3A04 Diode Laser Photoacoustic Detection of Automobile Exhaust Emissions

◯S. Civiš , V. Horká, and J. Cihelka
J. Heyrovský Institute of Physical Chemistry, Academy of Science of Czech Republic, Dolejškova 3, 18223 Prague 8, Czech Republic

ABSTRACT

A study of the infrared spectra of the CH_4, NH_3, N_2O and ethane gas has been carried out. These molecules are part of atmospheric pollution caused by emissions from automobile traffic. We tested the method of photoacoustic (PA) detection together with the laser semiconductor emission as a new tool for monitoring of limited concentrations of these atmospheric pollutants. The variation of the intensity of the PA signal with pressure was studied. The detection limits were determined for the individual gases in a mixture with air at the optimum pressure. The spectra of automobile exhaust gases at various motor temperatures were measured qualitatively and quantitatively. A new type of semi-conductor GaInAsSb/AlGaAsSb laser, working in the 4342 – 4362 cm^{-1} region at room and higher temperatures was used as the tunable radiation source.

RESULTS

The main target of the study was PA detection of gases absorbing in the area of emissions of GaInAsSb/AlGaAsSb based lasers. We concentrated on detection of CH_4, NH_3, N_2O and ethane, which are predominant molecules in pollution of the lower troposphere. We attempted to carry out detection, quantitative determination of the main components of automobile emissions and comparison with the individual spectra of the pure components.

Figure 1 depicts the photoacoustic spectra of CH_4, NH_3, ethane and N_2O in the 4360.5 – 4364.0 cm^{-1} region (laser current 100 – 40 mA), at a pressure of 100 Torr, and, for ammonia, 60 Torr.

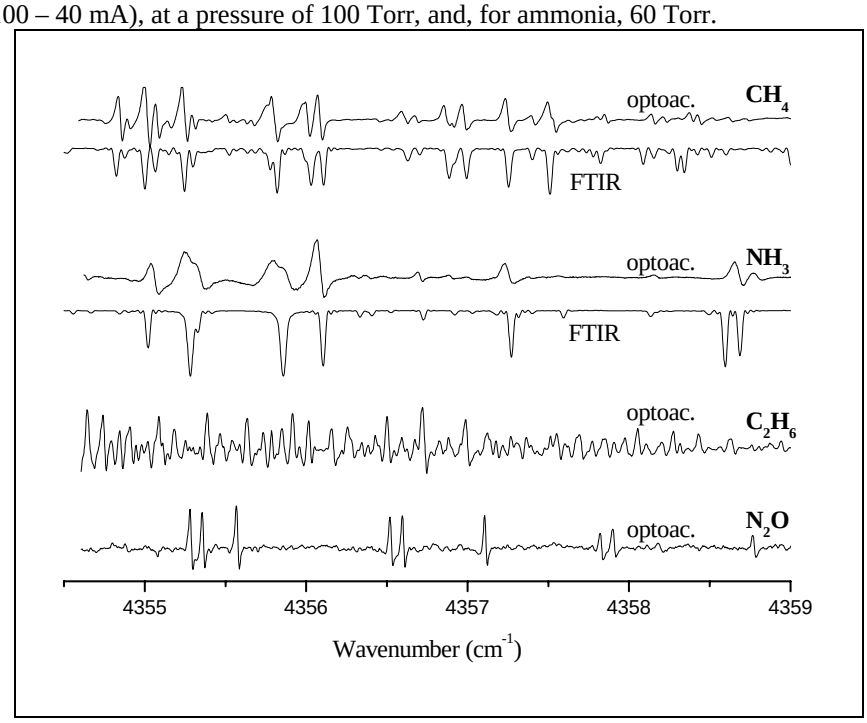

Fig. 1. Laboratory measurement of the spectra at a pressure of 100 Torr for CH_4, C_2H_6, and N_2O and 60 Torr for NH_3. CH_4 and NH_3 are compared with the FTIR spectra.

A study was carried out to determine the optimum gas pressure for maximum response of the PA signal. The optimum pressure for NH_3 is 65 Torr for CH_4 90 Torr and for N_2O 100 Torr.

Methane can be detected down to values below 100 ppm using the absorption line at 4362.0651 cm^{-1} (00011112-00000000 transition), ammonia below 1 ppm using the line at 4355.304 cm^{-1} (0110s-0000s transition) and N_2O only down to 10 000 ppm using the band at 4361.647 cm^{-1} (0002-0000 transition).

