Development of an optical system for lighting rooms with biologically safe and environmentally friendly sunlight

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Abstract. The article discusses the development and advantages of an optical system for lighting rooms with biologically safe and environmentally friendly sunlight. A passive system that does not consume energy is proposed. The analysis of artificial light sources by their spectral composition is carried out. It was found that the spectral composition most suitable for a comfortable human condition is an incandescent lamp, which has several limitations. It is established that the most environmentally friendly and safe solution is the use of sunlight. An energy-efficient natural light system has been developed, creating a comfortable environment for the eyes, well-being, and mood of a person.

1. Introduction
To create a comfortable indicator of illumination in the premises, high energy consumption is required [1-6]. These costs increase every year along with other electricity costs for other needs [6-15]. This, in turn, has a negative impact on the environment, as more fuel and other resources are needed for its production [15-26]. In addition, the transportation of electrical energy requires additional networks that create additional electromagnetic fields [27-33]. Currently, the main mass of light sources is made up of traditional artificial lighting sources: incandescent lamps, fluorescent lamps, LEDs, etc. The breadth of their application is associated with a relatively inexpensive cost, but at the same time their use entails high energy costs. Another important parameter that characterizes the light source is the spectrum and its components [1-4, 13, 33-35]. The similarity of the spectrum of the light source to the spectrum of the Sun provides a comfortable environment for the human condition and has a positive effect on its productivity. The ecology of the eyes is not disturbed [24, 25, 35, 36]. The absence of such lighting leads to the fact that the person turns on additional light. To begin with, let's compare different radiation sources and their spectrum: the Sun, an incandescent lamp, fluorescent lamps, cold and warm LEDs (Fig. 1).

In the research of the spectral compositions of various radiation sources, it was found out that the spectrum of the Sun is optimally reflected by an incandescent lamp, since its spectrum contains all the components of the spectrum of the Sun, but the incandescent lamp has a number of significant disadvantages associated with a short service life and the possibility of an explosion of the glass bulb when the spiral burns out. In other cases, the light sources have a truncated spectrum compared to the spectrum of the Sun [35, 37-39].
During work, it is very often necessary to use artificial light sources, even if it is day outside and the sun is shining, for example, in rooms without windows or where the light from the windows does not reach the corners of the room. There is also a common situation when the sun's rays at a certain time of day do not fall into the windows of the lower floors, the same trend is observed at a certain time of the year, regardless of the time of day. It should be noted that the roofs of residential buildings are better and longer illuminated by the sun. Therefore, one of the solutions to the problem of indoor lighting can be an additional collection of solar rays by optical systems located on the roof, and their transportation to residential and basement rooms through light guides.

2. The development of an optical system for lighting rooms with biologically safe and environmentally friendly sunlight
This article discusses one of the possible solutions—the design of a passive system of natural lighting of premises. The system includes collecting and scattering lenses, a rotating prism, quartz light guides and a transparent protective panel. A transparent panel is installed on the roof of the house. This system will function throughout the daylight hours. Consider two cases. The sun is high above the horizon (Figure 2) and when it is low (Figure 3).
In the first case, the sun's rays will fall both on the roof of the building and in its windows, but corners and hard-to-reach places, such as corridors or rooms without windows, will be poorly lit or not lit at all. In the second case, the windows of the lower floors will not be lit, and you will have to use lamps in the rooms, even if it is still light outside (summer evening). This situation is very often observed in the regions of the far North or in winter when the Sun is very low relative to the horizon. In both cases, the problems can be solved with the help of an optical system developed by us, which does not require electrical energy to operate.

A feature of the developed design of the optical system is the presence of a rotating prism [2, 35]. Its use makes it possible to eliminate 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 (Fig. 2). In addition, the use of such prisms allows you to revise the system for placing solar radiation collection on the roof. The roof is made in the form of four triangles connecting at the top. On each part of the roof is placed the receiving part of the optical system to collect sunlight. This allows you to use the developed lighting system more effectively all day long.
The use of rotating prisms made it possible to place the protective panel and collecting lens on the roof without protrusions in order to avoid the accumulation of debris and not to change the appearance of the building.

3. The results of the system operation
In the process of an experimental study of light transmission through optical fibers, it was found that the transmitted spectrum is not distorted (Fig. 4).

![Figure 4](image)

**Figure 4.** Checking the spectrum of light transmitted through a light guide using a diffraction grating.

It is convenient to use quartz optical fibers in the system (Fig. 5) because of their resistance to low and high temperatures, which will allow the system to work properly in all weather conditions.

![Figure 5](image)

**Figure 5.** Quartz light guide

4. Conclusion
The experiments have shown the effectiveness of using such systems, both from an economic and environmental point of view. In the daytime, light guides provide light in rooms without using electricity, and saving the resource of electric lamps increases their service life.

In the developed optical system, the wear of the equipment is minimal. The exception is the protective glass and gaskets for their installation. There is no heat loss in this system. In the case of
using an autonomous source of electricity for the home (diesel generator), the advantages from an environmental and economic point of view are obvious.

The psychological state and comfort of vision, in the conditions of an extremely high price for treatment, does not make sense to consider. It should be noted that in this light, indoor plants produce more oxygen, which is extremely beneficial for the environment [40-44].

The system is completely passive and works regardless of the presence of electricity in the house or office. It only requires close attention to the condition of the protective glasses.

