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MULTIFREQUENCY DIAL SENSING OF THE ATMOSPHERIC GASEOUS CONSTITUENTS USING THE FIRST AND SECOND HARMONICS OF A TUNABLE CO_2 LASER RADIATION

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High-energy and operation characteristics of a CO_2 laser have stipulated their wide use in absorption gas analyzers and lidars capable of measuring the concentrations of 30 gaseous components of the atmosphere with concentration sensitivity up to 10^{-9} atm. At the same time, the absorption lines of a number of important molecular species such as CO, N_xO_y, SO_2, etc. are off the range the CO_2 laser emits in. To measure the concentration of these components one can use the semiconductor lasers and parametric light generators, operating in the range of absorption bands of these gases.

However, in our opinion, more promising for these purposes is the development of simple reliable and effective parametric frequency converters of the CO_2 laser radiation.

This paper presents the results of field measurements of concentration of some gaseous components of the atmosphere along the paths, in Sofia, Bulgaria, using a gas analyzer based on the use of CO_2 laser radiation frequency-doubled with $ZnGeP_2$ monocrystal. The gas analyzer is a traditional long path absorption meter. Radiation from the tunable CO_2 laser of low pressure and from an additional He-Ne laser is directed to a collimating hundredfold Gregori telescope with a 300 mm diameter of principal mirror. The dimensions of mirrors of a retroreflector 500x500 mm and a receiving telescope (ø 500 mm) allow one to total intercept the beam passed through the atmospheric layer under study and back.

A detectable block of a frequency doubler is inserted into the beam at the gap between the laser and beam expander. The frequency doubler itself is a single crystal of triple semiconductor $ZnGeP_2$ of 10 x 20 mm cross section and 3-10 mm thickness with polished ends. In front of the crystal a focusing lens of BaF_2 is placed and after it a LiF collimating lens is located. The latter is used simultaneously as a filter, cutting off the CO_2 laser radiation.

The frequency doubler is described in detail in [1,2]. Although monocrystals of $ZnGeP_2$ have lower conversion efficiency compared with that of $CdGeAs_2$ monocrystals, they have better performance characteristics. In particular, they do not require the cryogenic temperatures for operation and have greater radiation resistance to CO_2 laser radiation (60 MW/cm^2 for laser pulses of 200 ns duration and more than 200 kW/cm^2 for c w lasers).

For tuning the CO_2 laser radiation onto the absorption lines of calibrated gaseous mixtures and for measuring the absorption coefficients of local air samples an optoacoustic detector (OAD) is mounted instead of the frequency doubler. The OAD sensitivity, determined using the mixture of ethylene and water vapor with pure nitrogen, was 30 $V/W \cdot cm^{-1}$, and threshold sensitivity in terms of the absorption coefficient was $10^{-7} cm^{-1}$ for the output power of the CO_2 laser about 100 mW. The frequency tuning of the CO_2 laser radiation made with a stepping motor driven grating, as well as the alignment of a frequency doubler along the phase synchronism direction, and fine tuning of the radiation frequency with a piezoelectric corrector are automated and monitored by a micro-computer. Also automated is the process of data acquisition and processing.

The micro-computer allows also the solution of the ill-posed inverse problem on determining the gaseous concentration from the multifrequency sounding data to be found using the Tikhonov's regularization method. The results in the form of concentrations of sounded gases and residual (after subtracting the selective absorption) attenuation coefficients are stored on the flexible magnetic disks.

Figure 1 presents the fragment of one cycle of simultaneous low path absorption measurements of concentrations of four atmospheric components at 16 CO_2 laser radiation wavelengths and the atmospheric attenuation coefficient at $\lambda = 0.63$ µm. At two points the comparative measurements of local concentrations using OAD have been made, which show good agreement with the path measurements.

Figure 2 gives the spectral behavior of the atmospheric absorption coefficient for this spectral range to illustrate the possibilities of measurements at the wavelengths of the second harmonic of CO_2 laser radiation. The frequency doubler of the R(18) and R(20) lines of a nine microns CO_2 laser radiation band coincides with the absorption lines of the fundamental band. The corresponding absorption coefficients are equal to 25.7 $cm^{-1}atm^{-1}$ and 10.28 $cm^{-1}atm^{-1}$. The third peak is evidently due to the absorption at N_2O line, which is strongly disturbed by the spectrally close H_2O vapor absorption lines. This fact requires additional laboratory tests. Figure 3 presents the fragment of temporal variation of CO concentration obtained using a long-path absorption gas analyzer.

