

# Field tests of the mobile lidar for tropospheric ozone sensing on horizontal (inclined) and vertical paths

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**Abstract.** The results of field tests of the mobile lidar for ozone sensing on horizontal (inclined) and vertical paths are presented. The lidar operates on the basis of the differential absorption and scattering method at wavelengths of 299/341 nm and allows receiving lidar signals on a trace up to ~18 km long. The lidar was installed on an isothermal van with an autonomous power supply system. Field tests were conducted on the territory of Tomsk. An example of field measurements is given and the result of lidar sensing is presented.

## 1 Introduction

Climate change control on the Earth is possible only through regular monitoring of atmospheric parameters [1-3]. One of the most important monitored atmospheric parameters is ozone. Ozone is regenerated from molecular oxygen by adding atomic oxygen to its molecule under the influence of ultraviolet radiation from the Sun. Therefore, approximately 85% of the ozonosphere is located at stratospheric altitudes from 15 to 45 km. Stratospheric ozone protects the Earth's biosphere from harmful ultraviolet radiation from the Sun. However, monitoring of tropospheric ozone from ~0.1 to 15 km is no less important, and particular attention is paid to the ozone concentration indicator in the ground layer. This gas is very toxic and directly affects human life and health both in everyday life and in transport. Therefore, constant monitoring of this gas is required by ground-based and satellite devices to prevent and warn of ozone degradation or exceeding the permissible concentration of gas. To solve this problem, new and improved tools for monitoring the ozonosphere are being developed continuously. V.E. Zuev of the Siberian Branch of the Russian Academy of Sciences (IOA SB RAS) developed and put into operation a mobile lidar for tropospheric ozone sensing on horizontal (inclined) and vertical paths [4]. This device allows obtaining information on the extensive distribution of ozone concentration with high operational accuracy and on significant spatial scales.

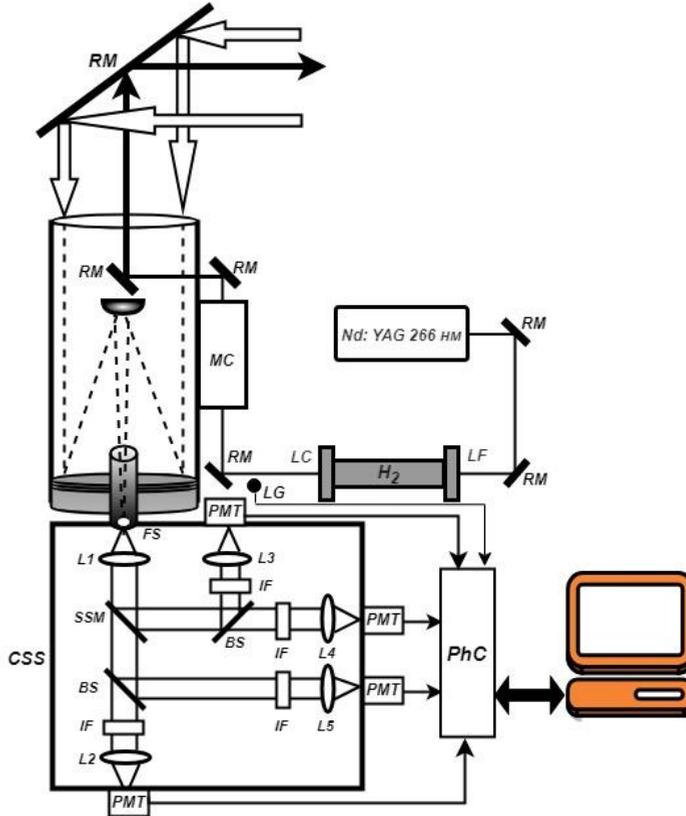
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## 2 Technical description

IAO SB RAS develops methods and means of remote atmospheric sensing. The result of such developments was the creation of a four-channel mobile lidar. This lidar has received patent protection, the design of which is described in detail in the description [5].

The block diagram of the mobile ozone lidar is shown Figure 1.



**Fig. 1.** Block-diagram of the mobile ozone lidar: Nd:YAG is the solid-state laser; RMs are rotating mirrors; LF is focusing lens; LC is collimating lens; H<sub>2</sub> is the hydrogen-filled SRS cell, equipped with lenses; MC is a mirror collimator; SSC is the spectral selection cell; FS is the field stop; Ls are lenses; SSM is the spectral splitting mirror; IFs are interference filters; PMTs are modules of H12386-210 HAMAMATSU photomultiplier tubes; PhC is PHCOUNT\_4E photon counter; LG is light guide for launching photon counter; Computer is personal computer for data acquisition and storage.

