ISSN 0236-2945

LIGHT & ENGINEERING

Volume 23, Number 2, 2015

Znack Publishing House, Moscow

LIGHT & ENGINEERING
(Svetotekhnika)

СВЕТОТЕХНИКА

Moscow, 2015

Editorial Office:
VNISI, Rooms 327 and 334
106 Prospekt Mira,
Moscow 129626, Russia
Tel: +7.495.682.26.54
Tel./Fax: +7.495.682.58.46
E-mail: lights-nr@inbox.ru
http://www.sveto-tekhnika.ru

Znack Publishing House
P.O. Box 648,
Moscow, 101000, Russia
Tel./Fax: +7.495.361.93.77

CONTENTS

VOLUME 23 **NUMBER 2** **2015**

LIGHT & ENGINEERING

(SVETOTEKHNIKA)

Light & Engineering
Vol. 23, No. 2, pp. 4-11, 2015

Svetotekhnika
No. 3, 2015

ON THE RELATION BETWEEN UP-DATED COLOUR VISION AND ARCHITECTURAL LANGUAGE THROUGH THE WARM-COLD COLOUR OPPOSITION

Lucia R. Ronchi

Giorgio Ronchi Foundation, Florence, Italy
E-mail: luciaronchi@palenque.biz

ABSTRACT

The present paper deals with the conjunctions and interactions between various disciplines, which explore human visual response and the semantics of colour, based on the language representation which operates on the higher levels in the brain than neural, non-language visual representation. To date, neurophysiologic research has not confirmed the existence of certain predicted mechanisms, so that a revision of visual modelling imposed. A question arises of the consequences for interdisciplinary conjunctions, involving the Vision Science and Lighting Engineering on one side, and Architecture with its allied fields on the other side. A literature review shows that in some cases the problems faced by non-language representation are not transferred to language representation, because of differences in processing. However, a team of visual experts has shown that a plethora of physiological effects, identified by traditional visual research at the neural (non-language level), which are not involved in the perturbations of the visual system, are successfully linked to language representation. In particular, this link, which is mediated by the environment (the favoured explanation after the influence of daylight, which lacks predictable neural mechanisms), explains the fact, reported but not explained in classical text books, that colour appearance can be communicated to others exclusively through language. The recent standardisation (2010) comes to be of interest (Biggam,2012, p.75) in this context, demonstrating the limited number of routes by which colour categories are added, based, in particular, on the opposition between red and yellow warm primaries and green and blue cold primaries, flanked, separately, by white and black. The debate of these facts in architectural studies is discussed.

Keywords: revision of colour vision modelling, colour appearance, warm and cold colour opposition, neural (non-language) and language internal representations, their difference in hierarchical levels, semantics of colour and architectural language

1. INTRODUCTION

The conjunction between different research fields is multidisciplinary, it involves several dimensions and ought to be explored in an encyclopaedia rather than a simple paper. However, our ambitious purpose consists of identifying some key situations, arranging them into a sort of "skeleton", looking for their "spine" through a sort of short circuitry. For instance, Vision Science, Lighting Engineering, Architecture and their allied fields share some particular dichotomies.

First, daylight, traditionally regarded as "optimal", has been rejected as such, due to a lack of the required physiological mechanisms; this has consequences for the relationship between artificial light and daylight.

The second dichotomy is a consequence of the preference for the environment instead, the complexity of which necessitates comprehensive responses, denoted by the diktat "from simple to complex, from local to global" (Brill, 1998, Valberg, 2005).

The third dichotomy is the existence of two internal representations of the observed object and scene: the neural, non-language, internal representation and the language representation (Damasio and Damasio, 1992).

The mutual relation between these two representations is clear in some respects, but some questions remain. In particular, we wonder whether the seismic shifts in the traditional modelling of colour vision research were reflected in language representation research, and if so then how. We consider the conjunction between Vision Research, Lighting Engineering, Architecture and its allied disciplines.

2. A GLANCE AT THE HISTORY AND RECENT PAST OF COLOUR VISION

It is well known, that from about 1759 to 1800, physicists were convinced that colour vision depended on some particular characteristics of light. In 1802 Thomas Young identified "retinal resonators" as responsible for colour vision, and in 1856 the Young Helmholtz theory was developed, assigning a relevant role to retinal photoreceptors. However, in the following decades Hering explored post-receptor organisation. Jameson and Hurvich, in the fifties, ascribed the relevant role to retinal ganglion cells. Electrophysiology confirmed this also including at first the role to the LGN (Lateral Geniculate Nucleus), but shortly afterwards this was contradicted. It was demonstrated that the message leaving the retina is achromatic, consisting only of the sum and differences of the responses of the retinal photoreceptors (for details, see Valberg, 2005).

Now, let us recall that from the operational side, research into the basic laws of visual functionality began to involve the peripheral stages of the visual pathway. Simple, small and brief test stimuli were referred to the spatiotemporal characteristic of the retinal receptor field response, and the pre-processing of the signal culminated at the first bottleneck at the entrance of the optic nerve. The pre-coded message was further elaborated at the LGN, before reaching the primary cortex V1. In traditional experiments, the surround that is the area beyond the background (which did not exceed 10° in diameter) was practically absent, consisting of a wide ring of black or dark grey, so that the response was mainly determined physiologically bottom-up, by minimising the top-down psychological and cognitive influences.

According to a traditional belief, the exposure to daylight, under which our ancestors developed, has been forging the neural structure of the human visual system so that the visual responses were optimised. However, no neural mechanisms assumed to support this primary role of daylight have been electro physiologically identified. So, the primary role is based to the "commands" given to the physiological mechanisms by the lit, complex environment, but not by daylight itself.

Brill (1988) noted that this obliges vision researchers on vision to leave the "captivity" of the laboratory for the "jungle" of the complex real (and natural) world. The corresponding diktat was "from simple to complex, from local to global". In fact the environment is variegated (containing objects of different forms), polychromatic, multi-dimensional, and ubiquitous in texture. A comprehensive response is needed due to the combination of several mutually interacting inputs.

In turn, laboratory research continued, identifying the details of seismic shifts occurring in traditional visual modelling. Practically each stage of the process was upset in one or another way. In particular, the assertion that both elemental and unique hues are strictly related was overturned. Elemental hues have a direct relation to activation and inhibition of early opponent cells, either in the retina or in the LGN, but even if the unique hues might be an inner, subjective, common reference for everybody, their electrophysiological correlates were not found. Moreover, the retinal ganglion cells are only a peripheral stage of colour opposition. It has been demonstrated that colour appearance is not strictly correlated with chromatic sensitivity. So, the trichromatic theory no longer needs to account for colour appearance (Mollon, 2013).

Finally, let us recall that the response to a complex stimulus presents various problems, not least because of the large number of factors involved, not all of which can be quantified. Therefore, further experiments are needed to assess the quality of perceived images with the accuracy requested by proper modelling based on a comprehensive global response.

3. TOWARDS MULTIDISCIPLINARY APPLICATIONS

The results of the operational works were described at the AIC meeting in Budapest in 1982. Schanda stressed the relationship between the traditional colour metrics and colour dynamics, a new science collecting knowledge on the use of colours as influential in shaping the environment by rendering the surroundings brighter and more colourful and including an appreciation of psychological space, and of various feelings. One of the keystones of Nemcsic's view was the harmony between components; the colour complexity and the environment of these colours, the relationship between hues and complex colours and between saturation and brightness, colour memory, colour feelings, colour shifts by adaptation, motion, various associations and preferences. In particular, the laws of harmony raised by simultaneous colour sensations were established by the association of Physics and Aesthetics.

In particular, Tosca (Proc.AIC'82) reported on how colours were chosen by architects. Some relied on their intuition and creativity without invoking the quantitative characteristics, and used a list of qualitative factors or conceptual proposals; words instead of measurements. The quantification of the input signals and human responses to colour were not familiar to everybody, hence they were not discussed at the design stage. After this, there were two possibilities:

– Some colour data were recorded using a colorimeter, mainly to assess the characteristics of the used materials, the selection of which had been dictated by practice;

– Colours had been selected based on specific conceptual pre-requisites, but it was difficult to quantify the dynamic influence of the topography, the role of architectural composition, the role of the urban scene, and the aesthetic colour distribution.

It was apparent that a proper, well-organized multidisciplinary research was needed. A highlight of the meeting AIC'82 was the proposal that researchers, whatever their background, should use the same experimental methodology, following the same scheme. This scheme should include the technical stage, the response stage, a list of intervening factors, two or three independent variables selected for a considered experiment, a consideration of their mutual interactions, and a list of possible combinations. Responses should be analysed either through questionnaires or by the use of SDS (semantic differential scales) with appropriately selected opposing terms at their extremes. An analysis of the principal components indicated the dimensions of a tridimensional model.

