The development of an optical system for lighting various rooms with sunlight

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Abstract. The necessity of using light in the room, the spectral composition of which corresponds to the spectrum of the sun for a comfortable state of a person, is justified. A passive system that does not consume energy is proposed. An energy-efficient natural light system has been developed, creating a comfortable environment for the eyes, well-being and mood of a person. An experimental study of the system operation was carried out. The dependence of the light intensity on the angle of incidence in the light guide is obtained.

1. Introduction
The deterioration of the environmental situation, the appearance of a large number of negative factors, as well as an increase in stress load negatively affects the state of human health [1-12]. This dramatically reduces its efficiency and contributes to the appearance of various diseases [10-19]. It is extremely difficult to improve the environmental situation, as this is a long process [11, 12, 20-27]. It is possible to exclude other factors or reduce their influence [20, 21, 26-31]. One of them is the level of illumination and the quality of the light wave. Numerous studies of scientists [15-18, 32-38] have shown that the most favorable effect on vision and the psyche is provided by sunlight. Therefore, the developers of various light sources strive to reproduce the spectrum of sunlight in the light stream.

With the increase in the cost of electric energy, the production of most light sources goes in the direction of reducing energy consumption, increasing the resource of its operation, as well as compliance with strict safety measures for operation [32, 33, 38-40]. Less attention is paid to the spectral component in the emitted light from the source, since the implementation of the full spectrum of the sun is very expensive technologies [33, 38, 41].

Our research has shown that almost all currently produced LED lamps have a truncated spectrum of sunlight, especially with a long service life [32, 35, 38, 41]. Currently, only two of the light sources produced fully reflect the spectrum of the sun. Traditional incandescent light bulb. It has a number of disadvantages associated with a low service life and the possibility of an explosion of the glass bulb when the spiral burns out. A lamp consisting of a combination of LEDs of different wavelengths that emit with different power (corresponding to the solar spectrum). The disadvantage of this lamp is the high price. If one or more LEDs fail during power surges, the light spectrum is distorted [41, 42].

Therefore, the search for various solutions related to the possibility of using sunlight, especially in residential areas, is extremely relevant at the present time.
2. Optical system and research methodology

In this work, one of the possible solutions is considered – the design of a system containing a set of optical elements that concentrate daylight, transmit it through a system of quartz light guides and disperse it in the indoor areas of the building. The system shown in Figure 1 includes collecting and scattering lenses, a rotating prism, quartz light guides and a transparent protective panel. The transparent panel is placed on the roof of the house.

![Figure 1](image)

**Figure 1.** Operation of the optical system for transmitting sunlight: 1-collecting lens; 2-rotating prism; 3-quartz light guide system with couplers; 4-transparent protective panel; 5-scattering lens.

This system will function throughout the daylight hours. The introduction of such a system has a positive impact on the health of people with continuous exposure to the visible spectrum of natural light. Other benefits include a reduction in energy losses and energy inputs from buildings, as well as a positive impact on the planet’s ecology by reducing conditional CO2 emissions into the atmosphere. The use of quartz light guides ensures the operation of the system in any weather due to their resistance to low and high temperatures. The presence of a rotating prism eliminates additional light losses due to reflections on the bends and walls of the light guide when transmitting it from the collecting lens to the vertical light guide.

3. Result of experimental investigations and discussion

The results of experimental studies have shown that in the developed optical system, when light is transmitted through optical fibers, its spectral composition does not change. Figure 2 shows as an example the results of the study of the radiation spectrum using a diffraction grating.

![Figure 2](image)

It should be noted that there is also no significant redistribution of the light intensity over the wavelengths in the studied radiation after its passage through the optical fibers. An important parameter in the developed design of the lighting system is the dependence of the illumination E in the room on the angle at which the light stream enters the light guide after the prism (Figure 3).

![Figure 3](image)

The dependence of the change in illumination E on the bending angle of the light guide θ after the introduction of sunlight into it was also studied (Figure 4).

With an increase in the angle at which the light stream enters the light guide, there is a decrease in illumination. Similarly, with a larger bend of the light guide, the illumination of the rooms decreases.
The conducted studies allowed us to establish that the most effective for transmitting sunlight in the optical system developed by us is the following. For any roof geometry, the optical axis of the focusing lens is perpendicular to the input surface of the light guide. The focus of the lens is placed on this surface of the light guide. The bending angle of the light guide can be minimized by increasing its length. The choice of the bending angle of the optical fiber in accordance with its length, as well as other parameters of the optical system are determined using mathematical modeling. The model is developed taking into account the design of the roof, since different placement of optical elements is possible for different cases. The optimum is determined by the maximum illumination.

Figure 2. The spectral composition of sunlight at the output of two optical fibers after the divider.

Figure 3. The dependence of the change in light intensity on the angle \( \alpha \) at which light enters the light guide for two types of light guides, graph 1 – a single light guide, graph 2 – a light guide with two branches.

4. Conclusion
Conducted studies have shown that when implementing the system, it is important to take into account the geometry of the roof and the angle at which the optical axis of the focusing lens will be located. The focus of the lens should be located on the outer surface of the light guide, the optical axis of the focusing lens should be perpendicular to the surface of the light guide on which the radiation falls. For each indoor lighting project, it is necessary to calculate the system and simulate its operation in order to determine the optimal configuration for the maximum intensity of light entering the premises.
Figure 4. The dependence of the change in illumination $E$ on the bending angle of the light guide $\phi$.

Thanks to its properties, the developed optical lighting system creates an atmosphere of comfort in the premises, and significantly reduces the energy costs for lighting, heating and air conditioning of the buildings in which it is installed.

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