Open-path diode laser spectrometer based on retro-reflective foils

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We present an absorption spectrometer that consists of a combined sending/receiving unit on one side of the absorption path and simple retro-reflecting foil on the other side. It is an inexpensive and easy to align instrument that performs well for small and large absorption paths. Characteristics of the reflective foils are briefly demonstrated.

1 Introduction

Common optical sensors for in-situ gas analysis require a certain effort for adjustment. One possibility is to position the light source and the detection optics at opposite sides of the absorption path. This so-called bi-static setup requires precise alignment of all optical components. Alternative solutions are based on single or multiple reflection of the laser light with mirrors that also have to be aligned (mono-static setups). Our mono-static instrument consists of a combined sending and receiving unit on one side of the absorption path and retro-reflecting foil on the other side. Since the foils reflect light to the direction of origin even for large angles of incidence, there is no need for tedious adjustment. In comparison to existing mono-static concepts, the device is inexpensive because it goes without costly reflecting optics. The foils originate from traffic applications and are industrially available and low-priced.

2 Absorption spectrometer

The spectrometer comprises a joint sending and receiving unit at one side of the absorption path and a retro-reflecting foil at the other side. Fig. 1 shows the schematic setup of the instrument: The light is emitted by a DFB diode laser that is controlled with a signal generator and a laser driver. It is collimated by a fibre-coupled collimator. It passes a 50-50 beam splitter that is required for detection.

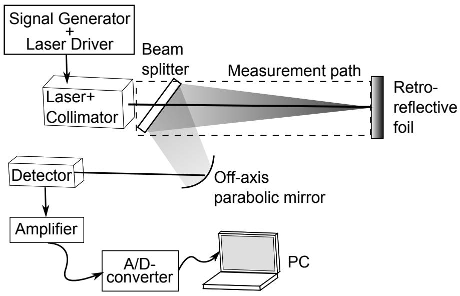

Fig. 1 *Schematic setup of the spectrometer*

At the opposite side, the light is reflected by a retro-reflecting foil. Since the collimation and reflection are not ideal, the reflected laser beam is slightly broadened. At the detecting side, 50$\%$ of the light is reflected at the beam splitter and directed onto an off-axis parabolic mirror. This mirror focuses the light onto a InGaAs photodiode.

In combination with Tuneable Diode Laser Absorption Spectroscopy ("TDLAS"), gas concentrations can be measured absolute and self-calibrating ([1]–[3]).

3 Retro-reflecting foils

We have tested different types of reflective foils. The simpler ones are realized with glass beads that have about 60 μm diameter. Fig. 2 shows two variants of these glass bead foils. On top, a foil with embedded beads is depicted. The light is defracted several times and reflected at a reflective layer.

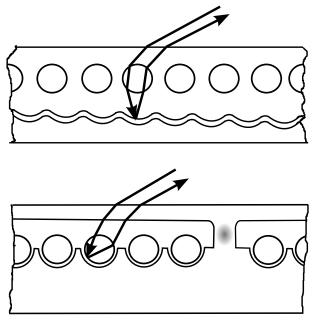

Fig. 2 *Retro-reflective foils with glass beads. Top: Embedded glass beads, bottom: encapsulated glass beads.*

A more advanced glass bead foil type is shown at the bottom of Fig. 2: here the beads are encapsulated. The reflection principle stays the same, but there is a layer of air between the beads and the surface of the foil, so light absorption is reduced. Consider that the protecting surface has to be connected to the rest of the foil by weldings where no reflection takes place. A different sort of retro-reflecting foils uses 10 μm-

scaled micro-prisms (view Fig. 3).

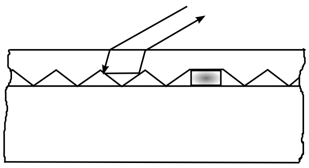

Fig. 3 *Microprismatic retro-reflecting foil*

The prismatic stucture is directly pressed into the surface foil. The light is only diffracted at the surface and reflected at the prism-structure. Some of these foils also require weldings between the base foil and the surface foil.