At this point, it seems pertinent to recall Tosca's report, (Proc. AIC 1988), six years later, after her experimentation with the scheme described above. Tosca stressed once more that architectural lighting was not limited to choosing a lamp and deciding upon its installation, number and location. At the technical stage, a photometer and colorimeter are insufficient for assessing the colour response in an urban landscape, for instance. The result of the measurements should not consist in a colour palette for architects, but in ensembles appropriate for choosing colours creatively, with respect for purely functional elements. The perception is also based on memory. The ability of the environment to compose a pleasant perception depends on the consistency and spatial distribution of objects and elements. There are numerous factors, some quantifiable, some not. The methodological stage devoted to response should include a polychromatic inquiry into the statistical significance of correlations between various parameters: preferences of the users (traditional or following fashion), environmental influences, colour rendering, results in the 3 D space, integration of various responses and of the semantic variables according to their frequency of occurrence, and so on. The analysis of the responses should be performed using SDS (Semantic Differential Scales), which have words of opposite meanings for pleasantness and ecological assessment at their extremes.

Another highlight of the 1982 AIC meeting was the use of colour language, discussed in the next section.

To conclude this section, let us consider that today, after more than three decades, there is a plethora of papers at our disposal; we can evaluate their results, draw conclusions and plan future experimentation. In terms of bibliographical references we might suggest the proceedings of the meetings of AIC (available on line (hhttp://www.aic-colour.org/congr.htm) and the journal Lighting & Engineering (in particular we are quoting here the issues from 2001). The literature reviews undertaken by the author are freely available upon request[1].

4. COLOUR LANGUAGE, SEMANTICS OF COLOUR AND ARCHITECTURAL LANGUAGE

While research on vision was solving the problems raised by the multiplicity of factors in retinal imaging, parallel research interests were attracted

[1] E-mail: luciaronchi@palenque.biz.

by internal representations of images. The key fact was their duplicity, as illustrated by the physiological model by Damasio and Damasio (1992). The former is the neural (non-language) representation for shape, colour, emotional effects, and interactions between body and environment. All of this occurs in both right and left hemispheres of the brain. The latter is language representation, the starting point of which involves only a few cells in the left hemisphere, and operates at brain levels where concepts are made and word forms are produced, which are higher functions than those of neural or non-language representation. Moreover, the "language of a scene", its summary and semantics may occur through successive fixations and through memory, in spite of its significant variability.

To employ some definitions, communication is the ability to use symbols for the purpose of exchange between persons, or to describe a perception to others. The contribution of language is of primary importance for the verbal description of colour appearance (Biggam,2012). Language implies various aspects of cognition, like meaning, memory and learning and the distinction between opposing pairs, including warm-cold. Linguistics deals with etymology and evolution of the terms for colour. Semantics is the study of how language conveys meaning. Colour is an element with its own language, which can be transmitted and taught in the collective imagination and cultural contexts. Colour semantics is the means by which language communicates types of visual impressions by describing and using everyday language or a scale of adjectives. Colour is a language, since it combines a number of cognitive functions, including meaning, learning, and memory. Colour language, which provides accurate and agreed upon information, is useful from both theoretical and practical standpoints. The observer deals with important information from: a) the distinct function; b) the symbolic function; c) the aesthetic function (Oberascher, Proc. AIC'82). Moreover, colour language has multiple roles since the possibilities for comparing information through colour with our spoken and written language are infinite (Hard, Proc. AIC' 82). Colour appearance as well as its related comparisons may be described with associative methods.

Colour vision has been evolving in parallel with language, with associative contact from time to time (Ronchi, 2013). The formal linkage probably occurred when colour language incorporated Hering's fundamentals, also considering some aspects of visual functionality, including colour opposition, which was associated with the retinal ganglion cells level in the fifties, but after the eighties, was considered to be localised to the higher centres.

In this way, we enter the field of environmental language, which for various reasons involves architects, in particular, because colour categorisation is inevitably linked to form categorisation. The intra categorical differentiation is very fine; however, sometimes it may be difficult to recall the names of very similar, hardly distinguishable, colours. In this case the name of the colour is replaced by a prototype colour of a similar and familiar object, observed or present in the environment.

Various authors agree that the environment may influence the semantics of colour when their description reflects the characteristics of a perceptual linguistic process. In the context of a complex and multidimensional real world, and the contextual elements coexist in the environment with the test object. Colour, climate, community, conjuncture, locality, as contextual elements, contribute to the sense of place through the physical environment, and life, soil, patterns of events, sense of time, habit experiences, colour identification and identity of the built environment, spirit of place, and harmony. In turn, after Newton (Proc. AIC 2001), colour as a language of place depends on a number of conceptual elements, palettes of events, communication, chromatic expressiveness, the linguistic world of semiotics. In addition, it has several components: the dimensions in visual space, syntax and construction, cognition and the importance of lighting. In turn, the development of "atmosphere" achieved by certain directions of illumination, based on theoretical models and connected with methods of the light-culture project, tradition and new cultural events, e.g. the Language of Arts (Bystryanseva, 2013).

According to Shchesetkov (2010) the Lighting Engineering Language faces unresolved problems of lighting science in the Light Design Arts. The palette of figurative and expressive terms extends, due to the specific nature of artificial and controlled illumination: its low intensity as compared to daylight, owing to various spectra, it is distinct from daylight, due to its kinetics and distribution in space. Following Habel and Zack (2012), Light Engineering has a great potential to improve the environment, not only in terms of visual perception, but also in terms improving general health and safety.

The architectural language is also considered as a sort of list of problems, which architects face every day. The architectural language and colours are main method for establishing a symbol system for the entire environment. Architectural colour language helps successful the cooperation between architects and consultants, insightful investigation into the psychological state of the user, understanding their emotional needs, and full integration into a specific building structure or landscape (Spillmann, AIC Proc.2008).

Colour may have indicative, symbolic, aesthetic function. Colour is one of the architectural means of shaping the environment, depending on the employed materials, other architectural elements, forms, structures, a purposely application of colour meaning of the world and the aesthetical sense. Colours are also the primary means for establishing a symbol system of the entire environment (Szep, Proc. AIC'82). The involvement of the architect is multifold and includes factors related to colour categorisation, and hence the semantics of colour. In addition, the meaning of the environment depends on the interpretation by the viewer as a physiological, psychological, social, and cultural contextualized space.

The involvement of architects was thus becoming clear. Various applications and modelling require an assessment of the quality of the environment. The mathematical assessment has been practically solved with the use of computers, by considering the architectural configuration, the details of facade structures, volumes, features, the distribution of colours and textures, in relation to chromatic contrast. But the visual quality has not yet reached an appropriate degree of definition.

At last, let us recall that Architectural Language was created to make use of the meaningful categorical colours through the SDS (Semantic Differential Scaling), and the principal quantified effects are along the following axes: warm-cold, dynamic – steady and tidy – untidy.

5. THE WARM – COLD COLOUR DISTINCTION

The important distinction between warm and cold, two sensations of colour appearance has been mentioned in passing, or even neglected, in the traditional text books on visual functionality, while it attracted the interest of Psychologists. The warm-cold dichotomy was conceived long ago, in the first millennium B.C. (Biggam, 2012) (Ronchi, 2014, Appendix). The labour intensive evolutionary sequence of colour categories culminated in the conclusion that the distinction between warm and cold colours constrains the trajectories or channels Sw=W, R, Y; Sc= G, B, Bl. These were standardised in 2010, after a long study into the evolutionary sequence of colour categories, as represented by categories and foci, where red and yellow are the warm primaries, green and blue the cold primaries, and white and black are separate (Biggam, 2012, p.75).

The literature on vision is rich in reports on this important topic; some of which are presented below. Sternheim and Boynton (1966) maintained that warm and cold are two adjectives characterised by different meanings, explained by the opposition in psychological temperature, but they do not exhibit physiological opposition. Therefore, they are only a composition. Boynton noted that the warm colours are brighter than the cold colours, and lie in different planes if the colour is presented as a solid. Sivik defined the warm-cold distinction as a robust cultural association, and wondered how to reconcile the definition of psychological temperature with the cognitive association (familiarity, memory).

Sunaga and Yamashita (Proc.AIC 2005) suggested that observers are capable of performing a spatiotemporal integration, based on memory, which generates a pleasant sensation about the test object, when the relationship between warm and cold colours approaches the golden ration. According to Nakamura (2005) we perceive the "atmosphere of the space" as warmer or colder, depending on the light-colour contrast.

5.1. THE COLOURIMETRIC COUNTERPART OF WARM-COLD FOR LIGHT SOURCES

The Correlated Colour Temperature (CCT) is defined as that of the blackbody (e.g. that of a fluorescent lamp of the same temperature), in given indoor conditions. When the CCT is high (e.g. 10,000 K), the chromaticity coordinates are x=0.330; y=0.320. When CCT is low, x=0.420; y=0.400.

