Compact Sensor for Photoacoustic Monitoring and Photochemical Dissociation of NO$_2$

Mikael Lassen, Anders Brusch, David Balslev-Clausen and Jan C. Petersen
Danish Fundamental Metrology, Matematiktorvet 307, DK-2800 Kgs. Lyngby, Denmark
ml@dfm.dk

Abstract — A compact and easy to use photoacoustic (PA) detector has been developed for the detection of nitrogen dioxide (NO$_2$). The detector is based on an integrating sphere as the PA absorption cell and LEDs as light sources. Combined with low-cost microphone the PA sensors provide a highly sensitive and low-cost solution for NO$_2$ monitoring. The PA sensor can easily be modified to measure many different atmospheric trace gases simply by changing the wavelength of the light source.

I. Experiment

NO$_2$ is a toxic atmospheric pollutant and is mainly emitted into the atmosphere due to combustion processes. The average mixing ratio of NO$_2$ in the atmosphere is typically between 5–30 parts per billion, but close to a combustion engine it can be orders of magnitude higher. NO$_2$ has a strong and broad absorption spectrum covering the 250–650 nm spectral, however below 415 nm photochemical dissociation of NO$_2$ occurs, which has been observed to reduce the PA signal as function of modulation frequency [1,2].

In this contribution we present a PA experiment with an integrating sphere manufactured from polytetrafluoroethylene [2]. The integrating sphere acts as the PA absorption cell, where a current modulated LED at 405 nm and with 80 mW optical power is used as light source. Using an integrating sphere as the PA absorption cell simplifies the system since the optical alignment becomes very simple and the optical power enhancement is automatically guaranteed [2]. Unfortunately due to the uniform distribution of the light field inside the integrating sphere acoustic resonances cannot be exploited directly for this type of PA sensor [2]. We have demonstrated an increase of the sensitivity of the sensor by attaching an 80 mm long organ pipe tube to the integrating sphere, which enhances the PAS signal 70 times due to the acoustic resonance of the tube.

The figure shows a simulation of the acoustic field pressure, where it clearly can be seen that a resonance only exist in the tube and not in the sphere. The total enhancement factor of the integrating sphere based sensor is approximately 3000 compared to a single-pass non-resonant PA sensor which makes the sensor useful for many practical applications, where sensitivity, low cost and compactness is needed [2]. Further we demonstrate online measurements of photochemical dissociation of NO$_2$ as function of modulation frequency.

References