Flux measurement of N_2O on agricultural areas using laser-based photoacoustic spectroscopy

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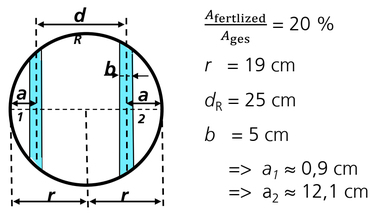
Agrifood systems account for one-third of total anthropogenic greenhouse gas emissions. There is a growing need for quantification of trace gas exchange and for mechanistic descriptions that can be used in models for prediction of future climate changes. Nitrous oxide is a long-lived ozone-depleting greenhouse gas (GHG) with a high global warming potential, it has approximately 300 times greater heat-trapping capacity than carbon dioxide and is the prime contributor to ozone layer depletion in the stratosphere. Over the last 150 years, atmospheric concentrations of N2O have reached unprecedented levels, increasing from 270 parts per billion (ppb) to 332 ppb. The Intergovernmental panel on climate change (IPCC) estimated that agriculture contributes about 60 to 70% of total global anthropogenic N2O emissions, mainly due to nitrogen (N) fertilizer use and emissions from animal waste [1].

Ongoing Project Background

Ideally, an efficient fertilization process using mineral nitrogen can reduce emissions of the harmful greenhouse gases nitrous oxide and ammonia to net zero. An optimization in nitrogen efficiency for example by the addition of coated N-fertilizers can significantly increase the yield and quality of the plants. Increased yield rates can be a consequence of advanced root volume and the improvement of plant biomass accumulation, especially during the growth stages [2]. The aim of the project is to evaluate the differences in the effectiveness of newly developed coated fertilizers (DOMO) and use of natural additives in terms of GHG emissions and yield and to assess their impact on the environment (nitrate leaching). For the investigations, arable land with sugar beet, wheat and maize is parceled out into test parcels. The test parcels differ in the fertilizer combination and in the dosing technique of applying the fertilizer at different soil depths. Different fertilizer machines (RAUCH) are used for this purpose.