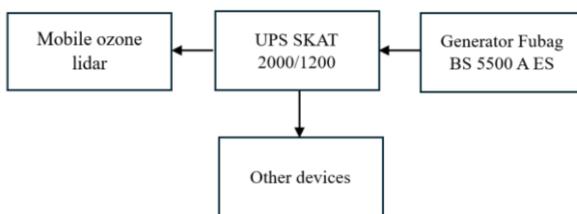
The mobile lidar is based on the SOLAR QX 500 laser source with a maximum pulse energy of up to 25 mJ at 266 nm and the Cassegrain telescope with main mirror diameter of 0.35 m and focal length of 0.7 m. These two main elements, together with the stimulated Raman scattering (SRS) cell, form the main dimensions of the protective platform or frame on which all lidar elements are fixed. The final dimensions of the platform are as follows: (Width × Length × Height) 520 × 1700 × 1350 mm. The total mass of the lidar reaches 150 kg. For field work, the lidar includes the Gentec Electro-Optics “MAESTRO” power meter, a frequency meter, Fubag BS 5500 A ES gasoline generator, and the uninterruptible power supply (UPS) Bastion SKAT-UPS 2000/1200 with voltage stabilizer as separate elements.

The main technical characteristics of ozone lidar are presented in Table 1.

**Table 1.** The main technical characteristics of mobile ozone lidar.

<b>Transmitter</b>	<b>SOLAR QX 500</b>
Energy per pulse, mJ	~25
Cooling system	Air-cooled
Sensing wavelength, $\lambda$ nm	299/341
Repetition rate	20/20
Pulse duration, ns	10
<b>Receiver</b>	<b>Cassegrain telescope</b>
Mirror diameter, m	0.35
Focal distance, m	0.7

In the field, to protect the lidar complex from sudden stops, the Fubag BS 5500 A ES generator at 5.5 kW and to stabilize the voltage, the Bastion SKAT-UPS 2000/1200 is included in the power supply circuit. It allows powering the lidar in idle mode for 2 hours or ~7-9 minutes in the lidar measurement mode, which is enough to overcome emergency situations. The Fubag generator is capable of powering the lidar for 8 hours without refilling the gas tank. The power supply block diagram in the field is shown in Figure 2.



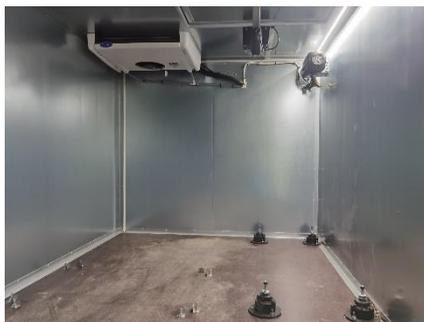
**Fig. 2.** Power supply diagram for the mobile ozone lidar.

For field work, the isothermal van 2834NF based on GAZ 330232 is used, equipped with an automated hatch (approximately 1 m by 1 m) with an actuator (linear drive) FY020 DC for outputting the laser beam into the atmosphere on vertical paths and receiving backscattered radiation. The appearance of the van is shown in Figure 3.



**Fig. 3.** The appearance of the 2834NF van based on GAZ 330232.

To prevent damage to scientific equipment during long expedition activities, the van was equipped with vibration mounts capable of withstanding a weight of up to 200 kg. The appearance of the lidar landing site and the fastenings to the vibration mounts is shown in Figure 4.



**Fig. 4.** The location of the mobile lidar attachment to the vibration mounts inside the van.

As can be seen from Figure 4, the van has an air conditioning system and a heat turbine for climate control. The lidar frame is bolted to vibration mounts and connected to ground through this mount.