As confirmed by authors like Nakamura (2005), a) people report a warm impression when the Colour Temperature is low, and report a cold impression when it is high; b) when describing the ambient atmosphere, both Colour Temperature and air temperature may be of influence.

Lighting and Engineering generally makes the distinction between warm, cold, and white sources. However, van Bommel (2005) demonstrated that some nuances of the "white lamps", that is cold-white and "warm white lamps", may create active or inactive (relaxing) atmosphere, respectively, through appropriate lighting design. It is a very interesting distinction.

We should not forget that the visual input into colorimetry is exclusively represented by the action spectra of retinal photoreceptors. What is subsequently created in the visual pathway cannot be measured by instruments. Van Bommel (2011) devoted an experiment to responses well beyond those, which can be explained by colorimetric involvement, like emotion, colour categorisation, colour meaning and lighting practice. He calculated the differences in the biological dose for the warm-white CFL incandescent substitute lamps and LEDs, and the biological dose for the white-cold CFL and LEDs, with a pronounced peak at 450 nm. No detrimental health effects were identified for Correlated Colour Temperatures between 2700 and 3000 K.

Some authors accept the colorimetric conceptualisation, which distinguishes the biological aspect in terms cold (active operation) and warm (recreation, relax). For instance, Habel and Zack are in favour of the CCT for the present and future Lighting Engineering. Others (e.g. Brainard and Provencio (2000), Rea (see Sliney, 2007)) maintain that the CCT should be re-defined, as it is not always a valuable biological and behavioural predictor.

5.2. THE PSYCHOLOGICAL COUNTERPART FOR SOURCES AND SURFACE COLOURS

The response to the assumed "psychological temperature", which is activated by the exposure to lighting and to surface colours, is widely described in the literature, and so a detailed report is not included in the present paper. Here we limit ourselves to mentioning, for instance, Nakamura's view (2005), that the colour temperature of indoor lighting is an important factor in pleasure and comfort perceived. However, much depends also on the interaction with air temperature; the climatic variable. In the case of surface colour, for example, Kobayashi and Suzuki (Proc.AIC'89) and Kobayashi et al. (1993) subdivided colour preferences into three groups of colour combinations: warm- cold, soft-hard and clear greys. Lee et al. (Proc. AIC 2003) related warm and cold to Hue.

The official rejection of psychological temperature was explained by Valberg (2005): that we are faced with a monotonous increase in sensation, but not with an antagonism, since there is no neutral point separating two opposing branches. However, supporters and opponents still coexist. Others, e.g. Saki et al. (Proc. AIC 2003), suggest a possible interaction between physiological and psychological effects.

To conclude, let us quote Bourbekri and Wank (2012) who investigated the role of all psychological factors, including mood and perception, in the cognitive performance of the occupants of an environment lit by a number of different spots of sunlight. The contributions of various inter-feature interactions were also considered, but the possibility of defining a comprehensive response has not identified. One of the reasons of this discouraging failure might be the large number of intervening factors, several of which are not quantifiable. Hopefully, the recent mathematics of complexity will find a solution.

5.3. THE PHYSIOLOGICAL COUNTERPARTS

Several experiments have been devoted to the search for physiological mechanisms responsible for the distinction between warm and cold colours. Some authors involved the retinal photoreceptors, more precisely the two overlapping systems of S- and L-, M cones feeding the Parvocellular system, which is in turn related to the response to shape and form. Others called into play the physiological antagonism at the level of retinal ganglion cells. The leading idea was that warmth implies a direction of excitation opposite to that of cold colours. But Valberg (2005) stressed that a specifically correlated excitation-inhibition does not exist in the retina. The precise location of mechanisms and systems actually correspondent to cold and warm colours is still expected to be found by neurophysiology.

Van Bommel (2005) considered the basic alternative represented by the photopic and mesopic spectral sensitivity functions. Rea (Ref. Sliney 2007) recalled that the circadian system has different spectral sensitivities for light sources with different spectral content. Boyce (2005) noted that for this reason it is difficult to artificially develop an efficient light source stimulating the rhythm of the circadian system. Sakai et al. (Proc. AIC 2003) considered the warm-cold opposition of surface colours, and noted that several responses may be used to make this distinction, by including perception time and the sense of elapsed time.

Without embarking on lengthy descriptions of interesting laboratory studies, one piece of research can be highlighted for its multidisciplinary flavour, going beyond the traditional boundaries of vision research. There are two kinds of internal representations of observed objects or scenes, which operate at two different levels in the brain, with the language representation operating on a higher level than the non-language one (for a review, see Ronchi (2013)). The possibility of their mutual interactions has not yet been fully explored. We wondered whether one or both representations were affected by the seismic shifts in visual modelling (section 2). Our summarised conclusion is that the problem has two faces: there is a link between the neural (non-language) and the language representations which exists in some cases, but not in others.

For example, the neural question of distinction between the unique and elemental Hering's colours does not affect the language representation because the semantics of colour operate at the level of categorisation, and red, yellow, green, blue are the primaries of the standardised warm and cold channels (Biggam, 2012). Also, the fact that the retinal ganglion cells cannot explain colour opposition is of no relevance for language representation, because the excitation-inhibition dichotomy is a generic property of the visual neural system; future research will surely discover its proper hierarchical location, as expected by the semanticists.

The physiological aspect which presents the link between the two types of representation involves some specific features of adaptation as well as the role played by the environment, which, in complex real or natural situations, has replaced daylight as the dominant influence (for a review, see Ronchi, 2014). It is widely known that the traditional research into vision first studied the (long term) transient light or dark adaptation, next the adaptation to contrast, to the spatial distribution, to texture, and so on. Moreover, various authors also assessed rapid adaptation; a change in sensitivity lasting a fraction of a second, responding to the onset or offset of adapting fields. A number of authors (Shapiro, 2003 with others like Mollon, Zaidi, Werner, Webster et al.) evaluated a large body of knowledge about adaptation and transferred it onto the complex environment, seen as a mosaic of small areas differing in size, colour, spectral reflectance and orientation. The main result was that the eye adapts to the dominant environmental structure, which is modulated spatio-temporally, on a fast time scale, resulting in a sort of compensation; i.e. even in apparently constant colour. In this way the link occurs at various levels, thanks to the contribution of the neural (non-language) representation to the language representation.

Architects are involved in the environmental response in a number of ways connected with colour categorisation, the semantics of colour, quality assessment of the environment. The mathematical assessment of quality has been practically solved using computers, by considering the architectural configuration, the facade structures, volumes, etc., the distribution of colour and texture in relation to the chromatic contrast. But the visual quality, based on the relationship between environment and colour language is not so simple. The first and second levels of rapid adaptation may act on the semantics of colour, if the description reflects the characteristics of the perceptual or linguistic process. It follows that colour appearance depends on the environment, and the warm-colour opposition represents a physiological conjunction. In fact, language concerns the differentiation between opposing pairs, including warm and cold colours. However, further experimental data are needed.

6. CONCLUDING REMARKS

The validity of the standardised channels, Sw (warm) and Sc (cold) is quite generic, ranging from spoken and written language (and various intermediary states), to the colour language of architecture and its allied disciplines. It has been confirmed that the warm primaries R and G occur more frequently than G and B ones (Ronchi, 2013, 2014), that is Sw/ Sc >1. In numerous cases we found that the ratio Sw/ Sc varies around a value of 1.62, the Golden Ration, which confirms work of previous authors interested in this "optimal" condition. Recently, around the turn of 2013/14, at least in Italy, and in particular in Florence, the warm-cold opposition, with highly saturated and brilliant colours, began to dominate images presented to the public in different circumstances. This has been observed on TV screens, on giant tourist information posters around the city, interiors with aggressive Sw painted walls, ceilings and floors and modest Sc in stores selling iPod or various types of portables computers, and so on, as well as numerous illustrations in recent expensive editions of books devoted to Florentine history. Some these cases could be regarded as a manifestation of a transient fashion, but the posters and books specifically evoke some perplexities. For decades the University has been studying the fidelity of colour reproduction in art materials. Now, the colours used are completely false. However, everything conforms closely to the standardisation of colour semantic channels. It is as if the architecture were experiencing a cyclical phase of development, like wearing a candid dress to the Parthenon and to the whole historical centre of Athens.

Lastly, it is pertinent to recall that language representation has not been affected by the tetonic shifts, which occurred in traditional modelling of colour vision, because the language operates at higher levels in the brain than the non-language representation, and therefore conflicts are avoided. Moreover, a favorable opposite effect occurred: a physiological link between non-language and language representation has been identified in rapid chromatic adaptation, which is not managed by the observer, but by the complex environment, which is now considered to be the driving factor, rather than daylight, because of a lack of apparent mechanisms needed for the assumed optimisation.

