Semiconductor Laser Based Low Power Ammonia Sensors for Remote, Unattended Agricultural Applications

GAS DETECTION

C. Kimar N. Patel and Rodolfo Barron-Jimenez, Pranalytica, Inc. Santa Monica, CA
Tel: (310) 458 - 0808 Email: patel@pranalytica.com

Optical absorption based ammonia sensors have made significant impact in the detection of ammonia in semiconductor fablines and environmental monitoring. Both of these applications require ultrahigh sensitivity of 100 ppt (parts per trillion) and high interference rejection capability for unambiguous identification of trace ammonia in the sampled gases. Also, these applications are relatively insensitive to the sensor weight, sensor dimensions and sensor power consumption since in these applications, sensors are used in a stationary configuration where line electrical power is available.

However, there exist unmet needs for ammonia sensing at tens of ppb level sensitivity but the sensor must be physically small, light enough to be portable, must have low power consumption for extended operation on internal batteries and must be housed in weatherproof cabinet for field deployment in outdoor environment. Pranalytica has announced such a sensor that meets all of these requirements and more, some of which are listed below:

1. Sensitivity: Better than 40 ppb, approaching 10 ppb of ammonia
2. Operation: Continuous without operator attention or intervention
3. Physical configuration and size: Completely self contained in 16" x 13" x 7" case
4. Cabinet: NEMA 4 cabinet for operation in adverse weather conditions
5. Power consumption: <48 W
6. Power source: Solar panel/internal batteries/AC line
7. Data communication: Through cellular telephone network; Internet connectivity
8. Built in GPS receiver for physical location and date/time stamp of every datum
9. Weight: <30 lbs

This sensor, called Nitrolux-S (Figure 1), meets all of the requirements of a rugged ammonia detector for agricultural source monitoring.

The Nitrolux-S utilizes laser photoacoustic spectroscopy for the measurement of optical absorption of the desired trace gas, e.g. ammonia, in the analyzed sample. But unlike Pranalytica's ultrahigh sensitivity ammonia detectors that use a tunable CO_2 laser as the source of radiation for the measurement of optical absorption of ammonia in the 9 μm-10 μm region, the Nitrolux-S uses a tunable semiconductor laser and an optical amplifier for measuring the optical absorption of ammonia in the 1.55 μm region. The difference in the physical size and weight of the CO_2 and the semiconductor lasers has made it possible to offer a sensor with adequate sensitivity, size/weight/power consumption and ruggedness advantages.

Technical Details:

Nitrolux-S was designed with portability and unattended operation in mind. It offers adequate sensitivity for applications in which sensor portability and ruggedness is desired. The technical description given below will clarify many features of the Nitrolux-S.

Figure 1. Nitrolux-S

The dynamic range of Nitrolux-S (0 to 100 ppm) covers the needs of the agricultural and environmental monitoring applications. Extended dynamic range is available as an option. Within this range the instrument response is linear to better than 0.999 (Figure 2). The uncertainty of these measurement is ±2% FS traceable to NIST standards. The sensitivity of the Nitrolux-S is better than 40 ppb. Figure 3 shows the 1σ replicate precision for zero ammonia concentration over 2 hours. Calibration stability is guaranteed for 6000 hours, however, re-calibration is recommended every 6 months.

Careful design of the Nitrolux-S has made it immune to interferences form other atmospheric constituents, such as carbon dioxide (CO_2), water (H_2O) and/or volatile organic compounds (VOC's). Figure 4 shows the detection of 1 ppm ammonia on dirty air, e.g. 1% CO_2 (normal atmospheric concentration of CO_2 is 500 ppm). The presence of CO_2 in the sample does not affect the ammonia measurement, its accuracy and/or sensitivity. In addition, Nitrolux-S will operate in

