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Remote Sensing of Mass Fluxes of Trace Gases in the Boundary Layer

Ch.Werner[1], R. Haus[2], F. Köpp[1] and K. Schäfer[2]

1: DLR - Institute of Optoelectronics, 82230 Weßling, Germany

2: Fraunhofer-Institute of Atmospheric Environmental Research
Rudower Chaussee 5, 12484 Berlin, Germany

The combination of remote sensing methods like Doppler lidar and FTIR or DAS-lidar offers the possibility to determine mass fluxes of gases remotely.

Doppler lidar measures the three-dimensional wind vector in the vicinity of diffuse sources or the velocity of air in a chimney plume if an industrial complex is monitored. FTIR is a multicomponent remote sensing method for gas concentrations. The Fourier transformation of an interferogram of a Michelson interferometer within a FTIR system converts the recorded intensity (function of optical path length) to a spectral signal (function of wavenumber). DAS-lidar is a range resolved method to determine the concentration of a specific gas along the given line of sight. Both informations, velocity and concentration, give the mass fluxes of the tracer (gas).

For explaination of Laser Doppler Anemometer (LDA) measurements the principle is demonstrated in Figure 1. The cw-LDA was introduced in 1983 (Köpp et al. 1983).

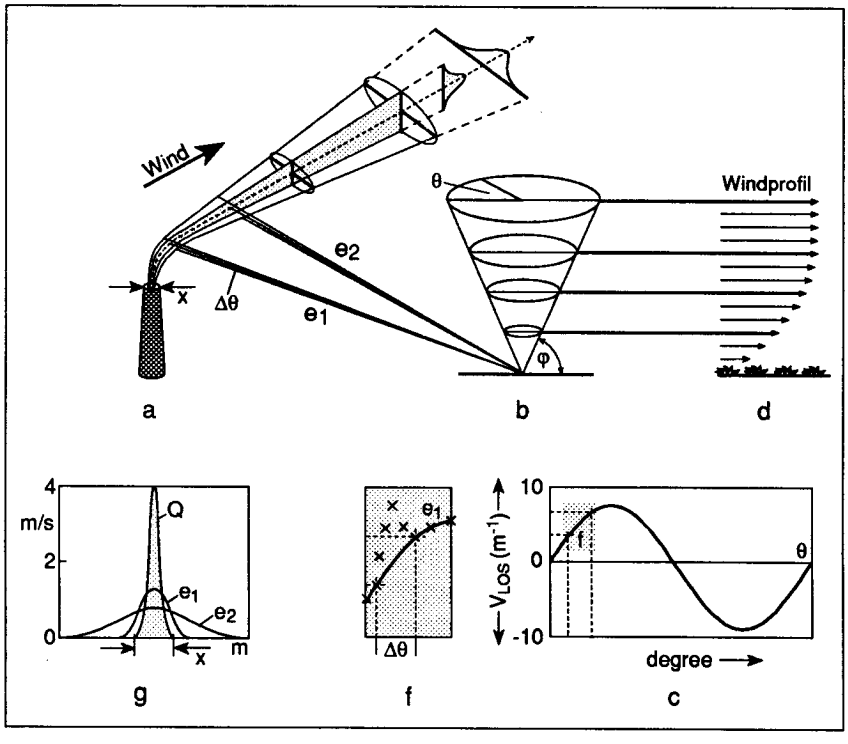

Figure 1 Principle of mass flux measurements using a LDA system

Figure 1a shows the chimney with the plume in wind direction and the diameter of the chimney x and Figure 1b the VAD-scan (fixed elevation angle φ over the azimuth θ. Focussing in different altitudes and performing full azimuth scans gives the wind profile (Figure 1d). A sine-wave fitting of the single line-of-sight (LOS) wind components is necessary to extract the wind vector (Figure 1c). To estimate the tracer velocity of the chimney a sector scan in the level of the top of the chimney is necessary (azimuth-scan angle $\Delta\theta$). This gives LOS measurements at different levels (e_1) and (e_2). These signals can be compared with the sector scan of the undisturbed wind field (Figure 1f). One can estimate the influence of the chimney (Figure 1g) and can determine the vertical wind component of the chimney top (area Q) from the diameter x.

A first test was performed at Munich-North power station with FTIR and cw-Doppler lidar. Fluxes of CO_2, CO, NO, and HCl were determined. The results are in good agreement with the fluxes measured by in-situ instruments of the power station. The method can be used to control industrial complexes from an outside observation site.

Figure 2 shows the map of the power station, the location of the LAD is marked by DLR and that of the FTIR is marked by IFU. The chimneys 1, 2, and 3 are indicated. Chimney 1 is 135 m heigh and has a diameter of 5 meters at the top. Three single chimneys are integrated in one.

