High Resolution Absorption Coefficient and Refractive Index Spectra of Pollutant Gases at Millimeter Wavelengths

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Abstract — A great advance in submillimeter spectroscopy came with the development of Fourier Transform Spectroscopy (FTS). This technique employed Michelson two-beam interferometer connected to a digital setup. This technique was mastered at the National Physical Laboratory, U.K., over 7 years from 1958 – 1965. Dispersive Fourier transform spectroscopy (DFTS) takes the idea of FTS a step further and introduces the sample in the active arm of the two beam interferometer. Our new dispersive Fourier transform spectroscopy technique employing polarizing wire grids for beam division, mastered by M.N. Afsar allows us to accurately measure spectra for transmission, absorption coefficient, refractive index, real and imaginary parts of complex dielectric permittivity of pollutant gases from 2 - 200 wavenumber per cm (60 GHz – 6000 GHz). In this paper, the absorption coefficient and refractive index spectra of pollutant gases are presented as a function of pressure.

Introduction

A great advance in submillimeter spectroscopy came with the development of Fourier Transform Spectroscopy (FTS). This technique employed Michelson two-beam interferometer connected to a digital setup. The line diagram of this can be seen in Fig. 1. This technique was mastered at the National Physical Laboratory, U.K., over 7 years from 1958 – 1965. Dispersive Fourier transform spectroscopy (DFTS) takes the idea of FTS a step further and introduces the sample in the active arm of the two beam interferometer. Our new dispersive Fourier transform spectroscopy technique employing polarizing wire grids for beam division, mastered by M.N. Afsar allows us to accurately measure spectra for transmission, absorption coefficient, refractive index, real and imaginary parts of complex dielectric permittivity of pollutant gases from 2 - 200 wavenumber per cm (60 GHz – 6000 GHz). In this paper, the absorption coefficient and refractive index spectra of pollutant gases are presented as a function of pressure.

Results

Pollutant gases are known to have very distinct rotational transition lines. In the case of Carbon Monoxide (CO), these lines are equi-spaced and at very precise frequency locations. The rotational transition lines for CO were observed as a function of pressure and can be seen in Fig. 2. As we increased the pressure of the sample gas, the exact position of the absorption lines did not move, however there was a change in the intensity. The refractive index spectra for the corresponding pressures can be seen in Fig. 3. As the pressure increased, the intensity of the rotational transition lines increased. The exact relationship between the increase in pressure and the increase in intensity can be seen clearly in Fig. 2. This relationship is close to linear and can be characterized by the following equation:

\[ y = 0.00003x + 0.0199 \]  

The relationship between the refractive index spectrum and pressure for CO gas was also measured and characterized. Absorption and refractive index spectra for a few other gases namely Carbon Dioxide (CO2) and Sulfur Dioxide (SO2) were also studied as a function of pressure. Examples of the rotational transition lines and refractive index spectra for CO gas at a certain pressure can be seen in Fig. 5 and Fig. 6 respectively.

Fig. 1. The gas chamber is an active arm of the interferometer and has a fixed mirror at one end and a polyethylene window at the other. An ultra sensitive liquid helium cooled, hot electron InSb detector is used in the setup. The pressure of the gas in the chamber is controlled with very precise and sensitive pressure valves and gauges.

Fig. 2. J''5 rotational line at different pressures. As the pressure increases only the intensity of the absorption lines increases and not the position.

Fig. 3. Dated refractive index spectrum at different pressures. As the pressure increases the dispersion through the absorption peaks becomes greater and the entire level of the spectrum decreases. However the position of the dispersion remains the same and confirms the absorption peaks in Fig. 2.

Fig. 4. Absorption peak intensity vs. pressure for the J'' = 5 rotational transition line of CO gas. There is clearly a near linear relationship between the increase in pressure and the increase in intensity of the absorption peaks.

Fig. 5. Absorption Coefficient Spectrum for CO gas at 520 Torr. CO gas has a number of equi-spaced rotational transition lines. These lines can clearly be seen here for the presented frequency range.

Fig. 6. Refractive Index Spectrum for CO gas at 520 Torr. The dispersion through each of the absorption lines can be seen. The more intense the absorption peak, the greater the dispersion through that peak.