Miniaturization and Application of Fiber Coupled Photoacoustic Gas Spectroscopy

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Photoacoustic gas spectroscopy is a gas analysis technique whose detection limit scales favourably with miniaturization. This project is mainly about the development of a miniaturization approach where instead of the whole gas analysis system, only the essential part for the gas detection is miniaturized, and connected to the other part of the system through optical fibres. It is a natural extension of our previous work around cantilever based fiber coupled photoacoustic spectroscopy, published in 2013.

Several advancements have been achieved in this project, and can be summarized as following:

-The photoacoustic sensor design has been improved. Sensitivity is now 30 times more than the previous work, and is close to what other bulky commercial photoacoustic gas analysers can reach. Background signal, that is commonly seen in literature on photoacoustic sensing, has been theoretically explained and further eliminated with a new sensor design. Better understanding of the noise component of cantilever based photoacoustic sensors has been realized by Allen-Werle deviation analysis.

-Two niche applications for miniaturized fiber coupled photoacoustic gas sensing have been explored. One is on sampling free fermentation process monitoring in a small fermenter. Interesting phenomenons during the fermentation process have been revealed though may not be practically useful. The other is on in−situ dissolved gas analysis for power transformer condition monitoring. It is by far the first demonstration of photoacoustic gas sensors that can directly work in liquid. If the experimental results we got can be upscaled to real power transformers, the immersed photoacoustic gas sensor concept we proposed could realize arcing fault detection of an average sized power transformer several days early than conventional dissolved gas analysers.

-A finite element model has been proposed based on Comsol Multiphysics for frequency response simulation of cantilever-based photoacoustic gas sensors. The comparison with experimental data has shown that this model reflects the reality very well. It has been further implemented to investigate the miniaturization potential of cantilever based photoacoustic gas sensors.

-A peer comparison between the interferometric readout and electrical readout techniques has been made based on tuning fork photoacoustic gas sensor. The comparison could serve as a good reference point for signal readout method selection for the photoacoustic gas sensing community. Few design guidelines have also been proposed for the development of all optical tuning fork photoacoustic gas sensors.

-A semi-distributed photoacoustic gas sensing concept has been explored. Preliminary experiments have been carried out to validate the concept and estimate the sensor sensitivity and linearity. Current challenge and future potential have been identified of this concept.

-The limitations of current study and the technique of cantilever based fiber coupled photoacostic spectroscopy in general have been given explicitly in chapter 9, along with some suggestions for further development.