MICROWAVE GAS ANALYZER WITH AN INTRACAVITY SPECTROPHONE

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We describe here a submillimeter gas analyzer with an intracavity spectrophone and backward-wave tube as a source of radiation. Results of first studies of real gas mixtures are presented.

Permanently worsening ecological conditions due to atmospheric pollution by gas emissions require organization of a system of atmospheric monitoring and control of emissions of many different gases.

Methods and means existing now are not capable of solving this problem, first of all, because of small number of gases that can be controlled simultaneously by a single device.

At the same time the results of high resolution microwave spectroscopy in millimeter and submillimeter regions demonstrate a possibility to derive methods and develop equipment capable of solving most these problems.

As a source of monochromatic microwave radiation backward-wave tubes are used. Owing to a narrow radiation line in backward-wave tubes the gas analyzers built on their basis have high selectivity since the influence of the interfering absorption lines is decreased as much as possible, and the wide range and the high rate of electronic tuning of the radiation wavelength make it possible to efficiently and simultaneously measure concentrations of large number of gases.

Since most of the gaseous pollutants have pure rotational absorption spectra the lines of which are within the millimeter and submillimeter spectral region, microwave gas analyzers may become universal means for mass control of industrial emissions.

We present here a microwave gas analyzer working in the region 118–180 GHz (wavelength of the order of 2 mm) with an intracavity spectrophone.

Figure 1 presents block-diagram of the gas analyzer. Radiation from the backward-wave tube *6* passing through a directional divider *7* enters the spectrophone cavity *8*. The cavity internal walls are polished what provides a multipass propagation of the radiation through the cavity. This makes it possible to increase the portion of radiation absorbed by gas and improve the sensitivity by the order of magnitude and more compared with a single-pass spectrophone.[1]

A portion of radiation from the backward-wave tube is directed by the directional divider *7* to the microwave detector *10* for control of the output radiation power.

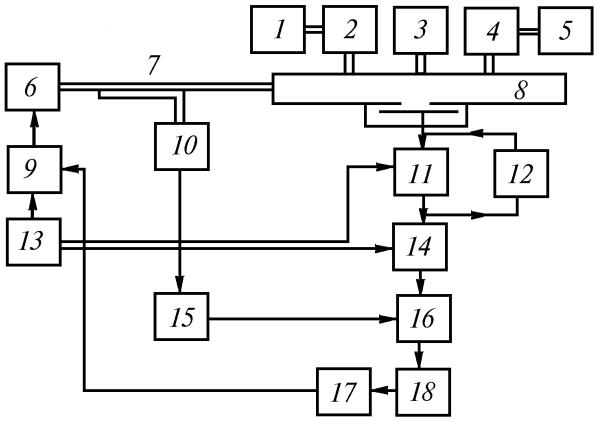

FIG.1. Block diagram of the gas analyzer.

The signal from the membrane of the condenser microphone arrives at the converter *11* made according to the scheme of a frequency-sensitive detector in a circuit of which a condenser microphone is included.[2] The system is completed with the membrane autotune block *12* which automatically keeps constant the microphone electrode separation by applying voltage of 0–40 V to the membrane.

From the converter the electric signal arrives at the synchronous detector *14* and further to the analog-to-digital converter *16* and then to an IBM PC XT computer *18*.

The signal proportional to the radiation power after amplification in the unit *15* comes to the second input of a dual-channel analog-to-digital converter *16*.

The computer-controlled digital-to-analog converter *17* generates control voltage for the power supply *9* of the backward wave tube, by which the electronic tuning of radiation wavelength is performed.

The base generator *13* synchronizes the operation of different blocks of the gas analyzer by feeding of meander to the power supply *9* for frequency modulation as well as to the synchronous detector *14*. In addition, the base generator produces high-frequency sinusoidal voltage with the frequency of 5 MHz applied to the converter *11* to support the operation of the frequency detector.

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Frequency modulation of the backward-wave tube radiation is used in the gas analyzer and that is why the first derivative of the absorption line profile of a gas interacting with the microwave radiation in the spectrophone cavity is recorded. By this means, a differential technique is performed which allows eliminating the nonselective absorption and improving the gas analyzer selectivity.[3]

In addition, operating pressure in the spectrophone cavity is chosen according to its maximal sensitivity close to 10 Torr (Ref. 4) that also improves the absorption line narrowing and increases selectivity of the gas analyzer.

An air or gas sample is pumped through a dust filter *1* and the float needle *2* into the spectrophone cavity. The vacuummeter *3* controls gas pressure in the cavity. The rough pump *5* trough the float needle *4* keeps constant the pressure in the spectrophone cavity *8*.

The gas analyzer has been tested on some absorbing mixtures. Some test results are presented in the Table I. In addition to the gases listed in the table, measurements with vapors of methanol, ethanol, formic and acetic acids, and some other gases and vapors have also been performed.

As is seen from Table I, the gas analyzer has high enough concentration sensitivity sufficient for atmospheric monitoring, and the number of gases being measured simultaneously can be quite large.

For this purpose the software package has been developed to support the operation of the gas analyzer and process measured information using minimizing of the interfering factors, fast Fourier transform and methods for solution of ill-posed inverse problems.

Now the work is in progress to make the gas analyzer as a single device.

TABLE I. Gases, studied with the microwave gas analyzer, the absorption coefficient values, and the values of minimum detectable concentrations.

Gas	ν_{res},GHz	k, cm^{-1} atm^{-1}	C_{min}, ppm
NO	150.504	0.47	0.02
N_2O	175.856	0.03	0.37
H_2S	168.760	0.05	0.22
S_2O	160.343	0.20	0.05
H_2CO	145.706	0.03	0.37
NO_2	123.966	0.003	2.80

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