REFERENCES

1. (AIC Proc.year) – The proceedings of the dated AIC meeting are freely available at the AIC website <http: aic-colour.org/congr.htm>, section Congress.
2. Biggam C.P. The Semantics of Colour// Cambridge University Press, Philadelphia, 2012.
3. Boubekri M. and Wang N. Daylight's influence beyond our eyes: investigating the mediating role of mood in cognitive performance, sunlit workplaces//Light & Engineering. 2012, Vol.20, #4, pp.37–50.
4. Boyce P.R. The virtues and vices of daylight//Proc. 10 th LUX EUROPA, Berlin LTC. 2005, pp.125–128.
5. Brainard G.C. and Provencio J. Photoreception of the neurobehavioral effect of lighting in humans//Light& Engineering.2008, Vol.15, #1, pp.5–18.
6. Brill M. Talking about colour// Colour Res. & Appl. 1988.Vol.15,#1, pp.14–18.
7. Bustriantseva N. Development of the theory of the evening city light medium//Light& Engineering.2013, Vol.21, #2, pp.21–24.
8. Damasio A.R. and Damasio H. Brain and language// 1992, Scient. Amer.Vol.226, pp.63–80.
9. Habel J. and Zack P. The present and future of Lighting Engineering// Light & Engineering. 2012, Vol.20 #2, pp.5–11.
10. Mollon J.D. introduction: T. Young and trichromatic theory of colour vision//In: Normal and Defective Colour Vision. 2003. J.D.Mollom et al. (Eds), Oxford University Press, pp.XX- XXii.
11. Nakamura H. Effect of air temperature and colour temperature on atmosphere preference made by general lighting// Light & Engineering. 2005, Vol.13, #1, pp.77–84.
12. Ronchi L. Experimentation on Colour Vision. Psychophysival and Interacting with Colour Language//Giorgio Ronchi Foundation 2013. Vol. CXVII
13. Ronchi L. The Semantics of Colour Sharing the Laboratory with Colour Vision, II// Giorgio Ronchi Foundation. 2014, Vol. CXIX.
14. Shapiro A.G., Hood S.M. and Mollon J.D. Temporal frequency and contrast adaptation// In: Normal and Defective Colour Vision, J.D.Mollon et al. (Eds.) 2003. Oxford University Press, pp.138–141.
15. Shchepetkov N.J. Light and city: what is its initial for an architect and for architecture?// Light & Engineering. 2010, Vol.18, #1, pp.71–77.
16. Sliney D.H. Summary from CIE Expert Symposium on Light and Health in Sept. 2006, Canada// Light & Engineering.2007, Vol.15, #2, pp. 92–103.
17. Sternheim C. and Boynton R.M. Uniqueness and perceiced hues investigated with a continuous judgmental technique// J. Exptl.Psychology. 1996, Vol.72, pp.770–776.
18. Valberg A. Light, Vision, Colour// New York, Wiley, 2005.
19. Van Bommel W. Visual, biological and emotional aspects of light research. New findings and their meaning for lighting practice// Light Engineering. 2005, Vol.13, #3, pp.6–9.
20. Van Bommel W. Incandescent replacement lamp and health// Light & Engineering.2011, Vol.19, #1, pp.8–14.

Lucia R. Ronchi,
Prof., physics graduated from the University of Florence in 1948. Attained a Ph.D. in Physiological Optics in 1955. Since 1949, she experimented at the INO (National Institute of Optics, Florence) in Visual Science, Psychophysics, Electrophysiology, theoretical backgrounds. From 1983 to 1991, she was Director (DD6) of CIE Division 6, Photochemistry and Photobiology, visual and non visual effects of optical radiation. From 1993 to 1997, she was the President of AIC (International Colour Association). In 2011, JUDD/AIC Awarded. At present she is working in advanced Visual Science and its Applications

Light & Engineering
Vol. 23, No. 2, pp. 12-14, 2015

Svetotekhnika
No. 1, 2015, pp. 64-65

LIGHTING DESIGN FOR THE INDUSTRIAL SECTOR FOCUSED ON COMFORT AND HUMAN ASPECTS

Christian Mazzola

Gewiss S.p.A., Cenate Sotto (BG), Italy
E-mail: christian.mazzola@gewiss.com

ABSTRACT

One of the most perspective fields of the solid state lighting application is the industrial sector.

But innovative inculcation is impossible without corresponding publicity discussion and professional explaining of new technique preferences at available for consumer level.

There are some practical, based on experience advices, which are giving the right understanding of LED lighting accepting and its using.

Keywords: lighting design, industrial lighting, SSL lighting, energy saving, inculcation

The scenario of progressive CO_2 reduction for European countries involves an achievable first step by 2020 and a second one much more ambitious step by 2050, which requires a drastic CO_2 reduction of 80% compared to 1990 levels [1]. This target can be achieved through significant uptake of renewable energy sources, CO_2 capture systems and general energy saving.

Industrial lighting seems to be one of the most attractive fields of application for the following reasons:

1. The SSL penetration is still very low;
2. The working hours are usually much longer than in other application fields;
3. There is a big opportunity to enhance the utilization potential in comparison with technical features of the old technology: above all heat restrict and hemispherical emissions;

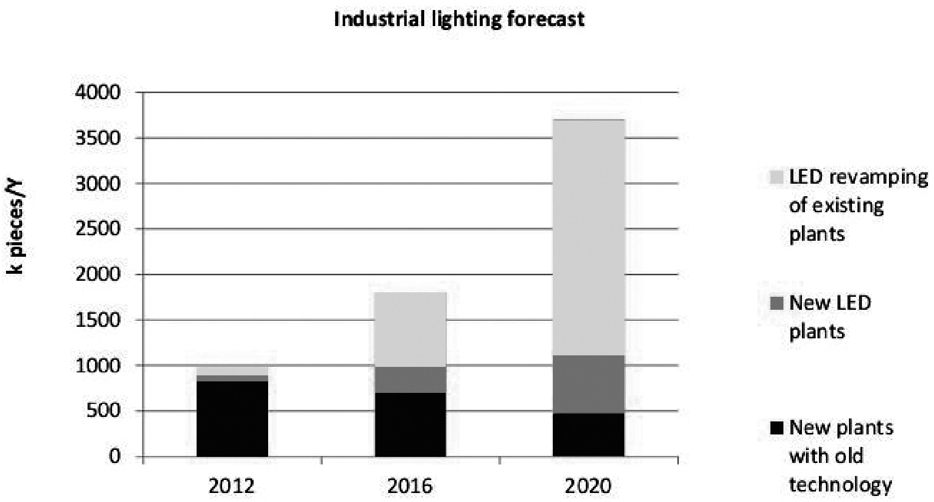


Fig. 1. Iindustrial lighting prediction

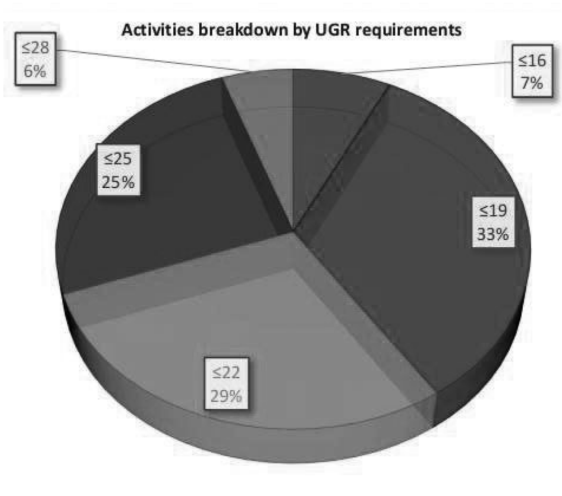


Fig.2. UGR requirements based on UNI EN 12464-1

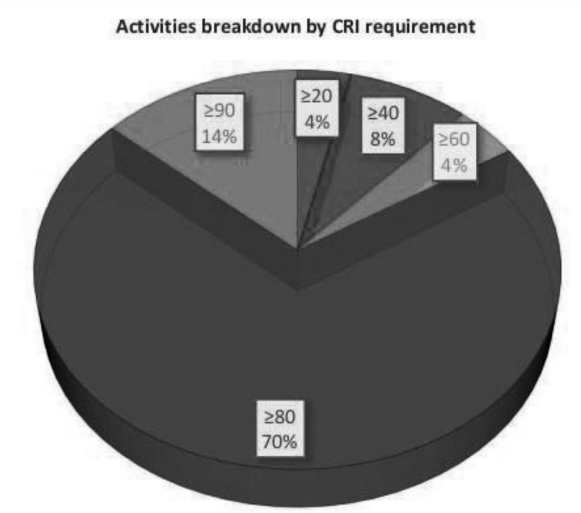


Fig.3. CRI requirements based on UNI EN 12464-1

4. There is an opportunity to improve overall working conditions thanks to better lighting equipment.

The reasons above explain the forecast for the development of the industrial lighting market in Italy [2] as shown in Fig. 1.

It should be noted that the opportunity lies not only in the simple comparison between performances of light sources, old and new; there are many clear benefits achievable from the enhancement of the whole value chain for the improvement process.

