Controllable light beam shaper in LED lamp

K D Nessemon¹, I V Popov², V V Belyaev¹,³, A A Belyaev³, V K Velichko³
¹RUDN University (Peoples’ Friendship University of Russia), Moscow, Russia
²Kometa Corporation, Moscow, Russia
³Moscow Region State University, 10a Radio st., 105005 Moscow, Russia

E-mail: nessemon@yandex.ru, vic_belyaev@mail.ru

Abstract. A design of an LED lamp with controllable shape and intensity of the light beam formed is described. The effect is achieved by dividing the light irradiating area for four section and their special fixation and fastening.

1. Introduction and problem definition
LED lamps are the lighting devices of new generation having a high light efficiency, a longevity, a small energy consumption [1,2].

Problems of LED lamps are as follows: light effectiveness, heat irradiation when using at various operating conditions. One of important problems is adaptation of the lamp to a specific workplace with a possibility of a variation of the illuminating intensity on it [3,4].

There is a set of the LED lamps having the various forms and mechanisms of fastening, for example, [5]. However when using these lighting devices it is impossible to create the given shape of the light spot since there is no possibility of management of a luminous flux – its intensity and orientation. Also at the operation of the LED lighting arrays operating temperature of a crystal increases that negatively affects exploitation performances of the light-emitting diode – life time and luminous flux are decreased, the radiation spectrum and electric parameters are changed.

The purpose of this work is development of the device providing the given direction (concentration or a scattering) of the luminous flux for the necessary type of illumination, namely common uniform, common local as well as achievement of high cooling efficiency with the reliable heat-removing device.

Let's call this device as controllable light shaper (CLS). It can be used as the lighting array in the production facilities and living conditions, both in rooms, and in outdoor areas for illumination ensuring.

2. CLS design
The aggregate CLS design is presented in fig. 1 [6]. The CLS comprises four sections. Each section consists of the basis on which profile edges of a radiator, a printed circuit board with the light-emitting diodes and an optical element (fig. 1,2) are located.

Because of extrusive manufacturing techniques all metal details of the design have profile type. At these manufacturing techniques, the surface area of the radiator is most increased for decrease of its thermal resistance for the heat transfer from the radiator into a surrounding medium.
Fig. 1. Axonometric drawing of the controllable light shaper (CLS). 1-4 are the CLS sections. 13 and 14 are the lower and top fixing elements for the sections 1-4 fixation and fastening.

Fig. 2. The device top view in the form of a circle or rectangular in the plan. 1-4 are the sections of the controllable light concentrator. 10 are the heat-removing radiators. 13 and 14 are the lower and top fixing elements for fixing and fastening sections 1-4 among themselves. There are not shown on the drawing the elements: the basis 5, the printed circuit board 6 with light-emitting diodes, the printed circuit board 6 the optical element 7 placed on the board 6. The heat-removing radiators are a part of the heat-removing element 8 of each section located on a substrate 9.
Owing to the fixing elements which connect all four parts of the controllable light concentrator it is possible to position each part under a different corner, regulating the direction of the luminous flux that allows controlling the light spot sizes (fig. 3).

Fig. 3. The CLS front view, cross-section C-C. The arrangement of each section is horizontal, inclined up or down in relation to the central vertical axis.

As shown in fig.3 the lower and top fixing elements 13 and 14 have grooves inside, they are positioned symmetrically in relation to the central axis. Thickening 12 of the extreme ledges of the heat-removing elements 11 are inserted into these grooves.

The CLS has a clamp 19 with a through hole which is on the same vertical axis with a through hole of the lower fixing element 21. The clamp 19 is performed rectangular in its cross-section, it has the top thickening 22 with longitudinal ledges on two opposite sides as well as the lower thickening with a rectangular aperture. The top fixing element 14 has also through hole of the top fixing element 26. All these through holes are provided for passing of wires to them from the printed circuit board for their connection with control units. The lower thickenings of the clamp 19 performed rectangular in its
section can be performed the different size longwise of the rectangle side in section depending on by what corner up or down the sections 1-4 need to be inclined, or to be arranged horizontally.