Previously we have shown that the foils reflect light for a large variance of incident light angles and distances between the sending/detecting side and the reflector [3]. Moreover, we have presented 1D and 2D profiles of the reflected light. Another interesting quantity is the reflection depending on the relative position of the laser beam on the foil. The laser beam was moved laterally along strips of foil with 100 mm length. At 1 mm steps, the reflection of light was detected. Note that 75$\%$ of the light are lost in the first place due to the 50-50 beam splitter. The percentage of reflection is shown in Fig. 4 for various foils. This measurement took place with a distance of 1 m between foil and collimator. In general, the microprismatic foils have a higher retro-reflectivity than the glass bead foils. On the one hand, the retro-reflection seems to work better with the prisms, since the glass beads may be not ideally spheric and scatter part of the light into other directions (view Fig. 5). Moreover there is more light absorption in the foil material especially for the embedded glass bead foil. The foils that have weldings reveal a periodic weakening of reflectivity.

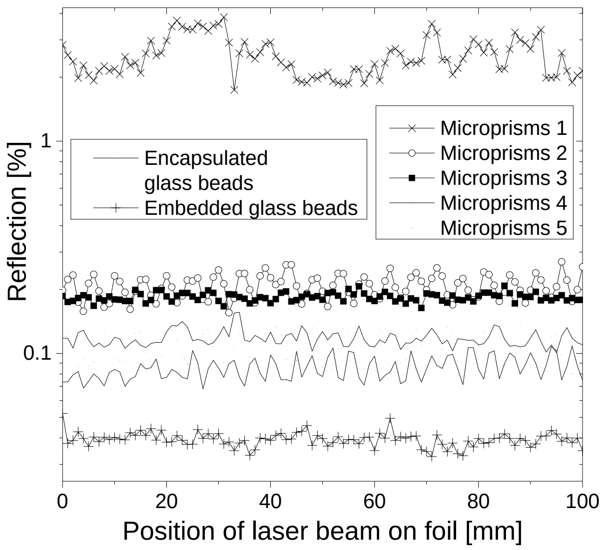

Fig. 4 *Reflection of laser light depending on the position on the foil*

This is caused by the regularly spaced weldings that are not reflecting light. Nevertheless, there is always some reflection because the laser beam is broader than the welding.

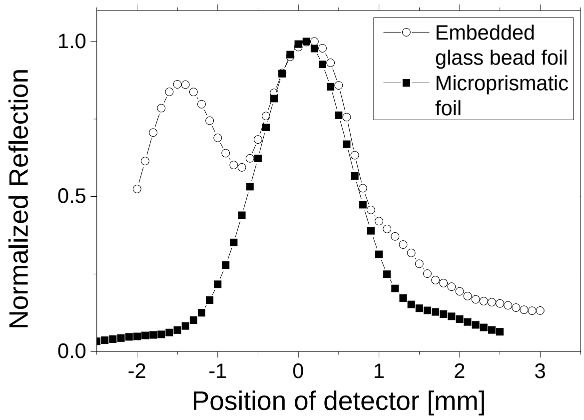

Fig. 5 *Normalized 1D profiles of reflection of microprismatic and glass bead foil*

4 Conclusion

We have presented a simple and low-cost mono-static absorption spectrometer that has a joint sending/receiving unit at one side of the absorption path and a retro-reflecting foil at the opposite side. Due to the characteristics of the foil, there is hardly any need for adjustment. Firstly there is no need for angular adjustment as we have shown in [3]. Additionaly, the exact position of the laser beam on the foil is not relevant, even if non-reflecting weldings are part of the foil. In combination with these foils, our mono-static spectrometer is an inexpensive alternative to common instruments that delivers good concentration measurements for long and short absorption paths as presented previously [3].

References

[1] O. Witzel et al.,“High-speed tunable diode laser absorption spectroscopy for sampling-free in-cylinder water vapor concentration measurements in an optical IC engine”, *Appl.Phys.B* **109**,521–532 (2012).

[2] S. Wagner et al.,“Absolute, spatially resolved, in situ CO profiles in atmospheric laminar counter-flow diffusion flames using 2.3 μm TDLAS”, *Appl.Phys.B* **109**, 533–540 (2012).

[3] A. Seidel et al., “TDLAS-based open-path laser hygrometer using simple reflective foils as scattering targets”, *Appl.Phys.B* **109**, 497–504 (2012).