It is broadly accepted that people are the key factor for this process, which cannot be viewed independently from how it will be perceived by the end users (the visual task). From this point of view, it is necessary to pay attention to the following aspects:

1. New technology will usually be perceived as less comfortable than the old one. Moreover, a standard approach has not yet been defined for the evaluation of the effective glare level (UGR), which have to be reached for lighting plant conformity;

2. Existing plants are generally insufficiently lit, not just because the original project was wrong, but rather because the lumen maintenance is much lower than that used for the calculation: in some cases also below 35–40 %;

3. From the technical point of view, there is strong research to suggest that pursuit for economical sustainability and energy saving is tending to worsen the quality of light.

It is therefore crucial that the convincing process is done in a structured way, considering evaluation times and representativeness of the new plant.

Some rules of experience should be followed in order to encourage the right perception of the new technology's benefits and its acceptance:

1. To assure of those who will take the final decision, considering their needs, one has to focus on energy saving, quality of light, light management, flexibility, best efficiency and so on. Speaking about quality of light, highlight the improvement over the minimum level defined in the Standard UNI EN 12464–1 for the specific type of work activity. The minimum level must be considered not as a performance level, but as a requirement.

2. Even if the current Standard cannot be considered suitable for the evaluation of the UGR values required in accordance with UNI EN 12464–1, it is still true that fixtures with lower UGR values (calculated in accordance with CIE 177–1995) are perceived as more comfortable. Reduction in UGR provides better human centric lighting.

3. LED samples are much more expensive than samples of the old technology used to be. Nevertheless, a single installation cannot make clear the advantages of the new solution's benefits and can create a bad impression of the new product, which does not derive from the features, but rather from the side-by-side comparison of different lighting results within an area with the same visual task. Chapter 4.3 from UNI EN 12464–1 can be useful to identify the homogeneous area where a test can be performed.

4. It is helpful to run the test for a sufficient length of time. This will avoid the initial bad feedback that comes from viewing the fixture continuously when an unbiased impression cannot be made

for the first few days. Usually, 2 weeks are sufficient to focus on the lighting improvement within the visual task area.

If we look the activities mentioned in the Standard UNI EN 12464–1, Chapter 5, it is possible to note quite detailed attention paid to the low UGR requirements, even though it considers the whole internal lighting application field and not just industrial lighting, Fig. 2.

The focus on quality of light seems stronger looking at the activities breakdown by CRI requirements, Fig. 3.

Unfortunately, there is not the same determined approach regarding correlated colour temperature where only very few activities have a Tcc requirement; moreover it is often over 4000 K and without any relation to the circadian effects evaluation [3].

Even with fewer hours of exposure the street lighting application field has already started a process of sensitization about the quality of light, sometimes not homogenous, but which can be extended to industrial lighting in order to improve the revamping process.

Otherwise, there is the risk that this great opportunity fails to include the lighting design knowledge and experience, whilst being focused too much on energy saving aspects, which are the reasons for the opportunity but not the sole way to realise it.

REFERENCES:

1. *Verso un'Italia low carbon: Sistema energetico, occupazione ed investimenti. Executive summary.* Rapporto Energia e Ambiente, Scenari e Strategie, ENEA, 2013.

2. *Based on Lighting the way: Perspectives on the global lighting market*, second edition, McKinsey&Company, 2012.

3. *See also the research A proposal of a simplified model to evaluate circadian effects of light sources*, L. Bellia and M. Seraceni, Lighting Research and Technology published online 13 June 2013.

Christian Mazzola,
an engineer. For more than 13 years in the Lighting sector in GEWISS, as the Lighting Manager in the Lighting Division, which is part of the Research & Development. In the last years has developed an in-depth knowledge in LED technology and its applications, especially in the Public and Industrial Lighting sector, understanding and suggesting optimal solutions of the product integrated with the needs of energy saving, quality and lighting management. Mr. Mazzola participates actively in the technical promotion of the new products launched by GEWISS, as a speaker at institutional and association conferences and providing support to our Commercial sector with their most important clients. From 2008 he represents GEWISS in ASSIL - (Association of Italian Lighting Manufactures) participating in technical groups and also on the market

Light & Engineering
Vol. 23, No. 2, pp. 15-23, 2015

Svetotekhnika
No. 2, 2015, pp. 11-15

ILLUMINATION OF NEW PEDESTRIAN STREETS OF MOSCOW

Grigory S. Matovnikov and Nikolai I. Shchepetkov

MArhI (SA), Moscow
E-mail: n_shchepetkov@inbox.ru

ABSTRACT

The article describes illumination level evaluations performed in 2012–2014 and municipal improvement to new pedestrian streets of Moscow. The following pedestrian areas were considered: "Tverskoi district", "Zamoskvorechye"" and "Crymskaya embankment", as well as some adjoining areas. Based on the performed natural measurements of lighting parameters and on evaluation of the quality of the light medium, conclusions are made about the results of implementing the city's programme of pedestrian areas' development.

Keywords: light medium, pedestrian spaces, lighting characteristics

In 2011, Mosow's new government embarked on a development programme for 2012–2016 of investment and improvement of the city for tourists, as well as creating a comfortable urban space [1]. Among major priority tasks, the development of the pedestrian system was undertaken: this included the improvement and reconstruction of streets and embankments in the historical city centre, creation of new pedestrian and bicycle routes, as well as improved convenience of pedestrian walkways along selected streets. Among the important parameters of comfort and aesthetic attractiveness of the city is the development of high quality street illumination, which should be in a harmony with the architectural illumination of facades and advertising light information. This approach was stated in the design concept approved in 2008 [2]. In this context, it should be remembered that the Arbat – the first pedestrian street in the city – first appeared in 1982 and its comprehensive construction is not yet completed [3]. This street gave birth to the famous metaphor "Arbat is covered in lanterns", which is an untranslatable wordplay and means in Russian to be flabbergasted.

The implementation of the new development projects in 2011–2014 mustered considerable interest in the professional community and amongst Moscow's citizens about the quality of the city medium and baseline conditions for life and development in the city. Unfortunately, this increased attention led to relatively primitive artificial illumination solutions. The architectural and light medium created on these streets was overwhelmingly mediocre in quality. It cannot take a turn for the better without a fundamental revision of the design technique and implementation.

During different seasons of year, more than 12 km of the 15 km of "new pedestrian areas" were examined for this study. Visual evaluation and photo recording, as well as measurements of lighting parameters in the evening (illuminances E_h, E_v, E_{sc} and $E_{4\pi}$[1]) were taken. Luminance was measured using the *LMK Mobile Advanced* luminance meter. The researched sites were parts of three large-scale pedestrian areas: 1) Tverskoi district, which was created in 2011–2013. Its expansion and reconstruction continues; 2) Zamoskvorechye (2012–2014); 3) embankments of Moskva River from Vorobyevy Gory to Krymskaya embankment. This work began

[1] Here h is horizontal, v is vertical, sc is semi cylindrical, and 4π is spherical. E_{sc} and $E_{4\pi}$ were determined as an average of E_v and (E_v+E_h) in mutually perpendicular planes at eye level. These were measured by luxmeter TKA-PKM 31.

in 2009 with a rebranding and reconstruction Gorky Park. Krymskaya embankment was transformed into a pedestrian area in 2013, and work at Vorobevy gory embankment is ongoing.

Unlike the programme's vision of creating a united system of pedestrian routes at the centre of Moscow, the nature of the researched areas is more fragmentary and insufficiently connected. Obviously, they were not envisaged as a uniform urban system at the concept level. They were developed under separate projects by different design teams without a single unifying expert or clear management. Instead of a well-thought-out hierarchical zoning of pedestrian routes with due regard for the specific conceptual character of each, more than 50 sites were separately selected for reconstruction. Their length was about 27 km [4]. Within the declared programme, the sites were arranged as independent pedestrian areas; this meant that none of them, with the exception of the Moskva River embankment, were able to function as fully pedestrian's streets with complementary features: recreational space, day and night time entertainment space, a tourist attraction and concentration of city street life.

A general quality evaluation of the former transport and pedestrian street and square transformation in Moscow into functional pedestrian's area, has revealed many systematic conceptual design errors, exacerbated by ineffectual project tender management. The implemented solutions in paving, gardening, "furnishing ", etc. are primitively but far from cheap. These are as follows: granite paving plates, borders and hawkers stands, flower beds and curbstones, retro lanterns of cast iron, identical, indifferently placed, with out-of-date, inefficient and blinding optics, with no regard for the contextual environment and without a support of total look façade wall lamps etc. There are practically no individually picked out small architectural forms, not to mention artistic sculptures, monuments or light forms to give a special charm and a "spirit of the place" (if such there is) to each medium's micro-ensemble, especially in the complex multilayered medium of the ancient centre of Moscow. In many cases, a rather intensive pedestrian transit flow is not structured and not directed. It is chaotically distributed over the whole width of the street. The greatest success is achieved in attracting townspeople and in arranging informal leisure in the warm seasons, using little tables placed in streets and on summer verandas of restaurants and cafes, especially in the Kamergersky by-street and in street Rozhdestvenka. Moreover, each project was highly specialized and divided: paving was completed by one supplier, lanterns – by another, nobody seemed to engage with facades as a complete, connected system, including facade illumination, as well as visual information. The low quality of the result illustrates this. From an architectural point of view, the light medium of the investigated streets is formed in an "every man for himself" manner. As an example of this absurdity: walking from Gogol boulevard to Zamoskvorechye pedestrian area, counts no fewer than nine various forms and types of street illumination solutions of varying degrees of pompousness and historical authenticity. A pleasant exception is the Krymskaya embankment, where some coordination of architectural and light solutions was achieved.

