Focus Reduction of greenhouse gases

Nitrous oxide sensor technology for optimized, climate-friendly nitrogen fertilization to boost agricultural efficiency

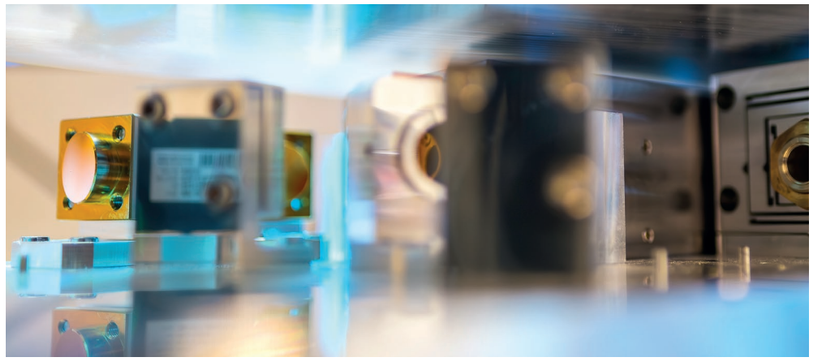
Mobile nitrous oxide sensor: The sample is taken at ground level using a bell jar; the actual measurement system is concealed in a case.

How can a nitrous oxide sensor make agriculture more efficient? And how are suboptimal nitrogen fertilization practices contributing to global climate change? Answering these questions requires an understanding of what nitrogen fertilizing has to do with nitrous oxide formation in the soil and the occurrence of nitrous oxide in the atmosphere.

Few people are aware that nitrous oxide (N_2O), which is also known as laughing gas, is a highly significant greenhouse gas just like carbon dioxide (CO_2) and methane (CH_4). Only trace amounts of N_2O are found in the atmosphere – however, the gas is around 300 times more harmful to the climate than CO_2 and thus still makes a considerable contribution to the anthropogenic greenhouse effect. But what does nitrogen fertilization have to do with nitrous oxide? In simple terms, nitrous oxide predominantly enters the atmosphere in two ways: through nitrogen fertilizers and intensive livestock farming; it is released when microorganisms break down nitrogen-containing compounds. According to data from the German Environment Agency, agriculture is responsible for some 80 percent of nitrous oxide emissions in Germany. The remaining 20 percent largely come from the chemical industry since nitrous oxide is released into the atmosphere during the production of both fertilizers and plastics.

More needs-based fertilization means fewer nitrous oxide emissions

Nitrogen fertilizers used in agriculture are therefore one of the main sources of atmospheric nitrous oxide. To reduce the proportion of this gas in the air, the use of fertilizers in agriculture must be minimized without depleting the soil's nutrient content and thereby decreasing its agricultural quality. The precise regulation of fertilizer use requires a better understanding of how gas is emitted from soil.



Using an innovative measurement concept that employs interband cascade lasers (ICL) as the light source, nitrous oxide can be measured in the mid-infrared range unimpeded by cross-sensitivity with other gases. The entire process is extremely quick and can be performed out in the field.

The content and distribution of nutrients in soil are important indicators for fertilizing soil efficiently and in an environmentally friendly and legally compliant manner. Researchers at Fraunhofer IPM recently started using a spectroscopic gas sensor to precisely determine the degradation of nitrogen-containing compounds by microorganisms in soil. The sensitive measurement system works quickly and at ground level to detect the amount of nitrous oxide that diffuses from arable land in cases of overfertilization – and can pinpoint the exact location of the gas. In the future, this data will be used to determine the optimum amount of fertilizer needed for individual fields. The aim is to minimize nitrous oxide emissions by reliably estimating the amount of fertilizer that will be required the next time the field is fertilized.

Mobile nitrous oxide sensor for fast, precise ground-level measurements

The team developed the nitrous oxide sensor as part of Fraunhofer's Cognitive Agriculture lighthouse project. Due to the extremely high sensitivity requirements, the researchers determined that a very compact and above all high-resolution laser spectroscopy sensor was the only technology up to the task. In the case of ground-level nitrous oxide, relevant increases in concentration are in the range of just a few ppb per minute (ppb, parts per billion). Consequently, the researchers decided to use an innovative measurement concept employing interband cascade lasers (ICL) as the light source. These are able to clearly measure nitrous oxide in the mid-infrared range, unimpeded by cross-sensitivity with other gases, achieving a drastic decrease in measurement time while simultaneously reducing power consumption. This compact, battery-operated measurement system allows quasi-mobile, real-time measurements of nitrous oxide to be taken for the first time – and can even be integrated into driverless agricultural vehicles. The Cognitive Agriculture project was successfully completed in late 2022. It involved seven Fraunhofer institutes in addition to Fraunhofer IPM.

Collaborative Research Centre ECOSENSE: Gas sensors for forest ecosystems

Since late 2022, Fraunhofer IPM has been working with the University of Freiburg as part of the Collaborative Research Centre ECOSENSE to research the negative impact of climate change on forest ecosystems. As carbon reservoirs, these ecosystems are important regulators of the climate system. In this project, the team at Fraunhofer IPM is firstly aiming to use miniaturized sensors to measure CO_2 flows in order to gain a better understanding of how they affect forest ecosystems. Secondly, the team is using a complex spectroscopic measurement technique to investigate the isotopic signature of CO_2 in the air. This signature allows conclusions to be drawn about the source of CO_2 in the atmosphere.

> "Nitrous oxide is around 300 times more harmful to the climate than carbon dioxide."
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> *Prof. Dr. Jürgen Wöllenstein, Head of Department*

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