EXPERIMENTAL MEASUREMENT OF THE LIDAR RATIO IN THE GROUND ATMOSPHERIC LAYER

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An original technique for real-time measurements of the lidar ratio in the ground atmospheric layer has been described. Field measurements of the lidar ratio have been carried out in the ground layer and the preliminary results have been obtained that prove the efficiency of this technique.

Reconstruction of the optical characteristics of the atmosphere from the experimental data obtained by the lidar sounding method is often difficult due to undeterminacy of the initial equations.[1] Various techniques for reconstruction that have been developed by the present time[2] are efficient only within the framework of some restrictive assumptions that, as a rule, cannot be validated from the experimental data.

Therefore, a problem is urgent of real-time determination of such atmospheric characteristics, *a priori* information on which makes it possible to solve correctly the lidar sounding equation. In particular, the lidar ratio, which is properly the normalized backscattering phase function, can be accepted as such a parameter. Knowledge of the lidar ratio even at some fixed point of space makes it possible to reconstruct the sought-after atmospheric characteristics with higher accuracy both for some fixed point and for the vertical profile as a whole.

In principle, one can obtain additional information on the atmospheric parameters using independent measurement means, for example, the nephelometric techniques.[3] However that leads to a complication of instrumentation and, in addition, decreases the speed of measurements. The variant is more acceptable when all data are obtained by means of a lidar.

To implement this idea, the scheme of sounding was developed that makes it possible to obtain the real-time information on the lidar ratio value by means of a laser radar.[4] This idea is based on the constancy of the ratio of the scattering coefficient at an angle of 45° and the volume scattering coefficient[5] proved by numerous experimental tests. The diagram of the experimental arrangement is shown in Fig. 1. The laser *1* emits the light pulse in the direction of the mirror *3* with the known reflection coefficient. The mirror is oriented so that its normal is at the angle of 22.5° to an incident beam. The angular divergence of the transmitter, the distance from the mirror to the lidar, and the mirror size are adjusted so that to provide complete interception of the incident light beam.

Thus, the incident light beam is reflected at an angle of 135° to its initial incidence direction. The backscattered radiation and the radiation scattered at an angle of 45° with respect to the lidar system are successively recorded at the input of the receiving system *2*.

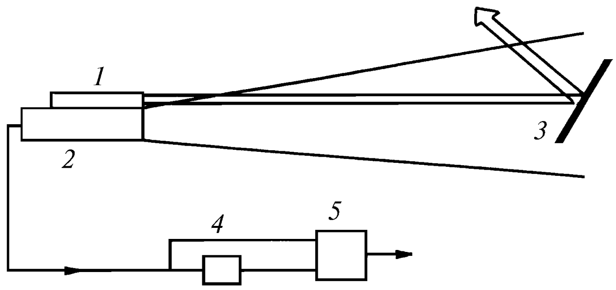

FIG.1.

A signal from the output of the receiving system is fed into two inputs of the division device *5*. The first input is directly connected with the input of the receiving optical system and the second output is connected through the delay line *4*. The delay τ is chosen from the condition that two signals corresponding to the moments t_1 and t_2 should be present simultaneously at the input of the division device. In so doing, the signal at t_1 comes to the receiving system from the scattering volume just before the mirror and the signal at t_2 comes just after reflection from the mirror. The value $\tau = t_2 - t_1$ is limited by two conditions: $\tau > 1/\Delta f$ and $\tau > t_0/2$, where t_0 is the laser pulse duration and Δf is the frequency band of recording instrumentation. Too large value of τ results in decreasing the accuracy of measurement due to the difference between the signal attenuation at the moments t_1 and t_2 and, in addition, the large value of the delay is rather difficult for practical realization. So the acceptable delay is 150–200 ns.

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All aforementioned is illustrated by Fig. 2, where the signals F_1 and F_2 at the outputs of the receiving optical system and division device are shown. To decrease the dynamic range, the signal F_2 is shown in logarithmic coordinates. It is seen from Fig. 2 that the signal V, which is proportional to the ratio $F_1(t)/F_2(t)$, appears at the output of the division device at the moment t_2 and hence contains the information on the lidar ratio at the point located just near the reflecting mirror.

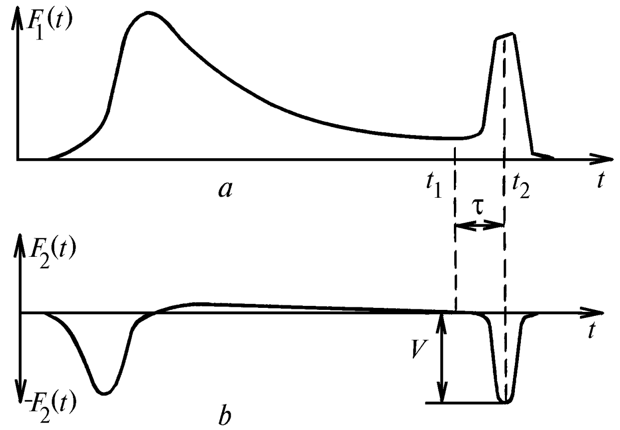

FIG. 2.

This device was calibrated under controllable conditions using the nephelometric setup[6] placed just near the reflecting mirror. The calibration consisted in determining the proportionality coefficient between the amplitude of the signal V and the value of the lidar ratio at the moment of measurements.

This technique was experimentally tested at the experimental station of the Institute of Atmospheric Optics under daylight conditions with the use of a two-path lidar[7] in August of 1994. Measurements were carried out in sunny weather with low surface wind 1–2 m/s. The underlying surface was a ploughed field; the reflecting mirror was placed at a height of 1 m and at a distance of 250 m from the lidar.

The diffuse reflection from the mirror due to the sedimentation of dust on its surface and other factors manifested itself as a short spike with duration t_0 in the leading front of the signal and was not recorded by the recording instrumentation with a bandwidth of ~10 MHz lying outside the frequency band corresponding to the laser pulse duration. Let us note that the unusual shape of the reflected signal shown in Fig. 2 and obtained *in situ*, is possibly explained by the effect of the diffuse component.

Field measurements were carried out in several cycles, with more than 500 signals in each cycle. Then they were statistically processed and the value of the lidar ratio for the ground layer was found to be equal to (0.032±0.009) sr, which is in good agreement with the data obtained elsewhere.[3] The above-indicated error in this case is the total estimate of the methodical error caused by the approximate knowledge of the value of the ratio of the scattering coefficient at an angle of 45° and the volume scattering coefficient, the error in calibrating, and the instrumental error. In general, these measurements were preliminary; however, they have demonstrated the feasibility of the real-time determination of the lidar ratio using the technique described here and showed that one can use the data obtained for increasing the accuracy of reconstruction of the profiles of optical characteristics from the lidar measurements.

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