Creative applications of light design theory for the city medium engages many designers because artificial illumination is one of the most powerful and flexible means of positive transformation of a city medium, especially in pedestrian spaces. This is a topical issue in all cities of the world, and an increasing attention is paid to it in developed countries. There is little scientific research into the quality of this medium. As part of the research process, the following parameters were determined: 1) correspondence to the accepted illumination standards (based on luxmeter readings); 2) subjective estimation of the space light saturation; 3) light-simulating effect of illumination using the human face and sphere model example; 4) evaluation of the luminance composition (based on luminance meter indications).

Tverskoi district from street Tverskaya along Kamergersky by-street and along street Kuznetsky Most to street Rozhdestvenka is illuminated using monotonous methods and facilities by means of street lamps with long poles 3.5 m height. The E_h values at the road surface are 4–11 lx. E_{sc} at eye level ranges from 11 to 53 lx, and illumination contrast (E_h/E_{sc}) amounts to 0.21 – 0.36 (on the average 0.28), whereas it should be 0.8–1.3 [5]. These indications and visual impressions characterise illumination in the street space as intensive enough near lighting supports but as arbitrary non-uniform, with a weak light-simulating effect, which does not provide high quality visual perception. Luminous flux direction is lateral (from the street lanterns), because the peripheral light of shop display windows and facades is weak and disordered; it can be characterised on a person face as unidirectional lateral. In some areas, it creates considerable luminance contrasts (20:1) at the average luminance of a face of 4 cd/m^2. In general, in the street space with dominating street illumination, the lanterns have not formed a harmoniously modulated, expressive, "animated" architectural light space (Fig. 1)[2]. It is only created by pools of "house" light of street fragments of cafes and restaurants in summer time in Kamergersky by-street and in Rozhdestvenka street. The light medium is damaged by the poor-quality illumination of randomly selected facades, which gives evidence of an absence of a uniform concept of the light ensemble, or about inability to form it. The implemented light-design solution does not invite discussion of a perceived street space at all: less than 30 % of the road surface is illuminated brightly enough, mostly there is no architectural illumination on the building facades. As for the street illumination, it simply does not reach the facades.

Certainly, even this light medium solution is better than what it was previously: loaded with vehicles and poorly illuminated. But has the rush for implementation and beautiful reporting been worth the cost?

In various points of the created light space of Kuznetsky most and Rozhdestvenka streets, white mask luminance measurements with $\rho = 0.8$ (models of a human face with reflection factor $\rho = 0.45–0.6$) as the major distinction object, were made within the pedestrian area. Their average values lie between 5.5–13 cd/m^2 depending on the closeness to a street lantern, i.e. the face of a person has an average luminance within interval 3–10 cd/m^2. Such values give evidence that the system of artificial illumination even in the historical centre of the capital city only provides pedestrians with the twilight levels with a distortion (in comparison with daytime) of colour perception (skin, hair, make-up, clothes colours change) [6]. If in addition to take into consideration a non-perfect spectral composition used in the light source environment, as well as the weak light-simulating effect of illumination systems (human faces seem to be plain), a question for future researches and illumination rationing in brisk pedestrian areas of a city arises: whether these conditions are good enough for visual perception. It is difficult to find evidence of the "comprehensive creation of a uniform light and colour medium" in the capital's centre. Our research in Tverskoi district and in others did not include an evaluation of light design solutions, because we could not examine them, but according to some information from the designers, implementation of the projects has little in common with their initial intentions. One of the reasons of some unsuccessful light design solutions was that it was impossible to defend their creative ideas and another was external limitations, which constricted their actions. Today, it is impossible to determine, which disadvantages are a result of the actions of designers, and which stem from the electricians, equipment suppliers and customers of the work.

Fig. 1. Kuznetsky most street, a view downwards from Rozhdestvenka street. Lanterns are blinding because with the dark facades and a wide street, their light is insufficient, and shop display windows are few. The light of the lanterns has a certain light-simulating effect (lateral light) estimated using the white mask and the sphere

Bitterness towards the low quality of the results when there were so many opportunities is felt not only by the project authors, but also by numerous consumers, probably without even realizing it.

Maroseika street reconstructed for the convenience of pedestrians, almost adjoins to the Tverskoi district. The main result, as well as in Bolshaya Dmitrovka street, was the enlargement of the sidewalks and narrowing of the traffic way from four to two lanes. This characterise these streets as mainly pedestrian, with limited possibility of vehicle traffic. This type of streets has a sidewalk, which is wider or

[2] Fig. 1–7 are photos of G. Matovnikov, and Fig. 8 is photo of N. Shchepetkov

Fig. 2. Maroseika street. Dominating lantern light from the top forms shadows, however the feeling of a major light ensemble is not created

equal to the traffic way. In addition, the illumination and the improvement are performed so as to improve the comfort and ease of pedestrian movement. Along Maroseyka street, general (utilitarian) illumination is provided by retro lanterns more than 6 m high located at 0.5 m from the traffic way on the sidewalks, spaced at 22 m. This solution does not correspond to either human scale or street scale, and primitive lantern optics together with powerful light-emitting diode light sources leads to a blinding effect. It is unlikely to be pleasant for residents of Maroseyka street, of which there are few nowadays. The street space is sufficiently saturated with light: E_{sc} at eye level is on the average equal to 24 lx. A light composition of the building front is not created: some buildings are illuminated architecturally, and some are illuminated disorderly with street lanterns only. And average luminance of building facades amounts to 4–50 cd/m^2, whereas luminance of a person's face on the average is 6 cd/m^2 (Fig. 2).

It is a paradox that quality of the created architectural light medium of Maroseyka street is as low, as in the examples described above, but for other reasons. We are beginning to speculate that the customer (the Mayor's office) realises the unsatisfactory results of the performed work and is trying to correct this somehow: either by installing lanterns lower (for easy servicing), or to install them at second floor level (the bulbs will be changed using customised vehicles). There are plenty more streets, which can be reconstructed by means of the trial and error method to find an optimal street lantern height. Isn't it an "innovative" method of designing street illumination in a new type of city space?

Some streets and by-streets in Zamoskvorechye pedestrian area allow entering vehicles, and therefore the lampposts are not located along the centre of the street. Besides, these streets have a different building nature: for example, on the one side of a street, there are buildings with cafes and restaurants on the ground floor, on the other side, a church fencing and a yard with trees and shrubs are situated. So, the illumination solutions usually have an asymmetrical nature. In Klimentovsky by-street, two-plafond lanterns with HPSLs are installed in a chess-board formation on different sides of the by-street and they are oriented along it, which is visually favourable for a powerful pedestrian flow towards the underground station. Due to an optimal location height (≈ 6 m), E_v values have a good distribution uniformity: from 20 lx directly near a lantern to 10 lx on the opposite side of the street. Such a distribution is also typical for $E_{h.}$ Its average value and E_v/E_h (≈ 0.3) relation are within the standard [7]. E_{sc} values are somewhat lower, on average they are equal to 6–18 lx, which is to a large extent because of a monotonous nature of the street lantern light distribution not supported by architectural and shop display window illumination (Fig. 3). White mask luminance measurements have showed that this changes slightly depending on the location in light field: average luminance near a lantern is 6 cd/m^2, and between lanterns it is 4 cd/m^2. Disadvantages of this light medium are typical problems of illumination using devices with HPSL: a low quality of colour rendition and low indicators of the illumination simulating effect (0.35–0.7). Nevertheless, due to highly located luminaires and to shop display window illumination situated here and there, the visual medium forms a uniform architectural light space. It cannot be named multifarious and does not have strongly marked dominants. More likely it can be called neutral. As well as street furniture, it performs its own function providing an acceptable comfort level, but does not have an imaginative individuality. The improvement and illumination do not interact with remarkable objects located on the site: a public garden and a church. The baroque church of St. Clement is practically not illuminated, except for several searchlights near the entrance, whilst the public garden nearby is illu-

Fig.3. Klimentovsky by-street. Shadow forming during winter period

Fig. 4. Ordynsky cul-de-sac. An uneven light distribution, "footlights effect" with snow, a bad shadow forming effect and an unsettling atmosphere

minated excessively. Along its perimeter, ten street lanterns of reflected light with MHLs are installed. Because of the perimeter location of the luminaires, a "stadium" space perception is created, which is not peculiar for by-streets. Improvement and illumination of the square in front of the metro station pavilion, Tretyakovskaya underground station, face the same problems. The searchlights installed on supports opposite to the exit, blind people leaving the underground. According to the design solution, these five supports (masts) with four MHL searchlights on each should illuminate the facades of the buildings located on the opposite side, but after installation they were directed on the square under them. Due to such a "generous" solution, E_h on the benches under the supports reaches 824 lx. Naturally, as R. Narboni wrote concerning this situation, such a bright light will frighten people off: during the measurements and photo recording, nobody could sit down in these places [8].

