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Novel gas cell design for CO_2 isotope composition measurements using mid-infrared laser absorption spectroscopy

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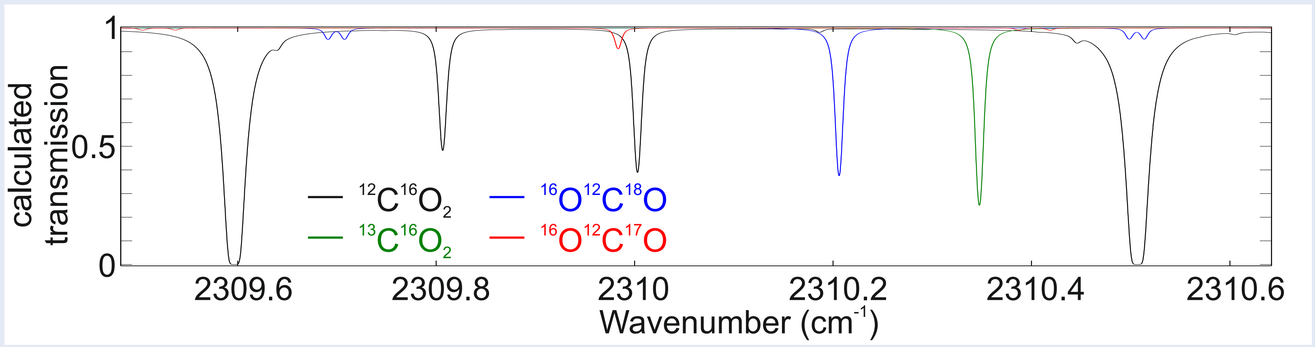
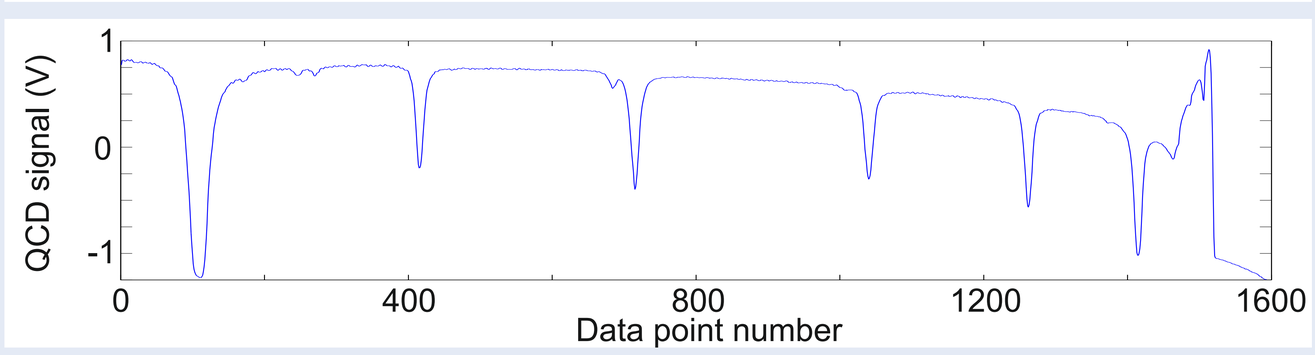
EMPA Materials Science & Technology

n|w Fachhochschule Nordwestschweiz

CO_2 isotopic composition measurements using mid-infrared laser spectroscopy



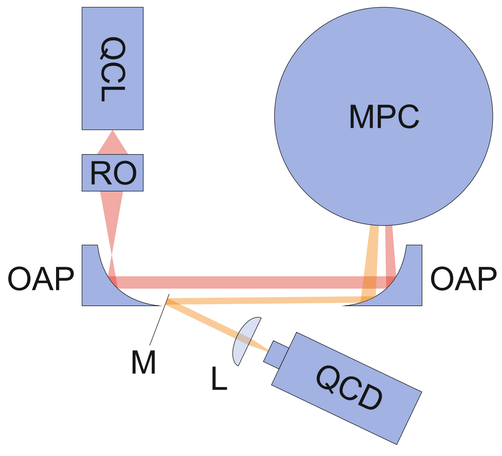


Mid-infrared laser spectroscopy is widely used to monitor trace gas species in industrial, medical, and environmental applications. Also known as the spectral fingerprint region, mid-infrared is especially attractive because it contains the strong fundamental ro-vibrational bands. The mixing ratio of CO_2 isotopes is of great interest for diverse applications such as:

- Human breath analysis: Analysis of the trace gas concentrations in human breath provides a non-invasive way for disease diagnostics. The CO_2 isotope concentrations can be used as an indicator for heliobacter pylori which is very often associated with stomach cancer.

