Lecture 5.

PHOTOACOUSTIC SPECTROSCOPY IN INDUSTRIAL APPLICATIONS

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Photoacoustic spectroscopy is an extremely sensitive technique for trace gas monitoring. In this method, the molecules of the species to be analyzed are selectively excited by a modulated laser beam of appropriate wavelength. The subsequent non-radiative relaxation of the excited molecules produces a periodic heating of the sample and hence, a pressure modulation. If the laser beam is modulated in the audio frequency range, an acoustic wave is thus generated at the same frequency. The amplitude of this sound wave is directly proportional to the amount of light absorbed in the sample (thus to the gas concentration) and can be easily detected using a simple and very sensitive microphone. In opposite to other traditional spectroscopic methods, in which the light transmitted through the sample is measured, photoacoustic spectroscopy allows the direct determination of the light *absorbed* in the sample. Therefore, it presents the advantage to be a zero-background technique, *i.e.* no signal is produced when no absorbing substance is present.

The sensitivity of the technique can be strongly improved using a resonant configuration, in which the measurement cell is carefully designed to be an acoustic resonator. When the laser modulation corresponds to an acoustic resonance of the cavity, an acoustic standing wave is built in the resonator. This standing wave can accumulate energy to an extend much larger than the energy input per cycle, leading to an increase of the wave amplitude in comparison to the non-resonant case. The acoustic signal is thus enhanced by the quality factor Q of the resonance, which can reach several hundreds for well-designed photoacoustic cells.

The basic principles of resonant photoacoustic spectroscopy will be described and the different types of resonances (longitudinal, radial, azimuthal) will be discussed. Then, an optimal design of a photoacoustic cell coupled to a CO_2-laser will be presented. This system has lead to the realization of a commercial instrument for extremely low NH_3-concentrations measurement. Applications of this instrument to the control of the atmosphere in clean rooms in the semiconductor industry and to environmental monitoring will be demonstrated. Different experimental results obtained in these applications and showing a sub-ppb detection limit will be presented.

Finally, applications of photoacoustic spectroscopy using near-infrared semiconductor laser diodes will be presented. Different cell configurations will be discussed as a function of the laser specifications.