

# Resource-efficient modular space greenhouse with LED lighting

D V Bylkov and A D Kapralov

Division for Material Science, School of Advanced Manufacturing Technologies,  
National Research Tomsk Polytechnic University, 30 Lenin Avenue, Tomsk 634050,  
Russia

Email: [prototype103faza@gmail.com](mailto:prototype103faza@gmail.com)

**Abstract.** The main goal of this project is the developing a design and configuration suitable for growing plants in microgravity conditions. For a decision, a block-modular design has been developed that will maximize the efficiency of using the growing surface due to the location of the plants on all faces. The resulting cubes can be cascaded to link with each other, increasing the desired volume. As a result, the installation will use less space at the station, than the modern using analogues. Design development was made by Autodesk Inventor software.

## 1. Introduction

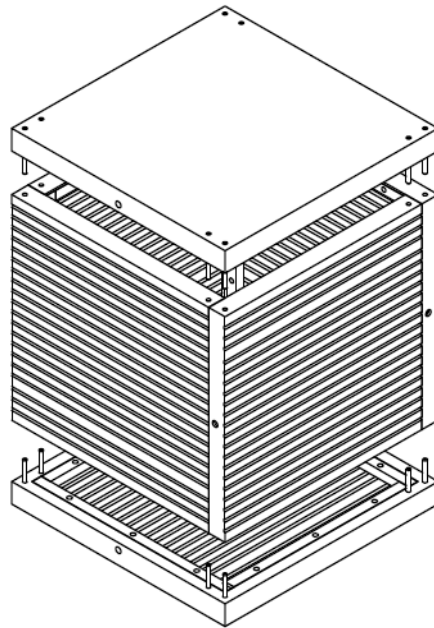
Nowadays, science and research programs in space develops very fast and ambitious. One of research areas is the study of the influence of space conditions (microgravity, low pressure, cosmic radiation) on plants [1-7]. Studying how plants react to life in space, we can learn more about how they adapt to environmental changes and thus understand the mechanism of functioning of plants in space, because this can be the beginning of the era of colonization and development of various planets. So, to speed up the studying of plants, a large number of experiments and research are needed, in this way, productive phytotrons are required for carrying out experiments in large volumes and at lower costs. Modern phytotrons cannot provide adequate performance, their useful area and the efficiency of growing plants does not allow making the required amount of experiments, which leads to plural deliveries of prototypes and delay in experiments. For example, delivery to orbit of a cargo weighing one kilogram costs about \$ 20,000 [14]. Thus, there is a great need to develop a new phytotron layout principle.

## 2. Materials and methods

The main idea to increase the performance of the phytotron is a noticeable increase in the effective area of plant growth, in contrast to the existing options for phytotron installations for space.

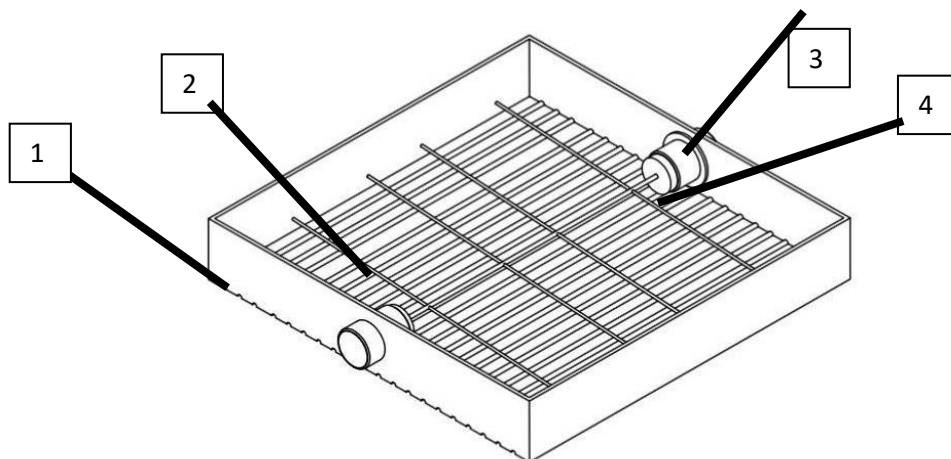
Thus, the layout method was put forward in the form of a cubic form. This installation will occupy less space at the station, unlike its already existing counterparts, due to the location of plants on all faces. In other words, the entire internal surface of the module will be used, which will make it possible in theory to achieve a six fold increase in production and, accordingly, to use six times less light sources.