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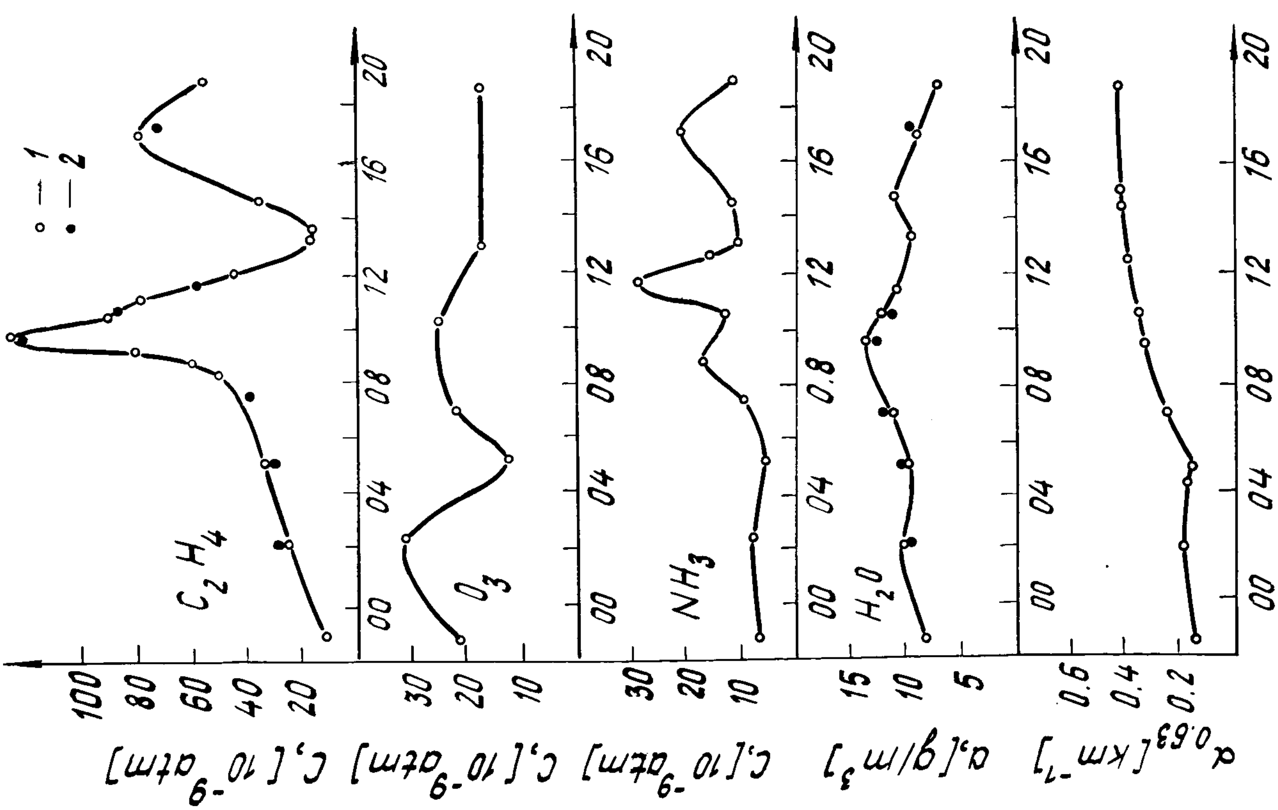

Fig. 1

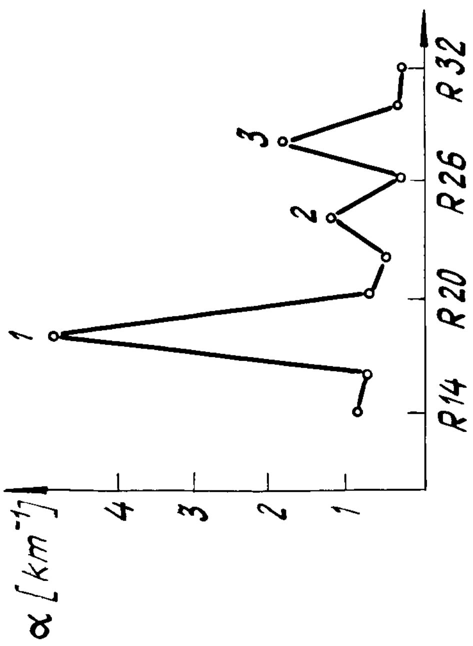

Fig. 2

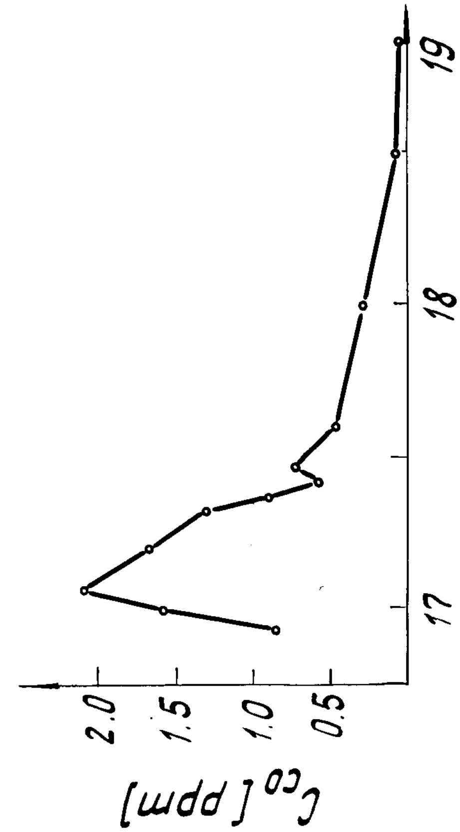

Fig. 3