Determination of cell constant via combined photoacoustic and direct absorption measurement

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Photoacoustic spectroscopy is one of the most reliable methods for measuring gas or aerosol concentration. Whenever a photoacoustic instrument is operated under field conditions it needs regular calibration, which is typically performed by using a calibration gas cylinder or cylinders. Unfortunately, calibration not only limits the reliability of the instrument (via the uncertainty of the concentration of the calibration gas), but it also increases operational cost significantly, and takes off valuable measurement time, as a typical field calibration lasts about 30 minutes or even more.

Here we suggest an alternative calibration method aiming at elimination of these problems. The proposed method is applicable whenever there is a component in the measured gas sample in a sufficiently high concentration to perform both photoacoustic and optical absorption measurement on its chosen absorption line. Our goal was to reduce the calibration time down to a few minutes.

The photoacoustic signal is the first Fourier-component of the product of the modulated power and absorption, the concentration, the cell constant and the concentration of the sample. All of these parameters are time independent (also the concentration is constant in a period of the signal generation) except the output power and output wavelength of the laser. Based on the measured power-current curve of the laser the photoacoustic signal can be simulated. The cell constant gives the sensitivity of the cell and mainly depends on the gas composition the geometry of the resonator in the cell and the microphone sensitivity [1].

In case of atmospheric aerosol measurement, water vapor is an evident choice as e.g. at the wavelength of 1371 nm it has a relatively strong absorption line which is accessible by a fibre coupled single mode DFB diode laser. This example will be shown in the following.

The proposed calibration procedure starts by recording the power of the diode laser as a function of the driving current of the laser under no modulation with a power meter placed right behind the photoacoustic cell. The temperature of the diode laser is set in a way to ensure that the recorded power-current (P-I) curve includes a well measurable absorption line (see Figure 1). The software, which is developed for this calibration procedure identifies the absorption line, fits a Lorentzian line profile on it, and calculates the absorption at each points. The simulated photoacoustic signal (PA) is based on this fitting. Next the laser current is set to be modulated while the laser temperature is unchanged and the photoacoustic signal PAS is measured by changing the constant component of the driving current. Finally, the following quotient gives the cell constant:

$$C_{cell} = \frac{PAS}{PA} \qquad \text{Eqn. 1}$$

The execution of the proposed method on a longitudinal differential cell yielded a calibration constant of C_{cell}= *20 mV/(mW·cm^{-1})*. By taking into account that the applied microphone has the sensitivity of *10 mV/Pa*, our result is in good agreement with the literature value [1, 2]. Furthermore the cell constant determination takes a couple of minutes, which is a very significant time reduction when compared to the typical length of on-filed calibration of minimum 30 min.

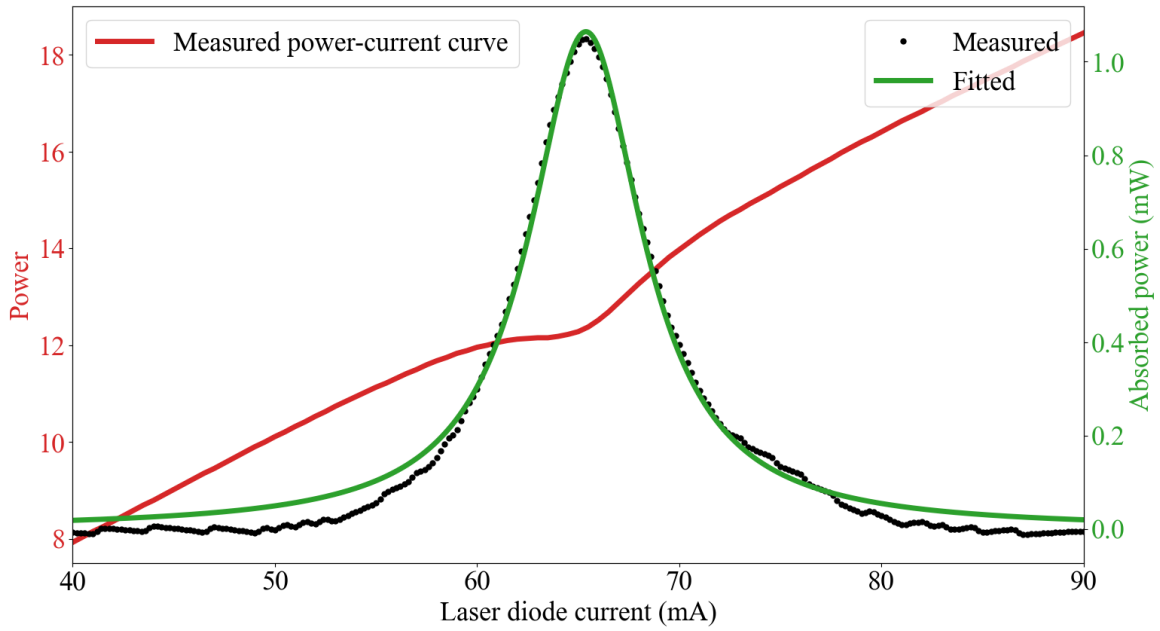

Fig. 1. The red curve shows the light-power as a function of the diode laser current measured by a power meter placed right after the PA cell. The black points are the absorption calculated from the measured data. The green curve is the fitted Lorentzian curve on the light power attenuation due to light absorption within the PA cell.

The method can be used to calibrate photoacoustic aerosol measurement instruments, and for sensitivity check in photoacoustic gas sensors, besides cell constant determination.

References

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