**Figure 1.** Total view of installation

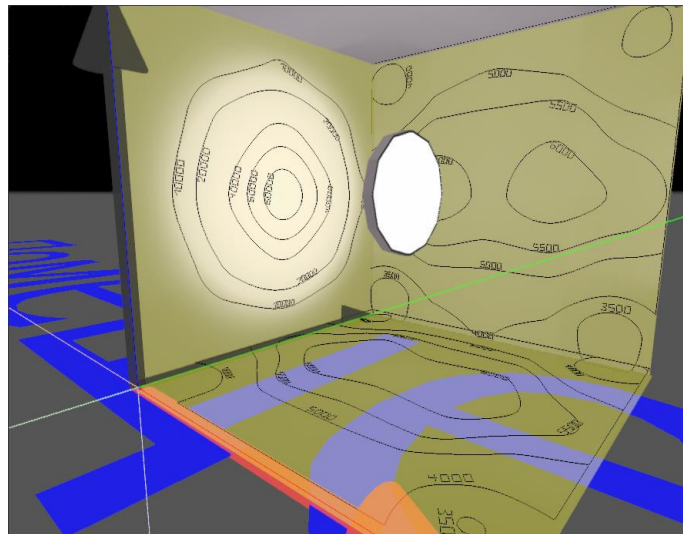
The module will consist of attachable cells, which in turn will have the following components:



**Figure 2.** Base building cell. 1) Housing - pallet. 2) Receiver for spraying nutrient solution. 3) Pipe with seal. 4) Bung.

In assembled condition, the cell will be a sealed plate with a substrate soaked in nutrient solution inside to hold the seeds. The cell will be covered with a special sheet in order to allow the seeds to germinate inside the cube. The substrate will be needed for tight retention of the root system and proper growth of the plant, as it will not allow the liquid to spread, but will evenly deliver nutrients to the roots.

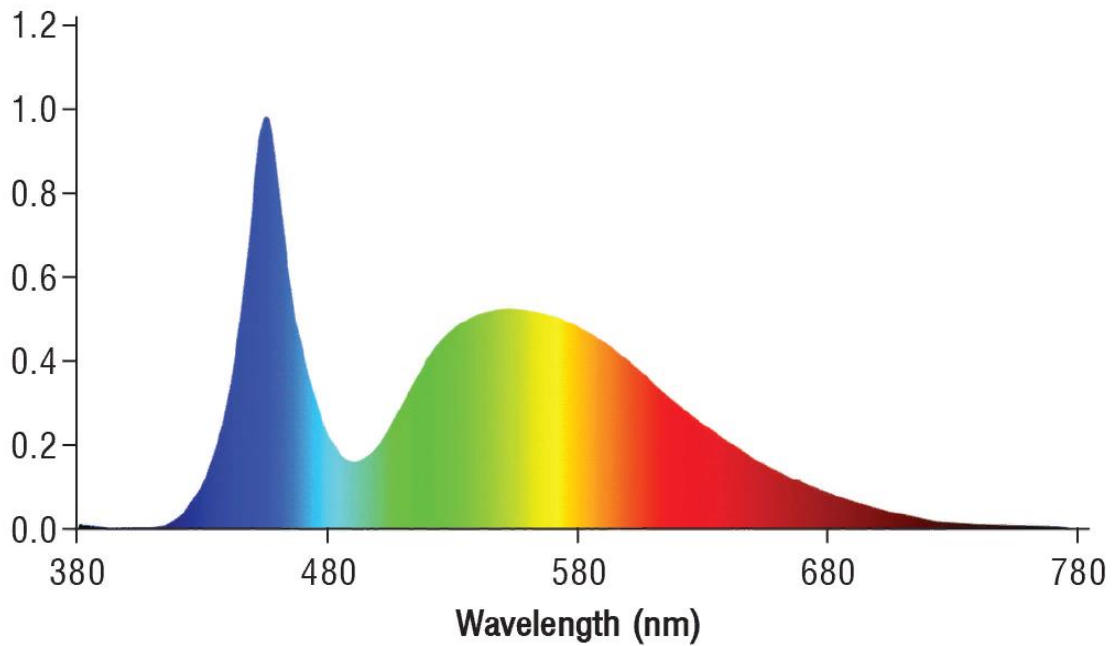
Another distinctive feature of this installation is a special arrangement of the lamp, which is made in the form of two hemispheres fastened together, located in the center of the installation. This configuration will allow you to evenly distribute the light energy and significantly reduce the cost of exposure.



