Optimizing a photoacoustic Soot Sensor for the Measurement of ultra-low Soot Concentrations in real-world Exhaust

Michael Arndt, Wolfgang Schindler, Klaus Harms, Herbert Reingruber, Tristan Reinisch, Stefan Riedler

Introduction:
Photoacoustic soot sensors are capable of measuring very low concentrations of black carbon, similar to those found in ambient air. In exhaust gas other chemical components can induce disturbances to the signal. By proper dilution of the sample disturbances can be eliminated, but this may not be desirable in certain application. Cross-sensitivities to water vapor, which are normally negligible, can become a problem at low dilution. Diluents different from air (e.g. N₂) can induce disturbances by changing the acoustic properties of the gas mixture.

Photoacoustic Resonator:
A standing acoustic wave in the resonator is generated by stimulating the particles with a modulated light source.

The Problem:
The System shifts the resonance frequency and the phase angle, when the acoustic properties of the gas change. This causes a change in the zero signal vector (see plot).

Current Solution:
Zeroing with filtered Exhaust prior to Measurement
By performing a zeroing with filtered exhaust and determining the resonance frequency at the same time, the disturbing effects get eliminated.

The Disadvantage:
The Approach works for many applications, but adds complexity. In the case of engine tests the engine has to be running during the zeroing. If the humidity or the acoustic properties of the gas change during the test, the compensation is less efficient.

Conclusion:
The new methodology has been implemented in the AVL Micro Soot Sensor plus signal evaluation Firmware. Cross-sensitivity to water is greatly reduced for measurements of gasoline exhaust. Acoustic disturbances caused by dilution with N₂ could be removed in laboratory and first test bed experiments. Investigations with more complex gas mixtures are ongoing.