XeCl-EXCIMER-LASER MULTIFUNCTIONAL DIFFERENTIAL ABSORPTION AND SCATTERING LIDAR

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Excimer-Laser and dye-laser Lidar systems for determining different impurities in the troposphere and stratosphere are examined.

The possibilities of these systems are analyzed. A mobile multifunctional lidar, based on an XeCl laser losing at a wavelength of 308 nm *and a dye laser losing at the wavelength* 300 *and* 450 nm, *for determining SO_2 and NO_2 in the atmosphere is described.*

The development of high-power excimer lasers, in particular, xenon chloride lasers, which laser at 308 nm, and tunable dye lasers, pumped by the same radiation, has made it possible to solve a number of problems in atmospheric optics: sounding of tropospheric and stratospheric ozone, determination of nitrogen oxide, sulfur dioxide, and other industrial pollutants, in the lower layers of the atmosphere. Thus, to determine the ozone concentration it is necessary to have laser radiation in the absorption band of ozone at the wavelength 308 nm and dye radiation with wavelength 339 or 353 nm, serving as a reference signal.[1,2] Dye radiation with a wavelength of 450 nm falls into the absorption band of NO_2 and dye radiation with a wavelength of 300 nm falls into the absorption band of SO_2. It is very important to determine the concentrations of NO_2 and SO_2, since emissions of nitrogen oxides (NO_2) in the atmosphere are responsible for the formation of photochemical smog and accumulation of ozone, which is a toxic substance and also contributes to the appearance of the greenhouse effect, in the lower layers of the atmosphere. Emissions of sulfur dioxide into the atmosphere cause "acid" rain.

A number of lidars based on xenon chloride lasers and tunable dye lasers have now been developed and are operating abroad and In the USSR.[3,4,5] The energy of the radiation of xenon chloride lasers for determining ozone in these systems ranges from 100 mJ up to 1 J. In the reference channel at the wavelength 339 or 353 nm it is 3 to 5 times lower. The receiving telescopes used in lidars have apertures ranging from 0.4 to 0.9 m. Lidar systems with these parameters make it possible to obtain within a period of 1 h accurate ozone concentration profiles up to altitudes of 40–45 km.

The lidar method of differential absorption and scattering (DAS) is most sensitive and makes it possible to obtain information, even with a modest lidar, on separate gaseous components of the atmosphere up to distances of several kilometers.[1,2] The method is based on the fact that the sounding is performed simultaneously at two close wavelengths, one of which coincides with the absorption line of the gaseous component under study. The concentration of molecules of a given gas is judged from the difference of the echo signals reflected by the atmosphere for both wavelengths. An obvious advantage of the method computer; a printer, and a X–Y plotter; an IBM PC/AT computer for on-line processing and display of the final results on a color monitor and printing the results in the form of charts, sections, and tables. The scanning system with the rotating mirror can also be controlled by the Elektronika-60 computer. A flat mirror, placed on a compact rotating apparatus 9, which can be moved along the roof of the trailer and is placed above the telescope tube, is used for operating in the scanning regime with small angles of inclination of the line of sight to the horizon (0–30°). We note that this system is well known,[1,8] and in this case it makes it possible to solve different sounding problems without changing the construction of the receiver-transmitter.

The lidar operates as follows. The two-chamber XeCl excimer laser generates radiation at the wavelength 308 nm in the form of two beams with energy up to 1 J in each beam and a pulsewidth of 30 nsec. One beam is used to pump the dye laser, whose radiation with the wavelength 353 nm and energy 250 mJ is used to form the elastically scattered signal from the aerosol particles. The second beam of the XeCl laser with wavelength 308 nm, falling into the absorption band of ozone, is directed simultaneously with the radiation from the dye laser into the atmosphere through the collimator 10.

In order to sound other gases in the lower layers of the troposphere the output signal can also be formed by a different scheme. For example, in the case when the NO_2 concentration is to be determined, radiation with the wavelength 450 nm in the absorption band and the second signal in the wing of the absorption line of NO_2 is that absolute calibration of the lidar is not required.

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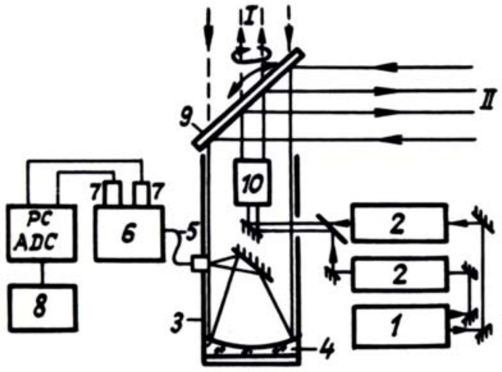

Analysis of the possibilities of existing technical means of laser sounding of the atmosphere leads to the conclusion that there are additional prospects for using a DAS lidar of the multifunctional type based on an XeCl laser. We describe below the results of our attempts to build a mobile DAS lidar based on an XeCl laser according to the rigid arrangement of a stratospheric upward-looking lidar.

The maximum range of the lidar for the transmitter and receiver characteristics indicated below was estimated taking into account the recommendations of Ref. 6 regarding the sounding of stratospheric ozone and is equal to 40–50 km. In the case of sounding along horizontal paths, using such an operating regime, the system allows for reception of the elastically scattered signal up to distances of not less than 10 km. This sensing potential can be achieved in daytime measurements with a 1.5 nm bandwidth of the interference filter.[7] The lidar is placed in an automobile trailer (a block diagram is shown in Fig. 1).

An XeCl laser 1, dye lasers 2, and the vertical tube of a large Newton telescope 3, at the bottom of which a mirror 0.5 m in diameter is placed, are mounted on a rigid common base. The optical waveguide 5 is used to decouple mechanically the telescope and the selective system 6. Signals from the photomultiplier (FEU) 7 are fed into the recording and information processing system 8, which includes the following a four-channel photon counter and a two-channel ADC, which are controlled by an Elektronika-60 must be obtained. In this case the radiation of the second beam of the XeCl laser is directed into a second dye laser. The proper selection of the active media of both lasers and continuous tuning over the spectrum make it possible to obtain at the output signals with the necessary wavelength.

In the case of SO_2 KDP crystals are used at the output of the dye lasers in order to double the frequency and to obtain signals in the absorption line of this gas, which lies near 300 nm. The above-described scheme for forming optical signals is flexible and makes it possible to regulate the parameters of the transmitting system with minimum changes in the construction. The simultaneous transmission of signals at two wavelengths makes it possible to reduce to a minimum the effect of fluctuations of the aerosol concentration on the measurement error.

The principle of operation of the receiving part of the lidar remains the same for the variants of measurements examined above. The received optical signal, which has two wavelengths, is collected by the Newton telescope 3 and is directed into the optical waveguide 5, whence it is fed Into the selective system 6, which separates signals by wavelength. This system consists of a polychromator, which makes it possible to separate the arriving radiation by wavelengths and direct it into the photodetector. The use of an optical waveguide substantially simplifies the optical scheme for directing the radiation to be analyzed from the telescope into the selective system.

The optical signals are converted into electrical signals on the FEU and are fed into the photon counter in the case when the altitude profile of ozone is sounded, when weak echo signals are recorded, or into an ADC in the other variants, described above, when the signal level makes it possible for the FEU to operate in the current mode. Further processing of the received information Is performed according to a fixed program, Including recording of the starting data on magnetic tapes, filtering, mathematical transformations, calculation of the concentrations of the gases studied, and printing out of the final result and display on a color monitor or plotter in the form of tables, graphs, charts, histograms, and sections.

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