Except Klimentovsky, B.Tolmachevsky and Lavrushinsky by-streets illuminated as described above with an asymmetrical lantern location, Zamoskvorechye pedestrian area also includes Ordynsky tupik (cul-de-sac) illuminated unusually. Here design solutions provided for use of light bollards to illuminate pathways, and luminaires to illuminate greenery and flower beds in the public garden near the temple in the name of "Joy of all who Sorrow". But these solutions were violated as well. Bollards were only installed shining on the sidewalk and on the bush behind it. As a result, their light is insufficient. The site in front of B. Tolmachevsky and Lavrushinsky by-streets also faces the above described illumination problem. From both sides, the site is framed with a building edge, but because of an inconsistency among the Moscow government departments, illumination designers appeared to be under extremely limited conditions. Facade wall lamps or suspended luminaires appropriate for such a narrow small street were for some reason forbidden. Installation of street lanterns with foundations was impossible because of an underground station located beneath. This led to an extremely unsuccessful solution: to illuminate this site with high bollards. As a result, the cul-de-sac became a real gorge with a barely illuminated road surface and dark, hanging walls of the houses (Fig. 4). The measurements confirmed a discrepancy of such a solution to the illumination tasks of the pedestrian street. Non-uniformity of E_{h} distribution is almost twice higher than the acceptable minimum, and illumination simulating effect at contrast values from 0.18 to 0.33, is practically absent. E_{sc} changes within unacceptably wide limits: from 18 lx along the street center line to 4 lx in the area of intensive pedestrian movement near the building facades. Luminance of the specified mask near a light source on the average amounts to 3 cd/m^2, and between two sources it is equal to

Fig. 5. Pyatnitskaya street, the light ensemble has not taken place yet, but there is a dominant. Illumination is insufficient, light-simulating effect is weak (illumination is not counted)

1 cd/m^2, i.e. face of a person, which is between two bollards, cannot be practically seen. Because of the low location of the light sources, a "dramatic" illumination with an inverse shade direction arises, which leads to problems in recognition and in reading emotions from the faces of the pedestrians. As a whole, one can characterise the light-design solution of the cul-de-sac as extremely unsuccessful. During snow, the visual situation becomes somewhat better.

In 2014, Pyatnitskaya street was included into Zamoskvorechye pedestrian area composition. Its illumination is achieved using two-side lanterns with a height asymmetry: one illuminates the road from 4.5 m height, and another illuminates the sidewalk from 3 m height. The lanterns with light-emitting diode sources installed at a 21 m step, arranged in a chess-board fashion (for the greater illumination uniformity). They don't provides sufficient illumination: E_{sc} on the average amounts to 9 lx, and E_h is 8 lx. Luminance of a person's face, as well as in Maroseika street is near 6 cd/m^2. Architectural and street illuminations aren't coordinated, the building front consists of buildings illuminated randomly (Fig. 5).

Krymskaya embankment represents another type of pedestrian space combining properties of a street and a park. As envisioned by the government of Moscow, Krymskaya embankment will continue the recreational area on the southern bank of Moskva River spreading from Vorobyevy Gory to Bolotny Island. At present, this area is divided into four sites, the boundaries of which are marked with bridges: Vorobyevy Gory, Neskuchny Sad, Gorky Park and Krymskaya embankment. In 2013 Krymskaya embankment site was attached to this recreational area released from car traffic. It extends to the Central Art House (CAH) and Muzeon Park area. Therefore, a uniform pedestrian space was formed. Due to the interest of Muzeon joint-stock Company in the high quality of the space being created, in the freedom of limitations of architectural heritage protection or fire safety, and due to a general "image-focused" nature of the project, a high level of design solution coordination between the general designer (MAHPI), the designer *(Wowhouse* bureau) and subcontractors, including light designers (*V-art* bureau) was reached.

The improvement materials and the installed equipment show the demonstrative nature of the project: various granite pavings, improvement elements made according to individual projects, lighting devices from leading European manufacturers: *Iguzzini* and *Traddel*.

The embankment space is arranged to meet its main functions: sports-transit (Moscow's longest bicycle route goes along the embankment), recreational (the embankment is linked with the CAH courtyard, Muzeon park and Gorky park) and public space (summer grandstands for meetings). The space zoning is performed using various textures and paving materials, which visually and texturally separate slow walk areas from bicycle areas and from active rest areas. There are other space zoning methods here: gardening islands of various kinds, geoplastic forms on the relief (rampants, breast walls, ladders), various thematic pavilions and small architectural forms. Opposite to the CAH building, a regular small park is planted. Closer to Muzeon, flower beds and green sites have a freer configuration. The zoning and scaling of the medium are also reflected in the light design: walking and transit areas are illuminated using modern lanterns with light emitting diode two-plafond luminaires installed at different heights: about 6 m for bicycle track and about 4.5 m for pedestrians. The embankment area adjoining the walking and transit areas is solved in a more chamber style: it is illuminated with bollards adjacent to the granite parapet of the embankment and with luminaires built in the breast and decorative walls. They form a more comfortable, "microscale" light space. The design solutions and applied

Fig. 6. Krymskaya embankment. Light design during different seasons at different points

equipment form a high quality light medium. For example, average luminance of the mask almost does not change depending on its position near a lantern or between them, and amounts to 6–7 cd/m^2. The illumination has a good simulating effect: E_{sc}, contrast E_h/E_{sc} and levels of E_h uniformity distribution in most cases are within the recommended limits. Illumination of green and recreation areas has a freer, playful nature. Decorative illumination of trees and flower beds is widely applied using ground and above-ground luminaires. Benches and deckchairs are illuminated with lanterns creating soft shadows.

Due to various and inventive solutions of the improvement, design and light design in the Krymskaya embankment area, an interesting architectural-light medium is created here. It has a remarkable nature and individuality. For the first time in Moscow, park benches with a "built-in light" are designed in the public space under the Krymsky Bridge. Unfortunately, they have already suffered vandalism. A certain "image" effect is reached, which shows that Moscow customers, designers and suppliers are in fact capable of creating a city medium attractive for pedestrians and modern in its aesthetics whilst meeting world quality standards (Fig. 6). Confirmation of this is the growing popularity of the Krymskaya embankment and recreational area on southern bank of Moskva River as places where Muscovites choose to rest during the day and in the evening, in winter and in summer.

At present, illumination of Vorobyovy Gory, the final fragment of the Moskva River embankment ensemble, continue. For the time being, the object is not officially complete, but since autumn of 2014, it practically functions in its new image. At the first stage of the investigation, we observed a universal replacement of obsolete yellow HPSL street lanterns with light emitting diode white light lanterns. In addition to the delayed economic benefit, the quality of the light medium is improved, which is noticeable at once. In some places dubious light-design solutions can be observed: absence of a personalised illumination of some pedestrian sites of the embankment, which are separated from the parallel illuminated traffic way with a dense gardening strip. Elsewhere the territory is not ready for analysis. It would be desirable that the ladder light forms (ways to water), which arose already in 2012, obtain a constant place and a style support in other light forms and in street furniture of the park (Fig. 7).

Based on results from all of the investigated areas, a conclusion can be drawn that in spite of the declarative uniform approach stated in the governmental decree, each pedestrian area was redesigned separately, exists autonomously and can be referred to a certain uniform assemblage only by its functional criteria. Levels of design, building and light design solutions and hence the quality of the medium vary greatly in each of these areas. However, there are negative characteristics specific to the areas, for example, their urbanistic locality: none of these areas provide a complete walking route uniform by image and content, at least between several significant landmarks, because these routes are interrupted by traffic streets and do not have an ensemble atmosphere, a "spirit of the place" [9]. Even in the case of the

Fig. 7. Vorobyovy Gory. Elements of light design of the pedestrian embankment

Fig. 8. St.-Petersburg. A pedestrian area (boulevard) in Malaya Konyushennaya street

Krymskaya embankment, the route is cut a wide traffic way, and a pedestrian needs good knowledge of the territory to know a fast way to the Zamoskvorechye pedestrian area located less than one kilometer away. Reconstruction of the existing pedestrian infrastructure, equipping it with modern facilities of vertical communications for limited mobility population groups (overground and underground passages with lifts, escalators, ramps etc.) and modern system of visual navigation, including the light navigation, would be a big step towards increased a connectivity of the pedestrian areas system, especially in the evening. One more fundamental problem of the pedestrian area located in the historical building territory, is the integrated approach to solving all questions of reconstruction, improvement, illumination etc. Light design of a city medium is working not only with the "floor" and the "walls" of city streets, but also the formation of necessary light-space characteristics for visual comfort and optimum structure of light field for pedestrians. However, financial and design questions of street, architectural and advertising illumination, as well as of improvement and reconstruction are separated. As a result, creative attempts of the most experienced light designers face insurmountable bureaucratic barriers, and so not the most successful solutions appear.