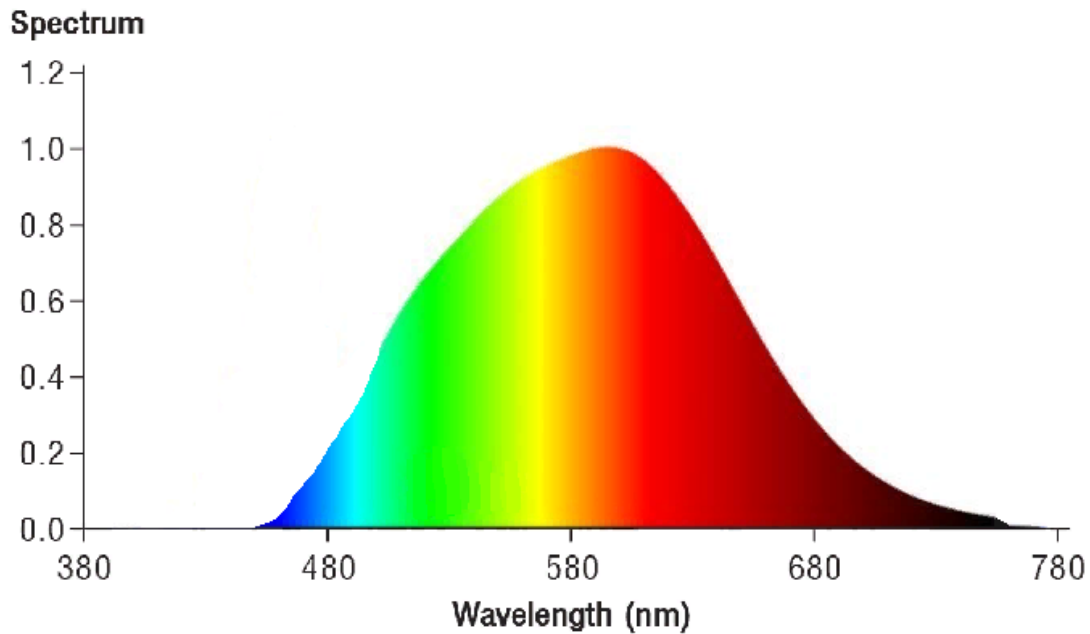
**Figure 3.** Principle of inside lightning.

Based on studies of the influence of the photon flux density on the growth rate of lettuce leaves, an irradiation regime was developed [8, 9]. The first eight days to create a photon flux density level -  $80 \mu\text{mol}\cdot\text{s}^{-1}/\text{m}^2$ , and starting from day 9 until the end of the growing season of the salad -  $160 \mu\text{mol}\cdot\text{s}^{-1}/\text{m}^2$ . The light source in the irradiation facility will use LEDs with a radiation wavelength within the maximum photosynthetically active radiation (400-700 nm.) [8, 11 - 13]. The structure of the light source includes a red LED with a spectral maximum of radiation at a length of 650 nm; and a white LED made on a blue crystal with an intensity maximum at a wavelength of 450 nm [10].

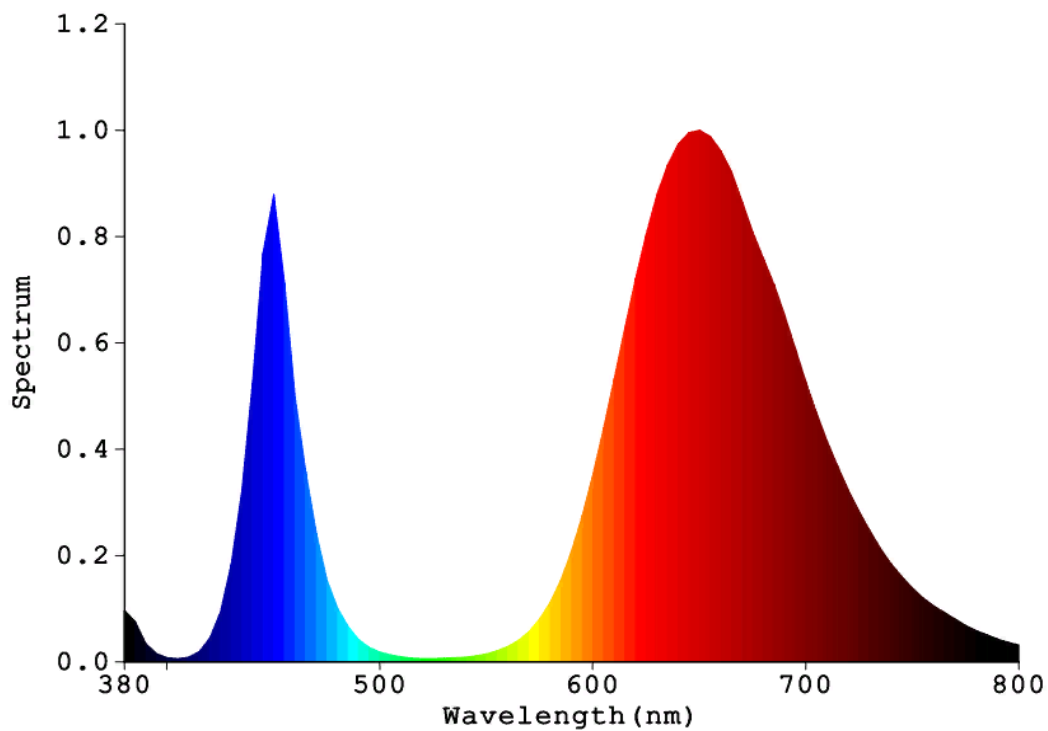
**Spectrum**



**Figure 4.** Spectrum of white LED.



**Figure 5.** Spectrum of red LED.



**Figure 6.** Total spectrum of lighting installation.

### 3. Conclusion

This work is a preparatory stage for the creation of a phytotron; it contains an analysis of information that makes us understand about the device of the phytotron as a whole.