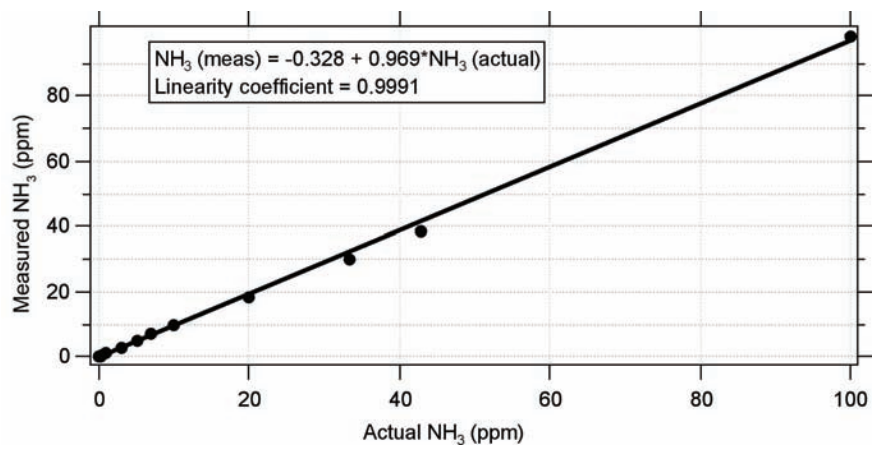

Figure 2. Linearity of the Nitrolux-S over the dynamic range

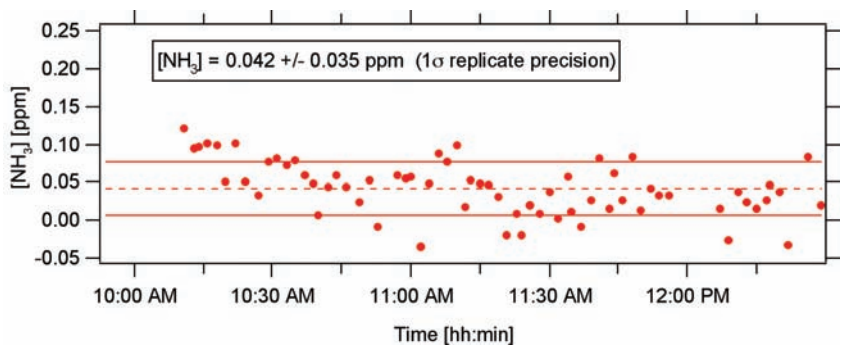

Figure 3. Replicate precision for zero ammonia over 2 hours

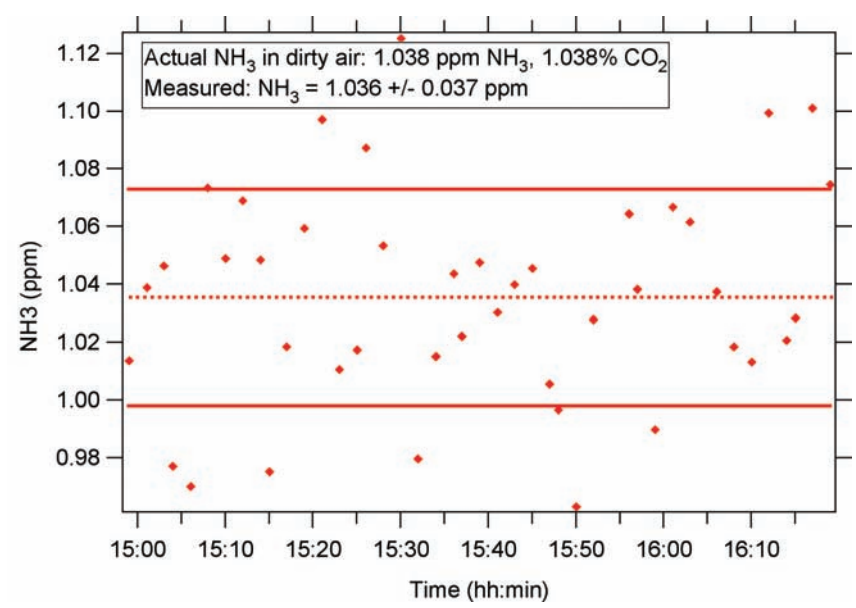

Figure 4. Ammonia detection is immune to other atmospheric constituents. e.g., CO_2

extreme environments with ambient temperatures from 0 to 40 ºC and under any humidity (ambient operating humidity 0 to 100 %) since water in the sample does not affect the instrument performance. To assure operability in harsh environments, the Nitrolux-S is housed in a NEMA 4 enclosure that is the accepted standard for field deployment of electronic instruments. The NEMA 4 enclosure with a "briefcase" form factor (16.2"x12.7"x6.6") provides portability and ruggedness and is dustproof, and waterproof. The Nitrolux-S is portable; it weights 30 lbs including the built-in re-chargeable battery pack that can power the instrument in continuous operation for about 10 hours. Figure 5 shows the Nitrolux-S field deployed in a cattle farm at the University of California at Davis.

