Azimuthally Excited Resonators for Photoacoustic Spectroscopy

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Photoacoustic spectroscopy is a highly sensitive technique for the measurement of trace gases. Previously, we have demonstrated the benefits of using 3D printing technology to rapidly manufacture small form factor acoustic resonators at low cost and high sensitivity [1]. We have designed a new 3D printed PAS cell that has been optimised to excite azimuthal resonances in the 10's of kHz range for a number of reasons. As transverse modes, the resonant frequency of azimuthal modes is not generally dependent on the length of the resonator, allowing for longer absorption pathlengths. Secondly, the diameter required to support a resonance in the acoustic frequency range is of the order of 10's of millimeters, much larger than the diameter of typical longditudinal resonance based designs, allowing easy integration of the resonator into mutipass, and cavity enhanced spectrometers. Furthermore, the increased cell diameter results in a decrease in the velocity of gas through the cell, reducing distrubance to the resonance structure. Figure 1 shows the acoustic pressure distribution for a 20 mm diameter resonator that is 40 mm in length. The presence of a node and antinode at the opposite vertices of the cell enables a two microphone detection scheme to be implemented, futher increasing the measured signal level. Despite the larger size and lower total acoustic pressure we have shown that 3D-printied azimuthally excited resonators have a similiar sensitivity to the longditudinal excited designs we have tested previously achieving a normalised noise equivilent absorption of 4.697×10^{-9} $Wcm^{-1}Hz^{-1/2}$

Despite the small size of the resonator itself, the equipment required for laser drive, modulation, and signal acquisition has a significantly larger footprint and high-power demand, which is not desirable in a field deployable sensor. We have also developed a low cost, compact embedded system using the National Instruments MyRio platform, which replaces much of this ancillary equipment. A digital phase sensitive detection algorithm is realised on the system's processor. The MyRio platform is capable of wireless networking and, as much of the signal processing is completed locally, a high number of sensors can easily be networked and monitored from a single remote workstation to enable multi point measurements.

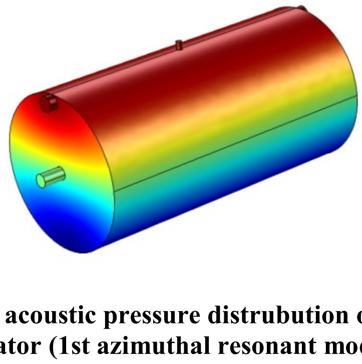

Figure 1 - FEM simulation of the acoustic pressure distrubution of a 20 mm diameter, 40 mm long acoustic resonator (1st azimuthal resonant mode, 10.05 kHz).

References:

[1] Bauer, R., Legg, T., Mitchell, D., Flockhart, G. M. H., Stewart, G., Johnstone, W., & Lengden, M. "*Miniaturized photoacoustic trace gas sensing using a raman fiber amplifier*." J. Light. Technol., **33**, 3773-3780 (2015)