- Environmental studies: The stable isotopes ^{13}C and ^{18}O are excellent tracers to determine the source of CO_2 in sampled air. Isotope ratio measurements allow to discern natural and man-made CO_2 exhaust as well as to partition different natural respiration paths.

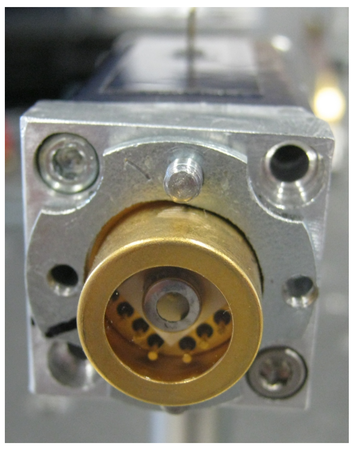
Mid-infrared laser absorption spectrometer setup



The laser beam is generated by a quantum cascade laser (QCL). A reflective objective (RO) and two off-axis parabolic mirrors (OAP) are used to shape the laser beam. The multipass cell (MPC) contains the sample gas. The collimated output beam is guided by a mirror (M) and focalized by a lens (L) onto a quantum cascade detector (QCD).

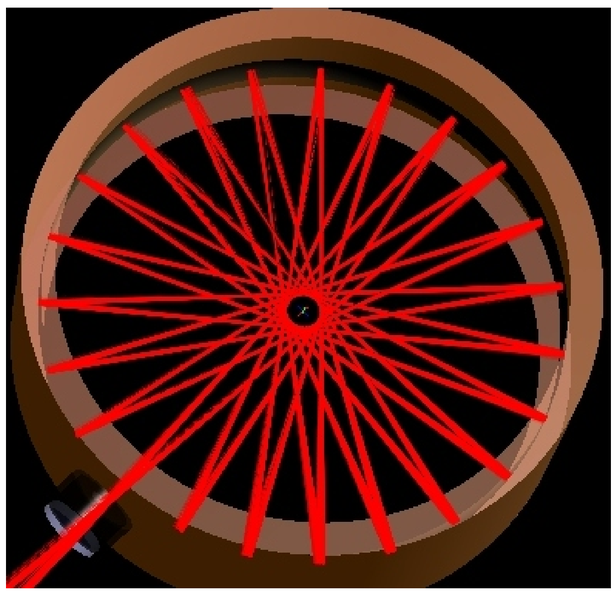
Latest detector technology: a quantum cascade detector

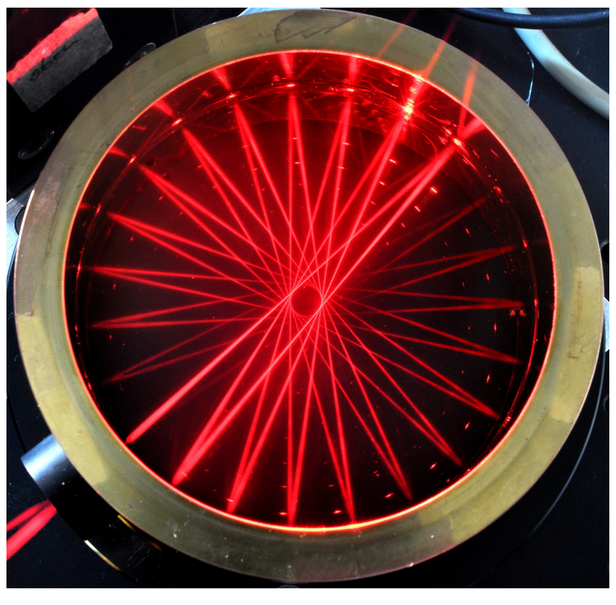
A quantum cascade detector is a spectrally narrow photon detector designed especially for mid-infrared light detection. The small spectral bandwidth allows for measurements with a very low background signal. Therefore, we obtain an outstanding signal-to-noise ratio in our setup.



