What types of NDIR sensors exist and how do they work?

An introduction to the principles behind transmissive and photoacoustic NDIR sensing

Characteristics of NDIR Sensors:

NDIR sensing has become the prevalent technique for measuring CO_2 concentration. The technology exploits the characteristic property of CO_2 molecules to strongly absorb infra-red (IR) light with wavelengths around 4.2 µm. When shining light of this wavelength through a gas sample, the CO_2 concentration can thus be calculated from the proportion of light that is absorbed.

It is important to note that NDIR sensors do not require a dispersive element, such as a prism or a diffraction grating, to discriminate for the targeted wavelength. Instead, the light produced by the emitter is shown through a non-dispersive band-pass filter, allowing only the infra-red wavelengths of interest to pass. These characteristics give the sensors their classification: **N**on-**d**ispersive **I**nfra-**r**ed.

Transmissive NDIR:

These NDIR sensors typically feature an IR emitter and an optical detector, such as a photodiode, at opposite ends of a specially designed optical cavity. The optical detector measures the amount of IR light energy that is not absorbed by (i.e., transmitted through) the gas sample. As the CO_2 concentration in the optical cavity increases, the amount of light detected decreases. Hence, this principle determines the amount of light energy CO_2 molecules have absorbed by calculating the difference between the measurement and a reference intensity at a known CO_2 concentration.

NDIR CO_2 sensors leverage infra-red absorption at 4.2 µm wavelength without the use of dispersive optical elements.

Note that this reference value heavily depends on precise positioning of IR emitter and photodetector, as well as the emission properties of the IR source and the optical cavity. Mechanical and thermal stresses acting on the measurement chamber can thus significantly falsify CO_2 readings. Furthermore, transmissive NDIR sensors generally require a minimal optical path length in the centimeter scale for enough IR absorption to occur to accurately measure lower CO_2 concentrations.

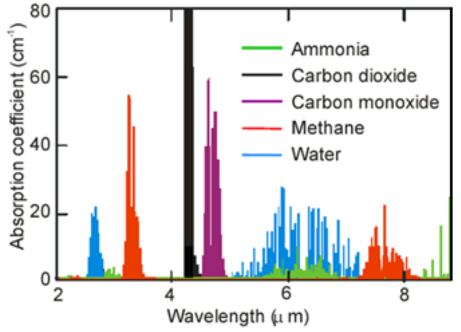
Photoacoustic NDIR:

In contrast to transmissive NDIR sensors, photoacoustic NDIR sensors detect the amount of energy that is absorbed by CO_2 molecules. When pulsing the infra-red emitter, CO_2 molecules absorb infra-red light periodically. This causes additional molecular vibration resulting in a pressure wave inside the measurement chamber. The higher the CO_2 concentration, the more light is absorbed, and thus the greater the amplitude of this acoustic wave becomes. A microphone inside the gas chamber measures this, from which the CO_2 concentration can then be calculated.

Photoacoustic NDIR sensing allows for much greater miniaturization of the measurement chamber. Furthermore, as sound waves are omnidirectional, relative positioning of emitter and microphone is unconstrained. Thus, photoacoustic NDIR sensors are usually more mechanically and thermally robust.

Further reading:

Learn more about the different types of NDIR sensing technologies in this review paper by D. Popa and F. Udrea of the University of Cambridge



Absorption spectra of common trace gases (HITRAN2016 molecular spectroscopic database)

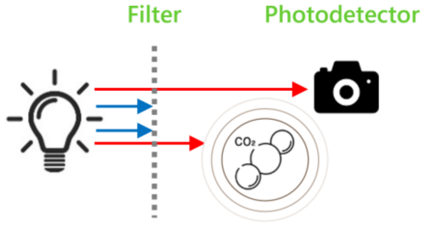


Illustration of a Transmissive NDIR setup

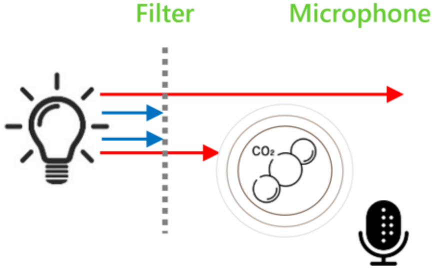


Illustration of a Photoacoustic NDIR setup