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GROUP **SPECTROSCOPY AND PROCESS ANALYTICS**

Sensors to improve agricultural efficiency

Crop yields need to keep pace with the growth of world population. Nitrogen-based fertilizers play an important part in this. Each year, over 120 million metric tons of nitrogen are spread onto fields across the globe. Less than a third of this quantity is actually needed, however, to achieve optimal yields. The excessive use of nitrogen not only pollutes soils and bodies of water, it also has a negative impact on the climate as it is converted to nitrous oxide. The goal, therefore, must be to tailor fertilization to actual needs. Measurement technology from Fraunhofer IPM can help to achieve this goal.

According to data from the German Environment Agency, farming is responsible for some 80 percent of nitrous oxide emissions in Germany (2016 data). Nitrous oxide (N_2O) is primarily formed in wet soils that have been excessively fertilized with nitrogen, usually resulting from the microbial degradation of nitrogen compounds. These processes already occur under natural conditions. However, they are greatly exacerbated by the additional nitrogen resulting from agriculture (liquid manure), industry and transportation.

Needs-based nitrogen fertilization

The problem is anything but new, and yet the emissions of nitrous oxide from agricultural land have not decreased in around 30 years. Numerous studies provide evidence of the direct correlation between the use of nitrogen fertilizers and nitrous oxide emissions. According to our current understanding, around a third of the climate-damaging nitrous oxide emissions can be traced back to the use of nitrogen fertilizers. Using such fertilizers sparingly and efficiently therefore not only makes economic sense, it also has several important effects on the environment: Contamination of soils and ground water from leaching is minimized, the habitats of many plant and animal species are preserved, and climate protection also benefits from sparing use of nitrogen fertilizers, since harmful nitrous oxide emissions are reduced.

Measurement technology supports innovative farming

Instead of simply reducing quantities, several innovative approaches to making the best possible use of nitrogen fertilizers are also currently under discussion. Here are the three most important ones: Firstly, novel dually stabilized nitrogen fertilizers are said to reduce nitrous oxide emissions in conventional spreading. Secondly, innovative incorporation techniques should be used to help place fertilizer at an adequate soil depth such that contact with the soil is minimized; this distribution method should eliminate volatile nitrogen loss almost entirely. Thirdly, concepts for soil use that generate and preserve humus, such as varied crop rotation, should create soils with stable nitrogen dynamics and minimal nitrogen losses.

Initial field trials of these innovative farming and fertilization practices not only show a reduction in the amount of fertilizer needed for healthy plant growth, they also reveal a positive effect on root formation and crop yield. However, it has not yet been possible to assess additional reductions in nitrous oxide emissions with sufficient precision. Measurement methods that are long established in soil science and forestry are either too expensive, too laborious, or too time-consuming to implement, meaning that modern measurements are always restricted to just a few scenarios. Existing data on nitrous oxide emissions are thus rather unreliable.

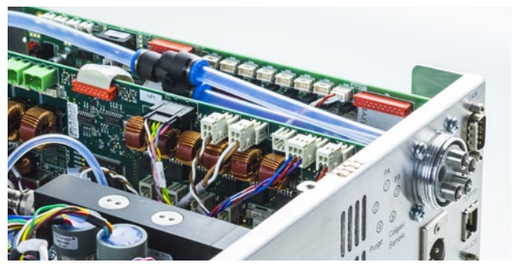
In Fraunhofer's **COGNITIVE AGRICULTURE** lighthouse project (COGNAC), eight Fraunhofer institutes are jointly conducting research on technologies that can maintain the high productivity and quality levels of conventional farming while bringing them into line with the objectives of sustainable, environmentally-friendly agriculture. Measurement data play a key role here, with the intention of making such data available as the basis of a digital ecosystem. New sensor technology for nitrous oxide detection is one of the elements being developed by Fraunhofer IPM as part of this project. The project is led by the Fraunhofer Institute for Experimental Software Engineering IESE.

Nitrous oxide sensors for ground level measurements

For over ten years, Fraunhofer IPM has been developing laser spectrometers for measuring nitrous oxide emissions – albeit chiefly for the automotive sector, since unwanted nitrous oxide is also generated in combustion engines. Building on this expertise, researchers are now developing a new type of nitrous oxide sensor as part of Fraunhofer's Cognitive Agriculture lighthouse project. The aim of developing these sensors is to enable mobile measurements of nitrous oxide concentrations at ground level and at points distributed directly across fields. A compact laser spectroscopy soil sensor that provides high-resolution results is needed for this particular application.

With this application, extremely high demands are placed on the sensitivity of the nitrous oxide sensor . This is because, in the case of ground-level nitrous oxide, relevant increases in concentration are in the order of just a few ppb per minute (ppb = parts per billion, 1×10^{-9}). The measurement methods commonly employed at present use individual containers or soil flux chambers distributed across the field to collect and accumulate gas emitted from the soil. In order to achieve measurable increases in concentration that can be analyzed, closure and collection times of up to 60 minutes are not uncommon with today's standard measurement techniques, since nitrous oxide is typically emitted from soil in quantities of less than 10 µg per square meter per hour.

The development focus for the new sensor is therefore on its ability to determine nitrous oxide emissions quickly and reliably. This is the only way to achieve the high degree of coverage required within practical measurement times. Consequently, Fraunhofer IPM is using an innovative new measurement concept employing interband cascade lasers (ICL). These allow for clear measurement of nitrous oxide in the mid-infrared range, unimpeded by cross-sensitivity with other gases, achieving a drastic reduction in measurement times while improving accuracy at the same time. For the first time, these compact, battery-operated ICL measurement systems are enabling quasi-mobile, real-time measurements of nitrous oxide, even integrated into driverless agricultural vehicles.



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