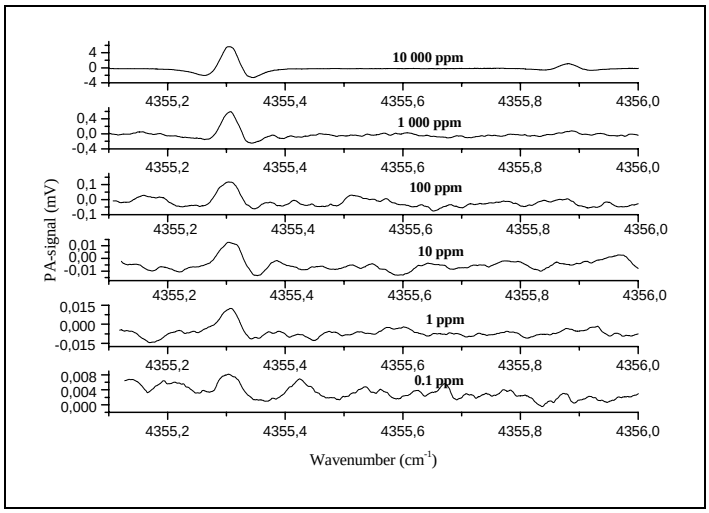

Fig. 2 Detection limit of ammonia at a pressure of 65 Torr. The pure gas was diluted with air.

Figures 2 and 3 depicts the spectra of NH_3 and comparison with the spectra of automobile emissions in the 4355 cm^{-1} area measured at a pressure of 70 Torr. The exhaust gases were collected immediately after starting the motor (cool) and after thorough warming of the motor by driving the vehicle (warm). The calculated content of ammonia was approximately the same in both fractions and equalled 225 ppm in the "cool" sample and 210 ppm in the "warm" sample.

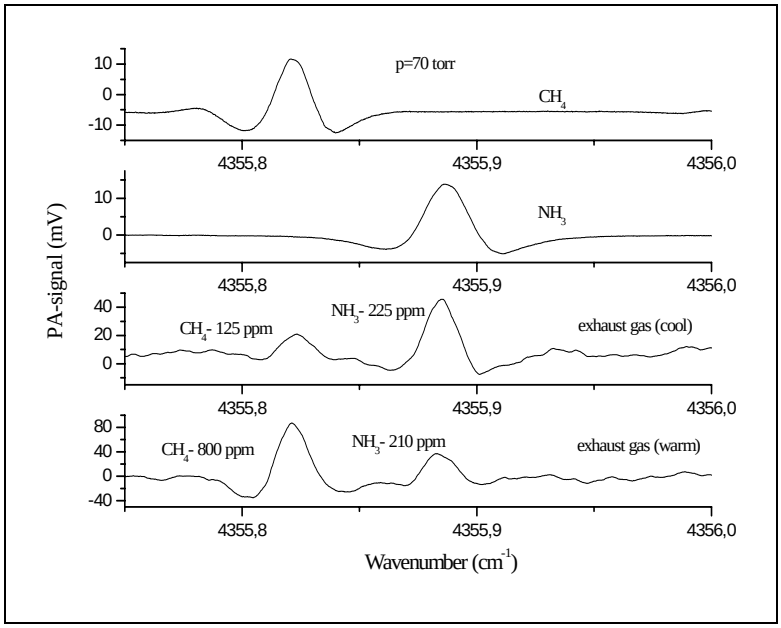

Fig. 3. Spectra of methane, ammonia and exhaust gases just after starting the motor (cool) and from the warm motor at a pressure of 70 Torr.

SUMMARY

The work was concerned with practical application of semiconductor lasers in combination with the PA detection. The rotation-vibration spectra of the gases CH_4, NH_3, N_2O and ethane were measured in the infrared region using of the GaSb laser. The dependence of the PA signal on pressure was studied for the pure components and their mixtures with air. The detection limits were measured for NH_3, CH_4 and N_2O. For ammonia was about 0.1 ppm. The method was applied in practice to monitor the contents of the individual kinds of molecules in automobile exhaust gases.

Its effectiveness, simplicity and low cost mean that the PA method combined with diode lasers could have extensive commercial applications.

ACKNOWLEDGEMENTS

.This work was funded by the Grant Agency of the Czech Republic, grant No. 203/06/1278. S.C. thanks J. Heyrovský Institute of Physical Chemistry for financial support with 120 Bruker reconstruction