References
[1] Logunov S, Rud V, Davydov R, Moroz A and Smirnov K 2019 *Journal of Physics: Conference Series* **1326**(1) 012024
[2] Logunov S, Davydov R, Vysotsky M, Dudkin V and Rud V 2019 *Journal of Physics: Conference Series* **1368**(2) 022056
[3] Sachenko A, Kostylyov V, Sokolovskyi I, Bobyl A, Terukov E and Shvarts M 2017 *Technical Physics Letters* **43**(2) 152-155
[4] Grevtseva A, Davydov R, Dudkin V and Rud V 2019 *Journal of Physics: Conference Series* **1326**(1) 012043
[5] Yushkova V, Kostin G, Davydov R, Dudkin V and Valiullin L 2019 *IOP Conference Series: Earth and Environmental Science* **390**(1) 012016
[6] Petrichenko M, Vatin N, Nemova D, Kharkov N and Staritcyna A 2014 *Applied Mechanics and Materials* **627** 297-303
[7] Murgul V, Vatin N and Zayats I 2015 *Procedia Engineering* **117**(1) 819–824
[8] Vatin N, Petrichenko M and Nemova D 2014 *Applied Mechanics and Materials* **633-634** 1007–1012
[9] Van S, Cheremisin A, Davydov R and Yushkova V 2019 *E3S Web of Conferences* **140** 09008
[10] Van S, Cheremisin A, Chusov A, Switala F and Davydov R 2019 *IOP Conference Series: Earth and Environmental Science* **390**(1) 012011
[11] Nikolaev D, Chetiy V and Dudkin V 2020 *IOP Conference Series: Earth and Environmental Science* **578**(1) 012052
[12] Lukashev N 2019 *Journal of Physics: Conference Series* **1236**(1) 012068
[13] Valov A, Davydov R, Rud V and Grevtseva A 2019 *Journal of Physics: Conference Series* **1326**(1) 012040
[14] Smirnova S and Nikolaev D 2020 *Journal of Physics: Conference Series* **1695**(1) 012136
[15] Sergeev V, Vatin N, Kotov E, Nemova D and Khoroobov S 2020 *Applied Sciences (Switzerland)* **10**(23) 1–16, 8739
[16] Davydov V, Dudkin V and Karseev A 2013 *Optical Memory and Neural Networks (Information Optics)* **22**(2) 112–117
[17] Davydov V, Dudkin V and Karseev A 2014 *Optical Memory and Neural Networks (Information Optics)* **23**(4) 259–264
[18] Davydov V, Dudkin V and Karseev A 2014 *Optical Memory and Neural Networks (Information Optics)* **23**(3) 170–176
[19] Davydov R, Antonov V, Makeev S, Dudkin V and N. Myazin 2019 *E3S Web of Conferences* **140** 02001
[20] Davydov V, Nikolaev D, Bukharov G and Pavlova Z 2020 Proceedings of the 2020 IEEE International Conference on Electrical Engineering and Photonics, EExPolytech 2020 **9243948** 227–229
[21] Davydov V 1999 *Russian Physics Journal* **42**(9) 822–825
[22] Myazin N, Yushkova V and Rud’ V 2019 *Environmental Research, Engineering and Management* **75**(2) 28–35
[23] Myazin N, Yushkova V, Taranda N and Rud V 2019 *Journal of Physics: Conference Series* **1410**(1) 012130
[24] Davydov V, Velichko E, Dudkin V and Karseev A 2015 *Instruments and Experimental Techniques* 58(2) 234–238
[25] Davydov V, Velichko E, Dudkin V and Karseev A 2014 *Measurement Techniques* 57(6) 684–689
[26] Davydov V, Dudkin V and Karseev A 2015 *Journal of Applied Spectroscopy* 82(5) 794–800
[27] Moroz A, Malanin K, Krasnov A and Rud V 2019 *Journal of Physics: Conference Series* 1400(4) 044009
[28] Moroz A 2019 *Journal of Physics: Conference Series* 1368(2) 022024
[29] Moroz A, Cheremisin A, Meshalkin A and Semenova N 2020 *IOP Conference Series: Earth and Environmental Science* 578(1) 012006
[30] Podstrigaev A, Smolyakov A and Grebenikova N 2019 *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 11660 LNCS 525–533
[31] Myazin N, Dudkin V, Grebenikova N, Rud’ V, and Podstrigaev A 2019 *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 11660 LNCS 744–756
[32] Moroz A 2019 *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 11660 LNCS 710–718
[33] Davydov R and Antonov V 2016 *Journal of Physics: Conference Series* 769(1) 012060
[34] Davydov R, Antonov V and Kalinin N 2015 *Journal of Physics: Conference Series* 643(1) 012107
[35] Davydov V, Nikolaev D, Moroz A, Dmitrieva D and Pilipova V 2020 *AIP Conference Proceedings* 2308 060005
[36] Davydov V, Cheremiskina A, Velichko E and Karseev A 2014 *Journal of Physics: Conference Series* 541(1) 012006
[37] Smirnov K, Glagolev S and Tushavin G 2018 *Journal Physics: Conference Series* 1124(1) 022014
[38] Smirnov K, Medzakovskiy V, Vysoczky V, and Glagolev S 2017 *Journal of Physics: Conference Series* 917(6) 062019
[39] Smirnov K, Glagolev S, Rodygina N and Ivanova N 2018 *Journal of Physics: Conference Series* 1038(1) 012102
[40] Davydov R, Antonov V, Molodtsov D and Trebuchkin A 2018 *Advances in Intelligent Systems and Computing* 692 915–920
[41] Davydov V, Dudkin V and Karseev A 2015 *Technical Physics* 60(3) 456–460
[42] Natorkhin M, Bobyl A, Cheremisin A and Sokolov M 2019 *Journal of Physics: Conference Series* 1236(1) 012011
[43] Moroz A 2019 *Journal of Physics: Conference Series* 1410(1) 012212
[44] Moroz A, Malanin K and Krasnov A 2019 *Proceedings of the 2019 Antennas Design and Measurement International Conference, ADMInC 2019* 8969090 114–116