Photoacoustic detection of atmospheric gases using micro tuning forks

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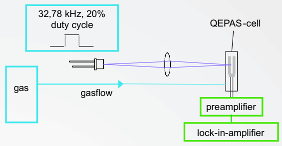
Motivation

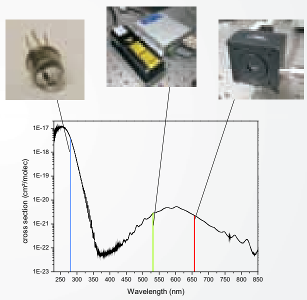
Photoacoustic spectroscopy is a well known method for the detection of atmospheric gases down to detection limits in the range of ppt. A new approach has been introduced in 2002 by Kosterev et. al. using a quartz tuning fork as a sensitive miniaturized detection device. This new technique is called quartz enhanced photoacoustic spectroscopy (QEPAS). Since then various designs and applications have been found. A QEPAS sensor is small and inexpensive due to its simple design and allows mobile applications or fibercoupled network systems for environmental monitoring. In this work we optimize the design for industrial applications such as early detection of fire gases or interior climate control of buildings. Some of the newest investigations are shown.

Detection of ozone - comparison of different light sources

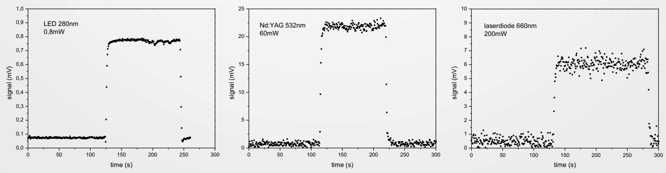
Various atmospheric gases are of environmental concern and/or economical interest. Ozone for example is a very aggressive gas which is hazardous to people and corrosive to many materials. Ozone is produced in generator housings of wind power plants and leads to serious damage to cables and contacts. The monitoring of ozone is helpful to reduce the maintenance costs of off-shore wind parks.



Principal setup of QEPAS

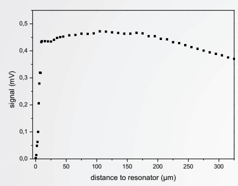


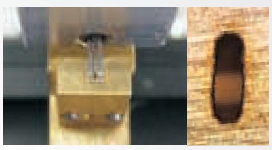
Absorption spectrum of ozone uv-vis



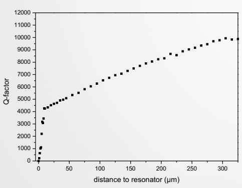
The graphs show the lock-in-signal (mV) of ozone (360ppm) using off-beam QEPAS with three different light sources. From left to right: UV-LED (280nm), Nd:YAG laser (532nm), laserdiode (660nm).

Optimization of the distance between tuning fork and resonator



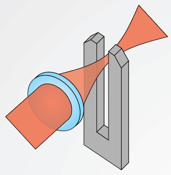


tuning fork above the resonator slit

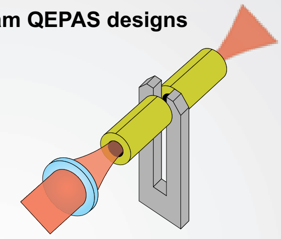


The optimal distance between tuning fork and resonator with 450 m inner diameter has been experimentally determined. For distances below 5 m the damping of the tuning fork's oscillation becomes high, leading to a decline of the signal. The optimal distance is found to be 120 m above the slit opening.

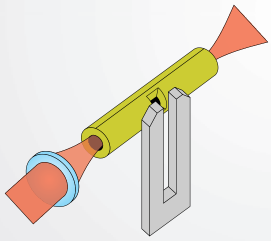
QEPAS and off-beam QEPAS designs



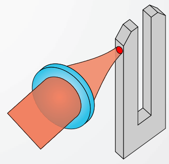
QEPAS without resonator



QEPAS with common resonator

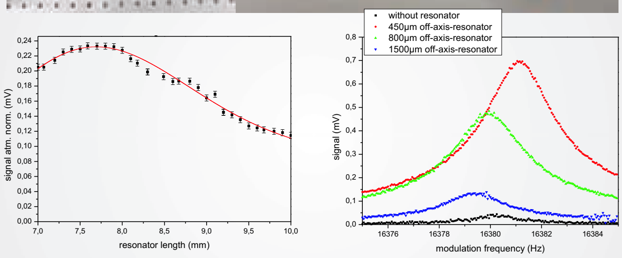


QEPAS with off-beam resonator



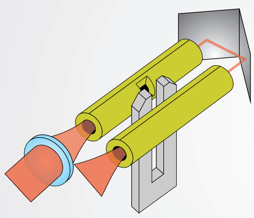
tuning fork as photomomentum detector (QEPOD)

Detection of oxygen - optimization of the off-beam resonator



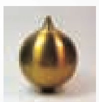
The length of the off-beam resonator has been experimentally optimized. The optimal length for a 0,5mm diameter resonator is 7,69mm. The detected gas is oxygen in air under atmospheric conditions. For the measurements a DFB diode laser at 762nm is used. Contrary to the ozone measurements 2f-wavelength modulation spectroscopy is applied. From the graph on the right side it can been seen, that a smaller resonator diameter leads to higher signal, as expected by theory. However, there are light sources with poor beam quality like LEDs. Their beam cannot be adjusted through extremly small tubes; therefore a trade-off has to be found and even using resonators with big diameters still leads to good results.

Outlook



double-off-beam resonator

$$f \quad \frac{c}{2} \sqrt{\frac{S_0}{V_0 \quad L}}$$



$$Q \quad 2 \sqrt{V_0 \left(\frac{L}{S_0} \right)^3}$$

Helmholtz principle to increase the Q-factor of the acoustic resonator

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