Optical design of joining a lidar with a television system of terrain orientation

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Abstract. Optical design of joining a lidar with a television system of terrain orientation is considered. This design allows simultaneously observing the object of study and recording the lidar signal reflected from it.

1. Introduction
One of the important tasks of remote laser sensing is precise guidance of laser radiation on the object under study. Usually guidance on an object is implemented by the rotation of the lidar platform with one or two scanning mirrors; the boundaries of the investigated space are determined with the help of an additional viewfinder: a television system consisting of an objective and a TV camera. In telescopes guidance on the object under investigation is carried out by means of a sighting guide (component 2 in Figure 1) displaced with respect to the objective of the telescope. This is permissible at measurements, since the objects of observation are at considerable distances from the telescope.

\textbf{Figure 1.} Telescope: 1 – telescopic system; 2 – sighting guide.
\textbf{Figure 2.} Lidar complex: 1 – lidar receiver system; 2 – viewfinder.
The distance to the objects being observed varies from 200 m to 30 km when lidar complexes operate. This leads to an uncontrolled displacement of the image relative to the center of the laser beam caused by the misaligned arrangement of the optical axis of the lidar receiver system (component 1 in Figure 2) and the optical axis of the viewfinder (2 component in Figure 2).

There are different optical designs for the television viewfinder placement in lidar complexes. In paper [1] the television viewfinder was installed on a rotary lidar column which allows combining the optical axes of the lidar receiving system and the television viewfinder only at a certain point in space. The television viewfinder on which the image is formed by means of a rotary mirror inserted into the receiving channel of the lidar is used in the lidar complex [2]. This ensures the alignment of the optical axes of the viewfinder and lidar receiving system. However, a disadvantage of this scheme design is the impossibility of simultaneously observing the object and recording the lidar signal coming from it.

The goal of this paper is to develop an optical design for the placement of the television viewfinder in a lidar complex that will allow simultaneous observation of the investigated object (without shifting its image relative to the optical axis of the lidar receiving system) and registration of the lidar signal reflected from it.

2. Optical design
The scheme design of the lidar mobile complex [3] includes a laser radiation source; a guidance system in the form of a single scanning mirror; a receiving telescopic lens system which conjugates radiation by means of a beam splitter-a dichroic mirror located at an angle of 45° to the optical axis of the telescopic receiving system, with the recording system of lidar signal behind it; the channel of the television viewfinder, which contains an objective forming image of the object on the matrix of the TV camera and is located behind the dichroic mirror on the optical axis of the receiving lens telescopic lidar system. However, an evident disadvantage of this system can be identified. When the lidar operates in a multi-wave mode, the receiving lens telescopic system introduces chromatic aberrations. In its turn, the dichroic mirror reflects only 75% of the radiation at the working lidar wavelengths. This leads to attenuation of the lidar signal.

In this paper, an original scheme design is presented (Figure 3). Here guidance on the investigated object is carried out with the help of two scanning mirrors (1, 2). Control over the laser beam guidance on the object under investigation is realized using an axial television viewfinder having a field angle of vision greater than the vision angle of the receiving system of the lidar. This makes it possible to see the image of the space surrounding an investigated object. The viewfinder is installed on the optical axis of the lidar receiving system behind the secondary mirror. The possibility of placing a TV viewfinder behind the secondary mirror is provided by the improvement of the design of the secondary mirror of the lidar receiving system [4]. The secondary mirror is designed as a mirror-lens component (4). The central region of this component D has a reflective coating and provides reflection of the light beam into the receiving channel (functions as a secondary mirror). The annular peripheral part of the mirror-lens component with the antireflection coating acts as a lens component, refracting the light beam, and together with the positive lens (5) focuses the image of the investigated space on the television matrix of the viewfinder (6). The mirror-lens component and the positive lens are calculated under the condition of minimizing chromatic and monochromatic aberrations. The focusing of the television matrix is made by linearly moving it along the optical axis of the viewfinder when observing objects located at different distances.

The proposed optical design of the axial television viewfinder combined with the lidar receiving system can be used not only in the considered Mersenne receiving telescope system, but also in the Cassegrain mirror systems (Figure 4), Ritchey–Chretien, Nasmyth, and other modified mirror telescope designs.
Figure 3. Optical design of an axial television viewfinder with a receiving system of the lidar and guidance system: 1, 2 – scanning mirror; 3 – primary mirror of the lidar receiving system; 4 – mirror-lens component; 5 – positive lens of viewfinder; 6 – CCD Matrix of television camera; 7 – flat mirror; 8 – lens of the receiving system of the lidar; 9 – photodetector of the receiving system of the lidar.

The viewfinder objective can be constructed from the objective (4, 5 elements in Figure 3) or mirror-lens components (2, 3 elements in Figure 4).

Figure 4. Optical design of an axial television viewfinder with a receiving objective of Cassegrain type: 1 – primary mirror of the lidar receiving system; 2 – mirror-lens component; 3 – spherical mirror; 4 – CCD Matrix of television camera; 5 – photodetector of the receiving system of the lidar.
3. Conclusions
In the optical design proposed above, the components of the lidar receiving system in combination with the components of the viewfinder construct the image of the latter at an axial placement of the viewfinder on the optical axis of the lidar receiving system. This greatly facilitates the alignment of the guidance and lidar receiving systems. This placement of the camera makes it possible to observe the absence of image parallax of the object on which laser radiation is directed. As an example, a photograph of a laser spot on a building, which was obtained with the help of the television viewfinder, is presented in Figure 5. The distance to the building is 4000 m. The continuous monitoring of the image of the space surrounding the object is provided by the simultaneous observation of the object and registration of the lidar signal reflected from it (Figure 6).

![Figure 5](image1.jpg)  ![Figure 6](image2.jpg)

**Figure 5.** Photograph of a laser spot on a building obtained with the help of the television viewfinder.  
**Figure 6.** Lidar signal.

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