Since the work is a design project, it will help us determine the form and layout of the phytotron. Of course, there is still a lot of work to be done on the development of the internal device of the phytotron, but thanks to this work, it is much easier to evaluate the ways of interaction between the parts of the phytotron, to think over the internal details, based on the overall design and construction.

So, this big step was made on the way to the development of this product, namely: the form of the phytotron was chosen, the principle and advantage of this form was explained; the main feature of which is the modularity of the design and internal use of the faces, the material and method of plant nutrition was chosen. All this allows us to qualitatively put together all further details that will ensure the functioning of the phytotron, as well as evaluate its capabilities.

### Acknowledgement

The work was supported by the Ministry of Education and Science of the Russian Federation under the State Program in the field of scientific investigations №13.3647.2017/PP

### References

- [1] Gupta S D and Jatothu B 2013 Fundamentals and applications of light-emitting diodes (LEDs) in in vitro plant growth and morphogenesis *Plant Biotechnol.* **7** 211
- [2] Bantis F, Smirnakou S, Ouzounis T, Koukounaras A, Ntagkas N and Radoglou K 2017 Current status and recent achievements in the field of horticulture with the use of light-emitting diodes (LEDs) *Scientia Horticulturae* **235** 437
- [3] Singh D, Basu C, Meinhardt-Wollweber M and Roth B 2015 LEDs for energy efficient greenhouse lighting *Renewable and Sustainable Energy Reviews* **49** 139
- [4] Morrow R C 2008 LED lighting in horticulture *Hort Science* **43** 1947-50
- [5] Yeh N and Chung J P 2009 High-brightness LEDs – energy efficient lighting sources and their potential in indoor plant cultivation *Renew Sustain Energy* **13** 2175-80
- [6] Li Q and Kubota C 2009 Effects of supplemental light quality on growth and phyto-chemicals of baby leaf lettuce *Environmental and Experimental Botany* **67** 59
- [7] Samuolien G, Brazaityt A, Jankauskiene J, Vir A, Sirtautas R, Novickovas A, Sakalauskiene S, Sakalauskaite J and Duchovskis P 2013 LED irradiance level affects growth and nutritional quality of Brassica microgreens *Cent. Eur. J. Biol.* **8** (12) 1241-49
- [8] Temnik S E, Smolyakova K V and Turanov S B 2016 Development of an effective quantum radiation regime for greenhouse lettuce *Intellectual energy systems: Proc. of the IV International Youth Forum, October 10-14, 2016, Tomsk* (Tomsk: TPU Publishing House) **1** pp 350-352
- [9] Turanov S B, Kozyreva I N and Yakovlev A N 2014 Methods for assessing photosynthetically active radiation *Modern equipment and technologies: Proc. works of the XX international scientific and practical conference of students, graduate students and young scientists, Tomsk, April 14-18, 2014* (Tomsk: TPU Press) **1** pp149-150
- [10] Bula R J, Morrow R C, Tibbits T W, Barta R W, Ignatius R W and Martin T S 1991 Light emitting diodes as a radiation source for plants *Hort Science* **26** 203
- [11] Brazaityte A, Ulinskaite R, Duchovskis P, Samuoliene G, Šikšnianiene J B, Jankauskiene J, Šabajeviene G, Baranauskis K, Staniene G, Tamulaitis G, Bliznikas Z and Žukauskas A 2006 Optimization of lighting spectrum for photosynthetic system and productivity of lettuce by using light-emitting diodes *Acta Horti* **711** 183
- [12] Li H, Tang C, Xu Z, Liu X and Han X 2012 Effects of different light sources on the growth of non-heading Chinese cabbage (*Brassicacampestris* L.) *J. Agric. Sci.* **4** 262
- [13] Korepanov V I, Omirova N I and Omarkhan A Sh 2016 LED illuminator for greenhouses (Tomsk: TPU Publishing House) pp 372-377

- [14] Dolgaleva O V 2018 *Design-project of modular system of phytotron for use in home conditions: bachelor's work* (Tomsk: National Research Tomsk Polytechnic University)