Nitrolux-S is simple to operate (turn key operation) and does not require pre-

preparation of the sample. The user attaches the sampling line with a ?" standard compression fitting. The built-in vacuum pump continuously draws the sample at a rate of ~0.120 SLPM. The particulate filter at the gas inlet is the only disposable component and its replacement is recommended every 3 months or earlier as required.

The Nitrolux-S can be operated in two different modes:

1. Continuous mode that updates measurements every 2 minutes.
2. The battery power conservation mode that permits a slowing down of the measurement cycle to once every 15, 30 or 60 minutes. When operated in the 15 minute duty cycle mode, the Nitrolux-S will operate for 48 hours on a single charge of the battery.

The battery pack can be re-charged from a 12 volt automobile battery, from the AC line (using the available adaptor) or directly from an 80-W solar panel (Figure 6.)

Figure 5. Nitrolux-S deployed on a cattle farm at the University of California at Davis

With power provided from either the solar panel, line or automobile battery the Nitrolux-S will operate unattended for extended period of time. Nitrolux-S internally stores ammonia measurements data that can be retrieved in-situ via a USB. To provide an extra

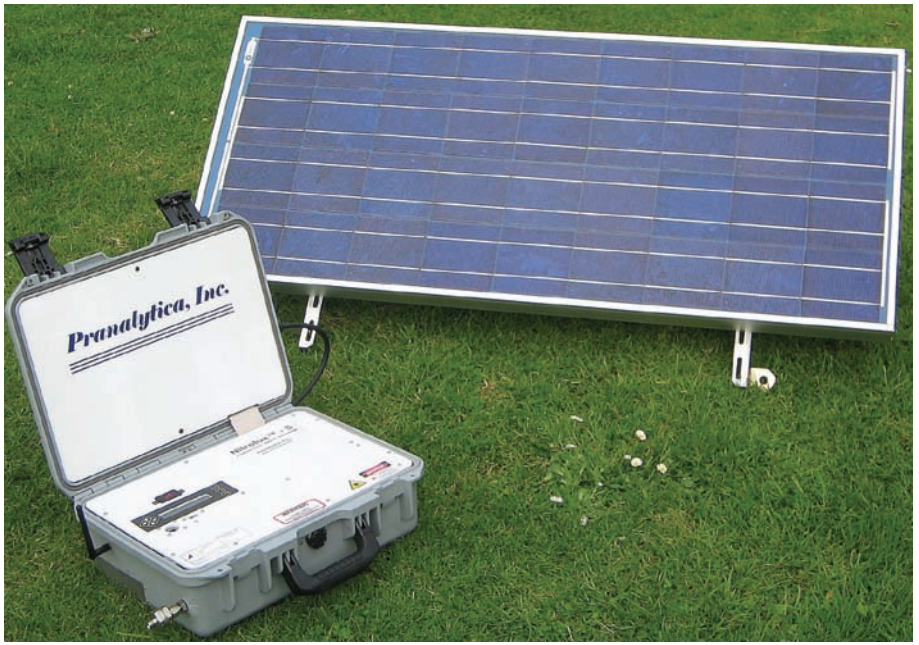

Figure 6. Nitrolux-S powered by an 80-W solar panel

level of control for field deployment, Nitrolux-S is equipped with a cellular modem (user activation required) that remotely allows the user to:

- Access stored data or to request the current ammonia concentration measurement. If the request is made during the down time of one of the non-continuous modes, it will perform a measurement and reply to the inquire within minutes.
- Set or re-set the alarm threshold and to receive e-mail or text message notifications when the alarm is triggered.
- Change the operation mode, purge the sample, or turn off the Nitrolux-S.
- Check battery power level.
- Receive notifications (e.g. via e-mail or text message) from the Nitrolux-S at the remote location about its health and power status that require a prompt action.

All of the above functionalities can be executed by the user from his/her own cellular phone or through a secure web site accessible all over the world.