$\frac{A_{fertlized}}{A_{ges}}$ = 20 %

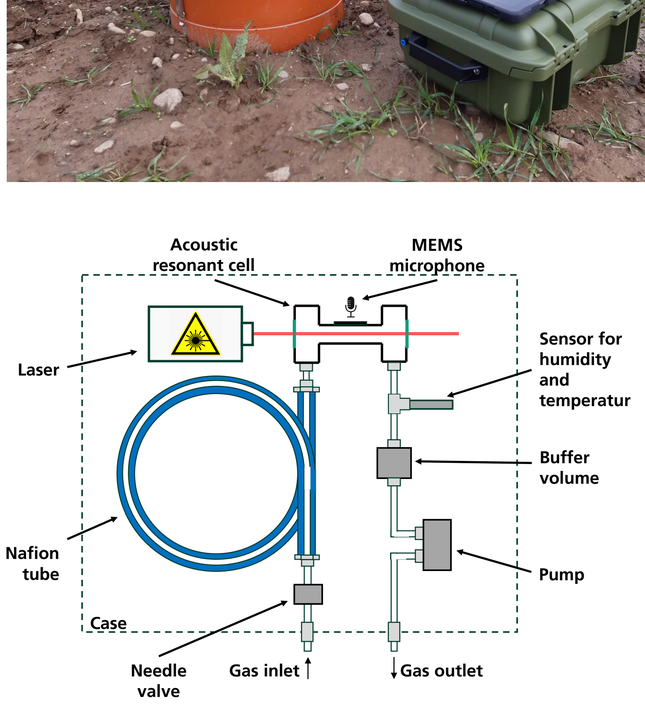
r = 19 cm

d_R = 25 cm

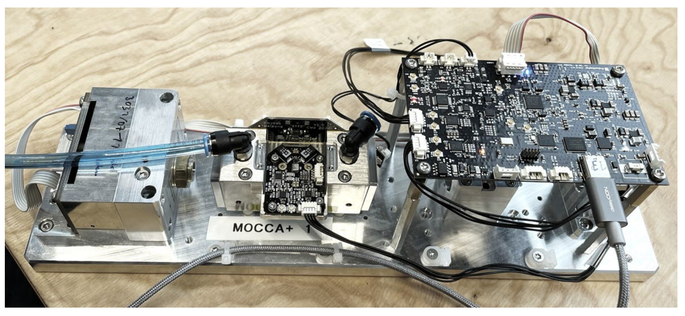
b = 5 cm

=> $a_1 \approx 0{,}9$ cm

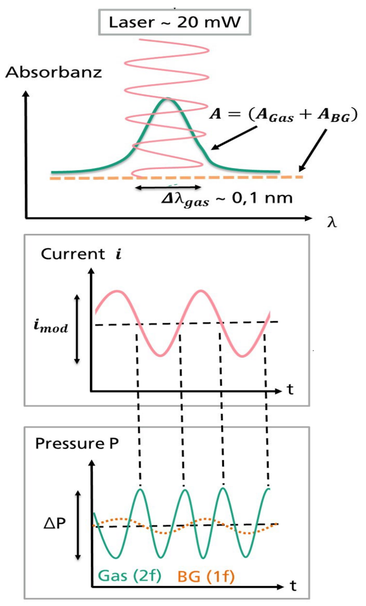
=> $a_2 \approx 12{,}1$ cm



Resonant photoacoustic analyzer



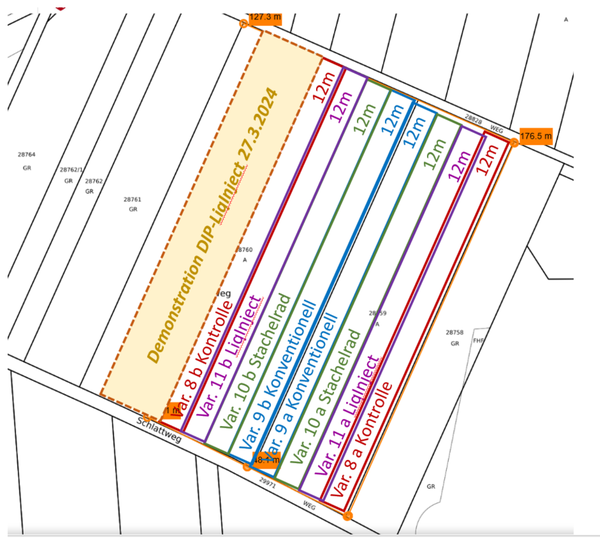
Compact PA gas analyzer channel, modular concept which can be combined with further analyzer channels

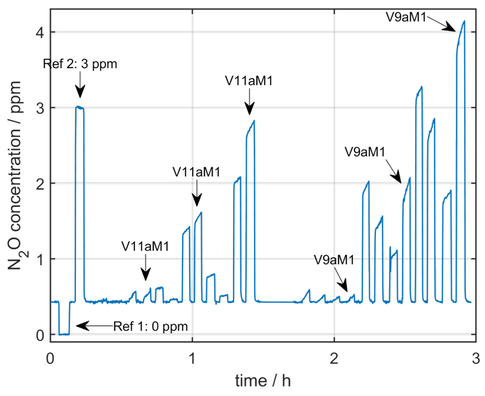


Typical modulation technique of the laser source, a wavelength modulation at the center of a gas absorption line results in a 2f acoustic signal (WMS-2f). Modulation frequency must be matched to the resonant frequency of the acoustic cell.

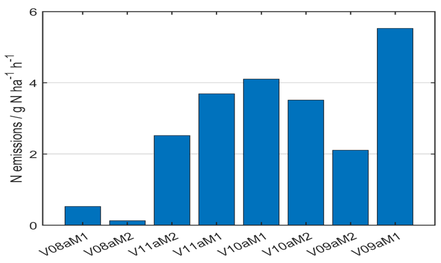
Special features

- Highly integrated electronic main board:
  driver for laser, PA cell and detector + data processing
- PA cell with readout PCB (MEMS microphone)
- Tracking of the resonance frequency
- Reference cell filled with N_2O gas + detector
- Low power consumption, can be battery driven



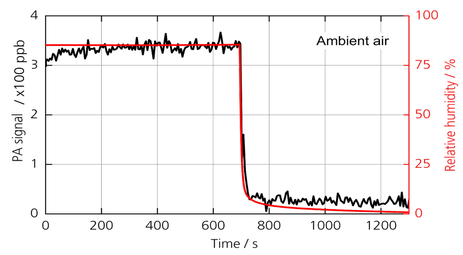


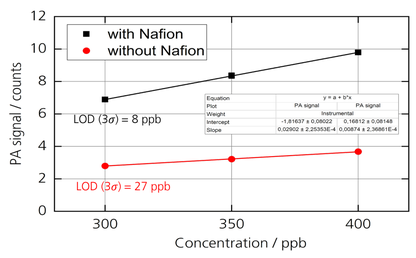
Left: arable land with wheat in stripes prepared with different fertilizing machines (LiqInject and sprocket wheel)
Above: Measurement example of a sequence of three repetitions across the measurement chambers of two strips each. The N2O flux is determined by the slope or increase between two (three) repetitions.
Below: Resulting Quantities of N2O net emissions derived from this



Field experiments

Based on the long-term experience from University of Hohenheim (Germany) the measurement chambers were manufactured which are composed of two components: a base, which is permanently inserted in the soil and a chamber top unit, which is put on the base only during the flux measurement. Although the principle of the method appears simple, some standardization in chamber design and deployment is needed to reduce methodological uncertainty and achieve better comparability between studies in the future [3, 4]. The gas sample is pumped out of the measuring chamber in a circular mode, the sample gas is tempered and continuously humidified for a reproducible detection (LOD < 8 ppb).





Dependence of the PA signal on humidity, measured in the laboratory. For a stable signal with optimum LOD, the humidity in the sample gas must be constantly enriched. Water is absorbed into the walls of the Nafion® tube and transferred to the dry gas stream.

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1 Rahman et al. (2021), *Ammonium Fertilizer Reduces Nitrous Oxide Emission Compared to Nitrate Fertilizer While Yielding Equally in a Temperate Grassland*, Agriculture 2021, 11(11), 1141; https://doi.org/10.3390/agriculture11111141

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4 Mohammad Zaman, Lee Heng, Christoph Müller (2021), *Measuring Emission of Agricultural Greenhouse Gases and Developing Mitigation Options using Nuclear and Related Techniques.* Springer ISBN 978-3-030-55395-1, ISBN 978-3-030-55396-8 (eBook), https://doi.org/10.1007/978-3-030-55396-8

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