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Optically stable circular multipass cell for compact and lightweight absorption spectroscopy

Manuel Graf, Béla Tuzson, and Lukas Emmenegger

Empa - Swiss Federal Laboratories for Materials Science and Technology, Air Pollution & Environmental Technology, Switzerland (manuel.graf@empa.ch)

Absorption spectroscopy is the method of choice for precise, fast, and contact free measurements of trace gases in a large variety of research fields [e.g. 1]. Today, there is an increasing demand for com-pact and lightweight spectrometers to be deployed e.g. on board of cars, drones, or balloons. Such mobile settings enable the monitoring of trace gas concentrations at a high spatiotemporal resolution at urban, rural or industrial sites, or even in the upper atmosphere. In order to enhance precision and detection limit, absorption spectrometers make use of beam extending multipass cells (MPCs) to in-crease the interaction path length between the probe laser and the sample gas, usually to many tens of meters. Currently, these cells are the major limiting factor towards small and lightweight instruments, because the established designs are not sufficiently achieving both compactness and optical stability. Herein we present a highly promising, versatile concept for compact and well controlled beam folding. Based on the idea of toroidal circular multipass cells as proposed by Tuzson et al. [2], we reconsidered the shaping of the reflective inner surface structure to realize an optically stable beam confinement. By doing so, we combine the constructional advantages of the toroidal cell, i.e. compactness, rigidity and low weight, with optimal optical properties. In contrast to the previous solution [3], optical noise from interference fringes is inherently minimized by the optically stable cavity design. Furthermore, the present concept accepts a wide range of input beam-shapes such that the required optics for beam pre-shaping can drastically be reduced. This implies further miniaturization of any system incorporating this cell. As a proof of concept, we report sub-ppb precision (at 1 Hz) of atmospheric methane measurement in a compact setup containing our novel cell prototype. The cell of 75 mm radius and a mass of less than 200 g extends the laser beam to 10 m within an effective sampling volume of only 140 ml. The results demonstrate the potential of this concept as a versatile solution for many future size- and mass-critical spectroscopic applications.

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