Modernization of the sm all lidar station of IAO SB RAS

V.N. Marichev[*1,2] and D.A. Bochkosvkii[**1,2]
[1]National Research Tomsk State University, Tomsk
[2] V.E. Zuev Institute of Atmospheric Optics SB RAS, Tomsk

ABSTRACT

Modernization of the instrumentation part of the Small Lidar Station of the V.E. Zuev Institute of atmospheric optics SB RAS (SLS) from the beginning of its work to present date is considered.

INTRODUCTION

Laser methods of the study of gas and aerosol composition of the atmosphere are widely used and take a special place in the modern scientific practice. It is caused by the high spatial resolution and speed of obtaining the data in comparison with the methods suing other principle of obtaining the initial data. Propagation of the laser radiation in the atmosphere is accompanied by some phenomena of interaction of electromagnetic radiation with the medium, such as absorption and scattering of light by aerosol particles, absorption and scattering by molecules of atmospheric gases, distortion of the optical signals by the turbulence of the atmosphere, and fluorescence. Recording the reflected signals and processing the change in the radiation characteristics by the modern methods, one can obtain the information about many physical values and parameters of the atmosphere, such as aerosol, temperature, pressure, air density, profiles of the concentration of different gases and so on.

Observations of temperature, density and scattering ratio in the lower and middle atmosphere are carried out now at the Small Lidar Station (SLS). During observations, analysis of the results obtained, and exploitation of the lidar complex, the necessity appears in modernization of some components of the instrumentation, development of the system of automated computer control and improvement of the capabilities of the software for processing the acquired data.

MODERNIZATION OF THE LIDAR STATION

Lidar investigations of the aerosol vertical structure in the stratosphere and the upper troposphere over Tomsk [1] are carried out at the Small Lidar Station regularly since 1986, and observations of the temperature and the atmospheric density are carried out since 1994.

At the initial stage, the lidar complex had the following specifications (Table 1).

The source of radiation was a LTI701 pulsed solid-state laser with continuous pumping of the active element (aluminum-yttrium pomegranate), the modulation of the radiation of which was performed by the acoustic-optical shutter with a frequency of 3 kHz. The telescope of the receiving system with the diameter of 1 m was designed upon the Newton scheme.

The first counter C-4B made it possible to simultaneously obtain the data in four independent channels up to 33 km with the resolution of 250 m. The second counter was designed using the modern element basis, that made it possible to increase the maximum altitude of sounding up to 47 km and to improve the spatial resolution to 12 m. The acquired data were stored as a computer file.

*marichev@iao.ru, **moto@iao.ru

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Table 1. Specification of the lidar in 1986

TRANSMITTER	
Radiation wavelength	532 nm
Pulse repetition rate	3 kHz
Pulse duration	0.2 μs
Average power	1 W
Beam divergence	10^{-4} rad
RECEIVER	
Diameter of the receiving mirror	1 m
Angle of the field of view	10^{-3} rad
Interference filter	
Transmission band	1 nm
transmission at 532 nm	46%
photodetector	PMT-130
RECORDING SYSTEM	
Photon counter C-4B	
Number of channels	4
Number of time intervals	128
Duration of a time interval	1.67 μs
Photon counter D1	
Number of channels	1
Number of time intervals	4096
Duration of a time interval	78 ns

The “Irzar 50 M” universal complex based on “Elektronika-60” was used as mini-computer. It consisted of two 2.5 Mb storage devices SM 540000/12, 15IE00.13 system terminal and the DZM180 printer. In addition, a color display and a plotter were linked for visualization of the data obtained. The display was a “Elektronika C401” color TV with a drive in E60 standard, and the plotter was an ‘ENDIM” two-coordinate recorder linked with the computer by means of I5 interface plate. The C192 oscillograph was used for visualization of the recorded return signals from PMT.

Due to the long-term operation of the lidar complex, the main part of its equipment and electronic-recording units technically and morally outdated, and the stage of modernization of the station as a whole was started in 2002. A number of measures aimed at the renewal of observations of the vertical structure of the aerosol distribution and temperature in the stratosphere was carried at SLS in Tomsk out by the beginning of 2008 [2].

As a result of the modernization, the main mirror was replaced by the mirror with e new coating. The quite powerful Nd:YAG laser (LOTIS TII model) with the pulse energy up to 200 mJ and the pulse repetition rate of 10 Hz at the wavelength of 532 nm was installed in the transmitter. The laser beam was collimated at the output to the atmosphere in the ratio 1:10 up to the divergence of 0.1 mrad. The angle of the filed of view of the receiving telescope was 1 mrad. Three channels for receiving the optical radiation were designed in the receiving system: stratospheric and tropospheric at the wavelength of 532 nm and the Raman channel at 607 nm. Spectral selection of the radiation in the channel was carried out by the interference filters designed at Barr Co. with the transmission half-width of 0.5 nm and 60% transmission in the maximum. To receive the radiation, the R7207-01 low-noise photodetectors operating in the photon counting mode and the H8259-01 photodetection unit (Hamamatsu Co.) with the adjustable electronic locking photocathode, high quantum efficiency (up to 30%) and speed, were used.

The lidar signals transformed to one-electron pulses were recorded by replaceable high-speed photon counters: PMM-328 (8 channels, band 120 MHz) and PMS-400A (2 channels, band 800 MHz). Subsequently, the PMS-400A two-channel photon counter was replaced by the PHCOUNT_4 four-channel counter.

The PHCOUNT_4 counter, the specifications of which is presented in Table 2, was designed at the Institute of atmospheric optics SB RAS. Comparative tests showed that the signals recorded by PHCOUNT_4 and PMS-400A are analogous to each other, and the presence of 4 channels makes it possible to expand the capabilities of the receiving system. Another peculiarity of the device designed at IAO is that the counter is constructed as an individual instrument, while the foreign analogs are internal units. Construction of the photon counter as an individual instrument makes it possible to divide the bench and the operator workplace with minimum expenses. In fact, only one USB-cable is needed, instead of 3 signal and one sync cable.