Novel multipass cell design: a one-piece toroidal mirror cell

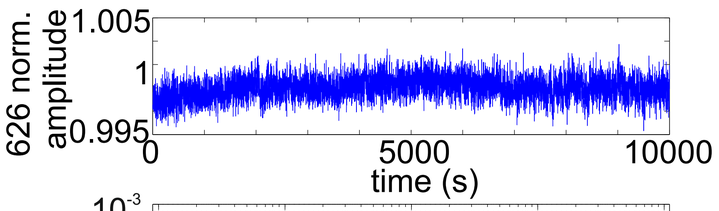
We have developed a new gas cell consisting of a diamond turned 80 mm diameter copper cylinder with a toroidal mirror carved into the cylinder surface. The FRED® simulation shows the star-like beam pattern which is formed by reflection of the light beam from the toroidal surface.

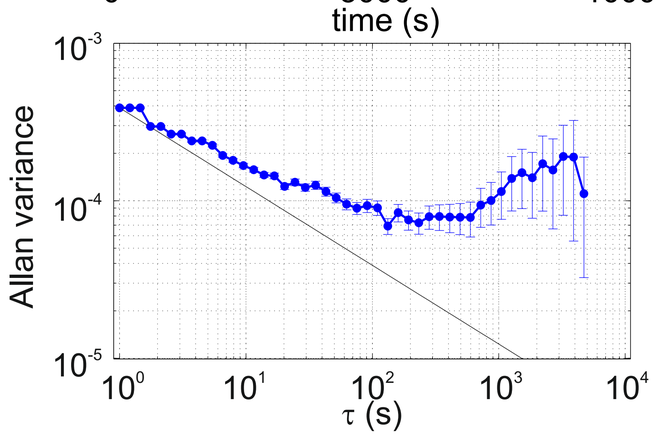




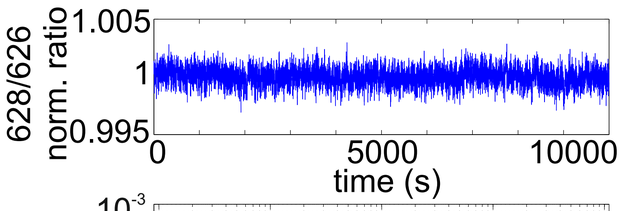
In the photograph, we show the experimental realization of the simulated beam pattern using a HeNe trace laser.

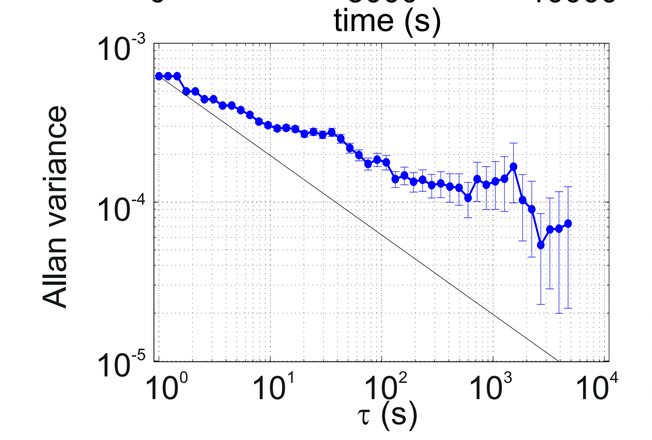
Isotope composition measurements with 0.1 ‰ accuracy





The combination of a quantum cascade laser, the toroidal gas cell, and the quantum cascade detector allows for high accuracy CO_2 isotope composition measurements. The concentration of a single isotope can be measured with 0.07 ‰ accuracy after 200 s averaging (see on the left). The $^{18}O/^{16}O$ ratio is determined with 0.1 ‰ accuracy after 600 s averaging time (on the right).





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