The upper part of the top fixing element can be performed in the form of a hook for hanging the device, for example, on the room ceiling. It can be also executed in the form of an inverted letter Π for the placement of the control systems of the printed circuit boards in its space. In such version a cover 31 inserted into grooves 32 of the ledges 33 is used too.

Heat-removing radiators 10 can be performed as profiled to decrease the thermal resistance. For formation of the convection fluxes they settle down apart from each other. They have different height. At the same time the radiators 10 have larger height on the one side the heat-removing device, than on another side.

At the horizontal arrangement of the sections one obtains the unidirectional light beam, at an arrangement of the sections at an angle up one obtains a scattered luminescence and at an arrangement of the sections at an angle down one obtains a concentrated luminous flux with higher intensity. In this case the area of the light spot is less. It is illustrated by calculations of the illuminating intensity created on platforms under lamps of different design (Table 1). We suppose that each section with the size d has the uniform brightness distribution. The illuminating intensity with Gaussian distribution on the coordinates is created on the platform under the lamp. At the horizontal arrangement of the lamp sections the light spot has the size of 2.8 d on the level 0.5 from its maximum. At the inclined down arrangement of the lamp sections the light spot has the size of 1.5d. The illuminating intensity in the spot center of is increase by 1.5 times. At the inclined up arrangement of the lamp sections the light spot has the size of 3.5d. The illuminating intensity decreases in its maximum level by only 20%. The design of both fixing elements and grooves in them provides an inclination of the sections 1-4 from 3° to 15°.

Table 1. Illumination generated on platforms under the CLS with sections that have size d.

| Coordinate, x/(d/2) | Relative illumination I/I₀ | From one CLS | From two CLS with the horizontal sections location | From two CLS with the inclined down sections location | From two CLS with the inclined up sections location |
|---------------------|----------------------------|--------------|--------------------------------------------------|---------------------------------------------------|--------------------------------------------------|
| 0                   | 1                          | 1.34         | 2                                                 | 0.66                                              |                                                  |
| 1                   | 0.67                       | 1.33         | 1.34                                             | 0.82                                              |                                                  |
| 2                   | 0.33                       | 0.82         | 0.67                                             | 1.08                                              |                                                  |
| 3                   | 0.15                       | 0.41         | 0.30                                             | 0.69                                              |                                                  |
| 4                   | 0.08                       | 0.17         | 0.15                                             | 0.33                                              |                                                  |

If one pair of the lamp sections is inclined down, and another one is inclined up it is possible to create the light spot of the elongated form.

3. Conclusions
The device providing the preassigned direction of a luminous flux (concentration or scattering) for necessary type of the illumination (uniform or localized) is developed. It is enough for variation over a wide range of illuminating intensity and creation of light bunches of a different form and orientation in the rooms of different function.
4. Acknowledgement
Authors express gratitude to the patent attorney of the Russian Federation V.V. Kovalenko for her assistance in drawing up the patent application [6].
The work is performed under partial support of the Russian Foundation of Basic Researches and Government of Moscow Region (project No. 17-47-500752).

References
[1] Jeffrey Y. Tsao, A fresh look at the energy economics of lighting and solid-state lighting // Journal of Physics D: Applied Physics. http://iopscience.iop.org/journal/0022-3727/page/Back%20to%20the%20future%20of%20solid%20state%20lighting.
[2] http://www.valosto.com/tiedostot/CELMA_LED(SM)054C_CELMA_position_paper_on_ADAPTORS_FINAL.pdf
[3] Gary Gordon, Interior Lighting for Designers. 5th Edition. Wiley. 2014.
[4] https://www.whichledlight.com/bulb-guide/led-bulb-beam-angle
[5] Patent for the useful model of the Russian Federation No. 100178, F21S4/00, patent holder of YUNISTAR OPTO CORPORATION (TW).
[6] Popov I V, Belyaev V V, Lekhin V , Leonisova I V. The operated light concentrator. Patent of the Russian Federation No. 116600, 20.05.2012. 10 pages.