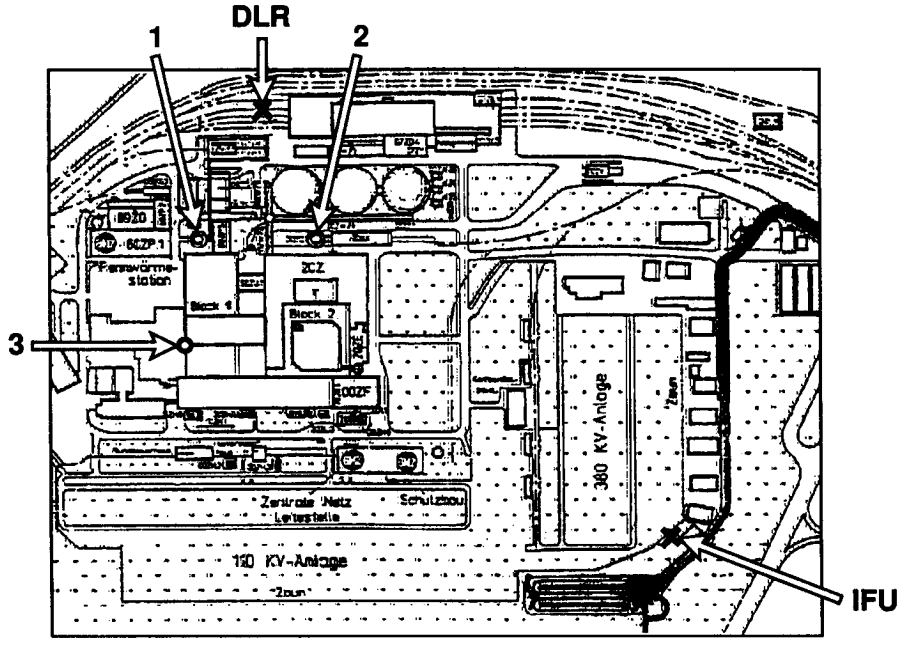

Figure 2 Map of the power station Munich-North with the container LDA and the van of IFU (FTIR)

The measurement volume of the LDA is sketched in Figure 3. It is limited by the focal volume (20 m length and 5 cm diameter at the chimney top).

The plume of chimney 2 was measured under different elevation angles. Figure 4 shows the vertical wind components.

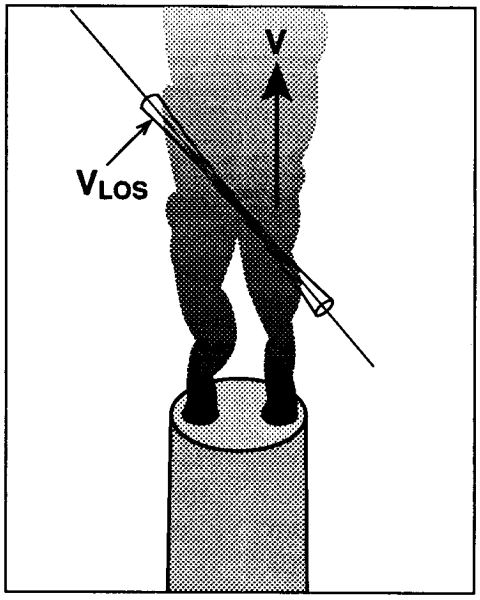

Figure 3 Principle of the LDA measurement volume

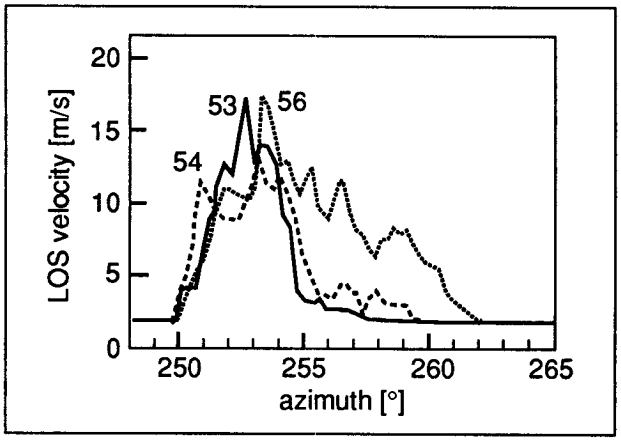

Figure 4 Vertical wind components of chimney 2 versus azimuth angle

As shown in the principle of Figure 1g, there is a spreading with increasing distance from the top of the chimney. At the same time the maximum wind component decreases. The measured velocity of about 20 m/s is in good agreement with the in-situ data of the power station (averaged velocity of 14 m/s for chimney 1 and 16 m/s for chimney 2).

References:

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Köpp, F., H. Herrmann, Ch. Werner und R. Schwiesow: Erstellung und Erprobung eines Laser Doppler Anemometers zur Fernmessung des Windes, DFVLR - FB 83 - 11, 1983.
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