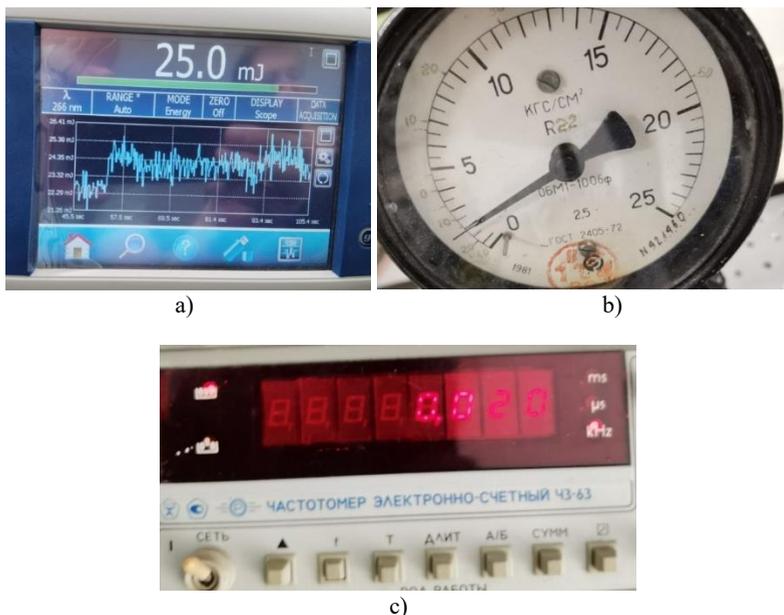
### 3 Results

Field tests of the mobile lidar were carried out in the city of Tomsk on cloudless days in December 2023 and April 2024 at night. This is due to the fact that the wavelength of 341 nm is close to the range of natural sunlight and a high noise level is recorded during the daytime. For horizontal paths, areas without people were selected. For vertical ones, it was enough to stand in places without street lighting. Pre-launch activities were carried out at the measurement sites: organizing the grounding of the lidar system and preparing the electric generator. For sensing on horizontal paths, the doors of the van were opened. For vertical probing paths, the van hatch was opened. An example of such preparation at the Basic Experimental Complex (BEC) of the IAO SB RAS (56.47 N, 85.10 E) with a demonstration of the horizontal probing path (for representativeness, a summer map is shown) is shown in Figure 5.



**Fig. 5.** Preparing for lidar sensing.

Before the measurements were started, the pulse energy on the QX 500 laser (266 nm), the repetition rate and the hydrogen pressure in the Raman cell were checked. An example of measuring such laser characteristics is shown in Figure 6.



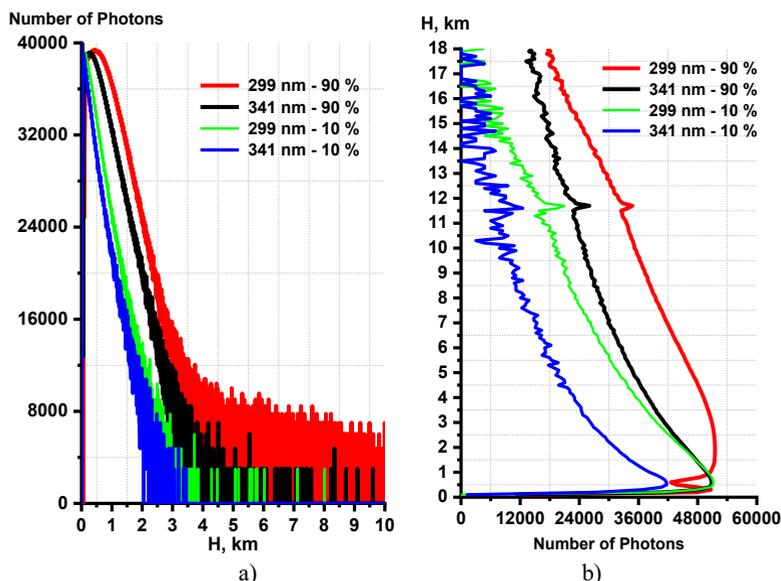
**Fig. 6.** Preparing for lidar sensing: (a) power meter readings; (b) pressure gauge readings; (c) frequency meter readings.

From Figure 6 it can be seen that the laser has survived transportation on the van and is in working condition. To output the sensing radiation, the optical elements were adjusted: the angle of inclination of the large rotating mirror and the rotating mirror at the entrance to the mirror collimator. During field tests of the mobile lidar, it was found that when the temperature in the van dropped below 18-20 degrees Celsius, the fourth harmonic generation ceased. To solve this problem, a thermal turbine was used, directed at the laser head. One of the serious problems in registering lidar signals is the problem of sudden appearance of cirrus clouds in the sensing zone and, as a result, loss or distortion of scientific data. An example of registering such an event is shown in Figure 7.



**Fig. 7.** Interface of the program for registration of lidar signals: cirrus clouds at the altitude of about 4 km.

To solve this problem, short measurement series of 5 minutes are set with the maximum possible spatial resolution of 1.5 m per data file. This reduces the chance of losing all data overnight. A number of measurements were made in the field and the results of lidar sensing on horizontal (inclined) and vertical paths are presented (Figure 8).



**Fig. 7.** Lidar signal in logarithmic form: (a) horizontal path, (b) vertical path.

Figure 7(b) shows the rare case of cirrus clouds being detected at an altitude of 11.5 km. Field test results in December 2023 and April 2024 showed that the mobile lidar is capable of performing ozone measurements on a horizontal (slant) path up to 5 km, and on a vertical path up to 18 km.

## 4 Conclusions

The mobile lidar for tropospheric ozone sensing on horizontal (inclined) and vertical paths was put into operation to solve the problems of expeditionary measurements of the spatial distribution of ozone concentrations. Ozone sensing is carried out at wavelengths of 299 and 341 nm and covers from  $\sim 0.1$  to 5 km on horizontal (inclined) paths and vertical paths from  $\sim 0.1$  to 18 km with a spatial resolution of lidar signals up to 1.5 m. The shortcomings of the lidar in the van identified during field tests were promptly corrected. In terms of technical parameters and capabilities, this lidar competes with modern foreign lidar systems. The mobile lidar with such parameters and capabilities is the only one in Russia.

## Acknowledgements

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