Popular Abstract

Photoacoustic trace gas analysis is a method of determining pollutants in gases. A very common example is the determination of CO_2 in atmospheric air. The method consists of absorption of infrared light, which generates heat. This is the same effect as the absorption of infrared sunlight that heats the earth. The infrared light source is typically a laser. This laser can be adjusted in optical wavelength ("color of the light") such that certain molecules are specifically well-suited for absorption. This means that a gas sample which contains a large amount of these molecules will absorb more light than samples with less of these molecules, thus generating more heat. When switching the laser source on and off periodically, the gas sample will heat up and cool off periodically. Since heating roughly corresponds to increasing pressure, the whole process results in a periodic pressure change; commonly known as an acoustic signal.

We use this technology to determine traces of heptane in atmospheric air. Heptane shares some properties with heated oil, and the overall goal is to measure oil contaminations in pressurized air for use in industrial applications. The sample gas is trapped in a photoacoustic cell. Here we apply the laser beam and measure the signal with a microphone. We develop mathematical models for the behaviour of the acoustic signal, including resonance frequencies leading to acoustic amplification. The models also include the effects of acoustic losses occurring in the cell, limiting the amplification factor at resonance. We investigate theoretically the impact of the cell geometry on the background noise in order to increase sensitivity and optimize the cell design to have the lowest resonance frequency coinciding with the frequency of the highest microphone sensitivity.

Further we develop theoretical models for the analysis of semiconductor structures used in optoelectronic technology such as diode lasers. We investigate which effect a change of the basis crystal orientation has on the internal electromechanical fields in the structure. These fields are of vital importance for optical properties, both in terms of optical wavelength ("laser color") and for efficiency.

Finally we also develop a rigorous theory of the photoacoustic effect within solids and the acoustic coupling to other materials. This can be used in medical application for measuring different material contents in e.g. human tissue.