of-ownership (no regular replacement and/or calibration)
- Low cost of the gas sensor through excellent scaling costs of the components

**microLGD Application Advantages**

For industrial applications the microLGDs' high selectivity toward ammonia and functional safety are especially crucial to avoid costly false alarms and unnoticed sensor failure. Traditional sensing solutions typically offer neither. In the case of electrochemical cells the presence of
under-critical ammonia concentrations can lead to premature ageing and failure of the cell, leaving a site without protection. The microLGD offers the additional advantage of low cost-of-ownership as regular replacement or frequent recalibration is not necessary.

Agriculture and livestock farming applications, as well as emission control applications are not accessible to current electrochemical detectors. Due to the permanent presence of NH$_3$ the cells age prematurely, whereas the optical microLGD sensor offers long lifetime and no cross-sensitivity. In emission control applications the measurement speed of the sensor could play a role in engine management applications.

Further developments in optics and laser technology may make it possible to carry out fast, non-invasive medical diagnostics for the early detection of ulcer and kidney disease, where the ammonia detection limits need to be on the order of 50 ppb.

**microLGD Ammonia Sensor Test Data**

The following shows typical test data of the ®microLGD Ammonia Sensor in terms of detection limit, repeatability, drift and stability against temperature variations for an operation between -40°C and +40°C, and 0 to 1,000 ppm NH$_3$.

For a better control of the set concentration values, the ®microLGD Ammonia Sensor was operated in a “flow-through” configuration.

The span data shows an extreme linearity over the entire range of concentration, and the calibration is highly stable, even after 11 weeks of operation.

**Detection Limit**

The extremely low RMS noise of 150 ppb gives an accuracy of 300 ppb, and a detection limit of 500 ppb at 3σ, or a detection limit of 1 ppm at 6σ.

**Repeatability**

The figure below shows a perfect repeatability test for set NH$_3$ concentration values of 0 ppm, 5 ppm, 10 ppm, 20 ppm, 50 ppm, 70 ppm and 100 ppm.
Stability & Temperature Drift

Short-term stability (80 minutes) at 20 ppm yields a reading of $(20.1 \pm 0.45)$ ppm, corresponding to an extremely low RMS noise of 0.15 ppm.

Tests on IR Microsystems' microLGD laser diode gas sensor have shown that stable, low ppm range measurements of ammonia are possible. This sensor positions itself as a real alternative to current electrochemical detectors that have serious shortcomings in terms of stability, lifetime, cross-sensitivity and speed. The microLGD NH$_3$ sensor thus opens a new perspective on applications in agriculture, industrial safety, automotive and medical technology.

The zero-concentration temperature drift (13.5 hours, see insert in above figure) was recorded under a variation of ambient temperature from +40°C to -40°C, yielding a reading of $(-0.3 \pm 2.5)$ ppm, with a RMS noise of only 1 ppm.

High Concentration Temperature Drift

A similar test at 100 ppm ammonia concentration (temperature variation from +40°C to -15°C over a period of 6 hours) gives a reading of $(101.4 \pm 2.5)$ ppm an a RMS noise of 0.8 ppm.
Specifications of the "microLGD Ammonia Sensor are given shown for typical applications. They can be customized to specific applications – please contact IR Microsystems for a detailed discussion for your needs.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Range</td>
<td>ppm</td>
<td>0 – 1,000</td>
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<tr>
<td>Operation Temperature</td>
<td>min / max °C</td>
<td>-40 / +60</td>
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<tr>
<td></td>
<td>min / max °F</td>
<td>-40 / +140</td>
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<tr>
<td>Storage Temperature</td>
<td>min / max °C</td>
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<td>min / max °F</td>
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<td>Humidity Range</td>
<td>% RH</td>
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<tr>
<td>Pressure Range</td>
<td>hPa</td>
<td>700 – 1,300</td>
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<tr>
<td>Accuracy (2σ) ¹</td>
<td>ppm</td>
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<tr>
<td>Detection Limit (6σ) ¹</td>
<td>ppm</td>
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<tr>
<td>Zero Drift</td>
<td>ppm/year</td>
<td>&lt; 2</td>
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<tr>
<td>Temperature Drift</td>
<td>ppm (-40 - +60°C)</td>
<td>± 2.5</td>
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<tr>
<td>Pressure Drift</td>
<td>% reading per 10 hPa</td>
<td>+ 0.23</td>
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<tr>
<td>Repeatability</td>
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<tr>
<td>T90 Response ²</td>
<td>s</td>
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<tr>
<td>T90 Recovery ²</td>
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<td>Warm-Up Time</td>
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<td>Maximum Ammonia Overload</td>
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<tr>
<td>Lifetime</td>
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<tr>
<td>Concentration Output ³</td>
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<tr>
<td>Power Supply ³</td>
<td>DCV</td>
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<tr>
<td>Power Consumption (typical/max)</td>
<td>W</td>
<td>1.6 / 2.3</td>
</tr>
</tbody>
</table>

¹ At 20°C, 1013 hPa
² Strongly influenced by gas sampling (diffusion time, flow-through time). Sensor output is 4 s.
³ To be specified on order

For further information, please contact:

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