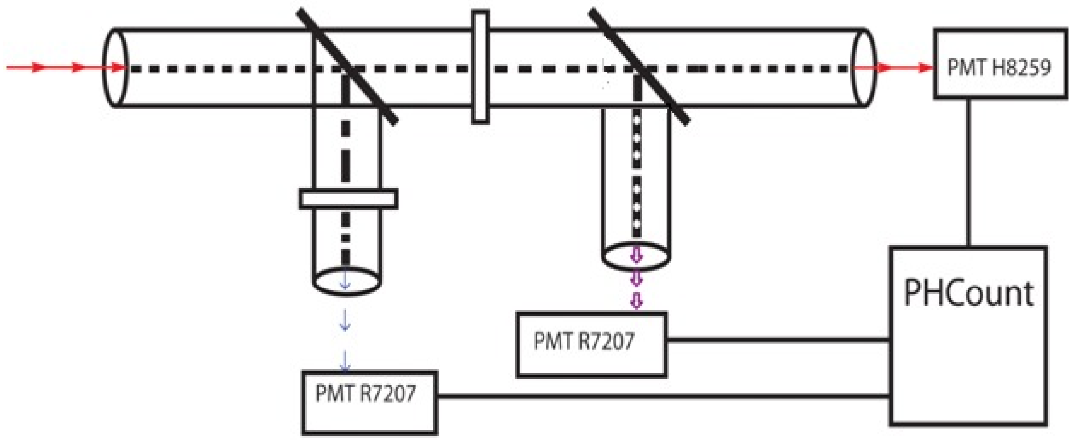

Figure 1. Block-diagram of the receiving unit: a) near zone channel; b) far zone channel; c) Raman channel.

Table 2. Main specifications of the PHCOUNT_4 photon counter

Number of channels	4
Counting rate	Up to 200 MHz
Spatial resolution (minimum)	48 m, 24 m, 12 m
Maximum path length	140 km ,70 km, 36 km.
Number of points on the path	3k
input resistance of the counting input	50 Ω
input resistance of the sync input	50 Ω
amplitude of the signal of the counting input	+3 V … - 3 V
amplitude of the signal of the sync input	TTL level
Set of the discrimination threshold	- resolution of 8 digits (8 mV)
minimum duration of the counted pulse	1.3 ns
Computer link	USB 2.0
Work temperature	10… 50°C
size	117 × 99 mm
Power supply	from USB-port

Putting the tropospheric channel into operation made it possible to receive the signals from less altitudes, which create overload of PMT of the main stratospheric channel and are removed by the electronic shutter. "Stitching" the signals of two channels makes it possible to obtain the continuous signal, from which the long vertical profile of the aerosol stratification can be calculated, including upper troposphere, stratosphere and mesosphere.

The Raman channel was created for measuring temperature and more accurate selection of the aerosol component when normalizing the tropospheric signal (elastic scattering) to the Raman scattering signal, which is proportional to the real density of atmospheric air.

In 2014, the LOTIS TII laser was replaced by the LS-2137U-UV3 laser (a special model of the LS-2137U serial laser on AYG:Nd^{3+} with electrooptical modulation of the Q-factor and transformation of the radiation wavelength of the main frequency (1064 nm) of generation to the radiation of the second harmonics (SH) (532 nm), the third harmonics (TH) (355 nm) with outlet of the radiation of SH and TH to the same optical axis, operating in the frequency mode. The main specifications of the laser are presented in Table 3. The photosensor module with the H7422P-40 built-in cooling unit with more than one order of magnitude greater sensitivity was installed instead of the previous photodetector (R7207-01, Hamamatsu) in the Raman channel. The aforementioned measures provide for reliable receiving the Raman signals from the altitudes up to 30 km.

Table 3. Specifications of the LS-2137U-UV3 laser.

PARAMETER, UNITS	**NOMINAL VALUE**	**REMARK**
Wavelength of the generated radiation, nm	1064 532 355	
Radiation pulse energy, mJ	700 400 210	1064 nm 532 nm 355 nm
Pulse repetition rate, Hz	10	Frequencies of 5; 2; 1; and 0.5 Hz are provided by the sutter operation mode
Pulse duration at the level 0.5, ns	≤7	
Laser radiation beam diameter, mm	≤8	
Energy divergence of the laser radiation at the level of 0.86, mrad	≤0.8	
Electric power of the pumping pulse, E_H, J	≤60	Average power of pumping ≤750 W, so that at the set energy of pumping E_p max the pulse repetition rate is determined by the relationship $F \cdot E_p = 750$
Power, W	≤1000	
Polarization	linear	Polarization plane of SH is horizontal, Th and FH – vertical

The FL57ST41-0406B stepping motors will be installed soon to the output mirror for its adjustment relatively to the receiving system. The main specifications of such motors are presented in Table 4.

Table 4. Specifications of the FL57ST41-0406B stepping motors

Full step, deg	1,8
Error in the angular step, deg	±0,09
error in resistance of the motor windings, %	10
error in inductance of the motor windings, %	20
maximum radial runout of the motor shaft, mm	0,02
maximum axial runout of the motor shaft, mm	0,08
maximum permissible axial load on the shaft, N	15
maximum permissible radial load on the shaft, N	75

CONCLUSIONS

The SLS lidar complex allows regular and prompt obtaining the profiles of the scattering ratio up to the altitude of 70 km, temperature and atmospheric density in the altitude range 7 to 60 km with the spatial resolution of 200 m [3, 4].

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