It seems that our light designers, either due to ignorance or by necessity, reinvent the wheel every time, constantly stepping on a rake. Globally, a crucial and varied experience of city illumination of pedestrian areas is being accumulated. The historical centres of many European cities, especially those which underwent significant post-war reconstruction (Vienna, Cologne, Bonn, Aachen, Jerusalem, etc.), are pedestrian to a great extent. In others cities (London, Berlin, Paris, Lyons), pedestrians have a full priority even in the streets with traffic lights, [10]. We have our own mentality: posh owners of magnificent shops easily drive along stone blocks of the pedestrianized Stoleshnikov by-street or along the granite plates of Kuznetsky most street with their big cars. Probably, it is the same mentality which does not allow officials to apply rational illumination methods to the projects (for example, wall luminaires on building facades). Comparatively narrow streets in the historical building areas of major cities are in many cases illuminated with intensive light from shop display windows and interiors of shops and restaurants (at the buildings' ground floors) and with the lit signboards of these public places. Utilitarian street luminaires such as wall luminaires or standing lamps as necessary elements of the city's engineering infrastructure exist in these streets, but they do not play a key role in the saturation of street spaces with light, only compensating the frequent local dips in illuminance level. There are support luminaires, especially along traffic streets in the centre of Rome and Paris, but they are spread out on a par with facade cantilever, or less often, with hawser suspended luminaires.

In general, wall luminaires, (sconces), are a historic archetype, which disappeared from the domestic street lighting in the 20th century. Between two ages, we (the workshop of architectural illumination "Mosproekt-3") introduced them back into the practice of Moscow's practice of the architectural illumination. Unfortunately, this trend has had no developments, even in cases where it is the obviously needed, for example in the Ordynsky cul-de-sac or in Rozhdestvenka, Maroseika, Bolshaya Dmitrovka and others comparatively narrow and densely built up streets, where a limited free space is blocked up with supports of street lanterns.

Nevertheless, there are successful examples of the light design of pedestrian spaces in domestic practice, including a complex historical medium. This entails in particular, St-Petersburg, where it was possible in-house, without external specialists, to create attractive examples of street illumination and improvement of several pedestrian streets in the historical centre (Fig. 8). Without competing with Moscow by scale of the performed programme, these examples win by a considerable margin in their design solutions and level of implementation. Certainly, St.-Peterburg remains the most European style city of Russia by the quality of its city medium today as well as 300 years ago.

REFERENCES

1. The State program of Moscow city "Town-building policy" for 2012–2016. URL: http://stroi.mos.ru/ (addressing date: 01.02.2015).

2. The Governmental decree of Moscow "On the Concept of a uniform light-and-colour medium of Moscow city (with the changes of the 9 th August, 2011)", of the 11 th November, 2008 № 1037-ПП.

3. The report "Basic provisions (concepts) of development of the historical core of the centre, formation of pedestrian streets and areas" at the 6 th session of the Moscow City council of People's Deputies of the 20 th convocation, 1988

4. The Governmental decree of Moscow "On pedestrian areas of the city value of Moscow city", of 13.09.2013. 606-ПП.

5. *Shchepetkov N.I.* City light design. Moscow: Architecture-C, 2006, 320 p.

6. Reference book on light engineering / Under the editorship of Yu.B.Aizenberg. The third revised edition. Moscow: Znak, 2006, 972 p.

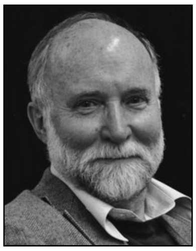
7. Building regulation 52.13330.2011. "Natural and artificial illumination". Actualized edition of the Building regulation 23–05–95*. Introduction date: the 20 th May, 2011.

8. *Narboni R*. La lumière urbaine: éclairer les espaces publics. Paris: Le Moniteur, 1995.

9. *Glazychev V.L, Egorov M. M, Ilyina T.V., et al.* City medium. Technology of development: Table-book / Under editorship of *V.L.Glazychev*. Moscow: Ladya, 1995, 240 p.

10. *Gale. Ya.* Cities for people. Moscow: Alpina Publisher, 2012, 277 p.

Grigory S. Matovnikov,
an architect. Graduated from the MArhI (SA) in 2012. A post-graduate student of the Chair "Architectural physics" of the MArhI (SA)



Nikolai I. Shchepetkov,
Dr.of architecture, graduated from *MArhI* in 1965. At present he is Chief of the "Architecture physics" *MArhI* Chair, professor of the Moscow Architect Institute (State Academy), laureate of the State Premium for Moscow architecture illumination, member of "Light & Engineering" editor board

Light & Engineering
Vol. 23, No. 2, pp. 24-26, 2015

Svetotekhnika
No. 2, 2015, pp. 18-20

LANDSCAPE ILLUMINATION OF THE ALEKSANDROVSKY GARDEN, MOSCOW

Sergei V. Chuvikin[1]

GRIVEN Russia, Moscow
E-mail: sergey@griven-russia.com

ABSTRACT

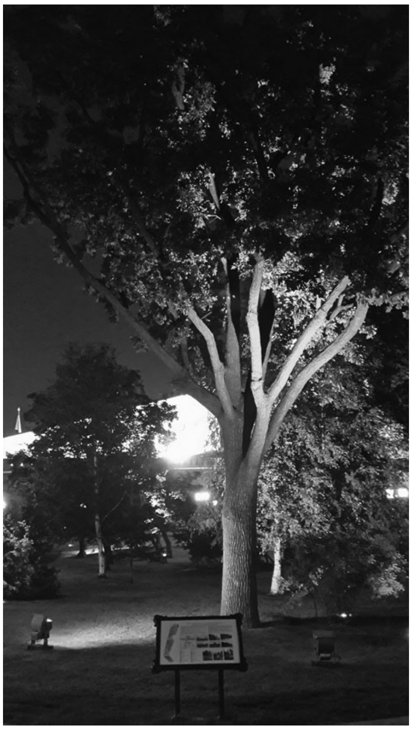
The article provides a brief history of the creation of the Aleksandrovsky garden in Moscow and on the plan of its recent large scale rearrangement. In particular, attention is given to the rearrangement of landscape illumination of the top and middle gardens. The work was performed within construction and mounting operations including architectural and art illumination of the buildings located in the designated "Protected area round the Kremlin". Illumination of the small natural features was achieved using advanced technologies developed by *GRIVEN* Company. Special attention was given to an original illumination concept proposed by specialists from Svetoproekt Company.

Keywords: light emitting diodes, MHL, colour changers, optics, light point, control system, light, *RGBW*, power

[1] The pictures of E. Kiryushina.

A BRIEF HISTORICAL BACKGROUND

The Aleksandrovsky garden is located behind the Iversky gate, a slope of Borovitsky hill and lines up the western wall of the Kremlin from Revolution square to the Kremlin embankment. Previously, the river Neglinka ran here; later a ditch was dug out from the Red square, connecting the Neglinka with the Moskva River. Thus, the Kremlin was surrounded by water from the all sides, and in ancient times it was an unassailable fortress. However in due course, the bank began to fall and overgrow, household constructions appeared, and all of this took away much of the scenery. Therefore, when restorations of Moscow began after the Patriotic war of 1812, the ditch was filled up, and the river Neglinka was ducted away. In the 1820^{s}, Emperor Alexander I ordered gardens to be made at this place. An outstanding Russian architect Osip Ivanovitch Bove, who was appointed the main architect of the Moscow Res-



toration Commission after the fire of 1812, supervised the recovery work.

Bove conceived the Kremlin garden as a park, in which a strict axial layout was combined with winding paths, picturesquely grouped by flowerbeds and bushes, romantic ruins and architecture of small forms. The ground was leveled and covered with turf. The best gardeners were invited for the garden to be arranged. Various kinds of trees and bushes were planted.

Bove designed the main entrance to the garden from Voskresensky square, and so the Kremlin garden was connected with Teatralnaya square.

The dynamical space of the garden going along the Kremlin wall was not closed: from the opposite side, behind Borovitsky gate, it had an exit towards a thoroughfare along the Moskva River and was connected with the greenery of the boulevards surrounding the walls of the Kremlin.

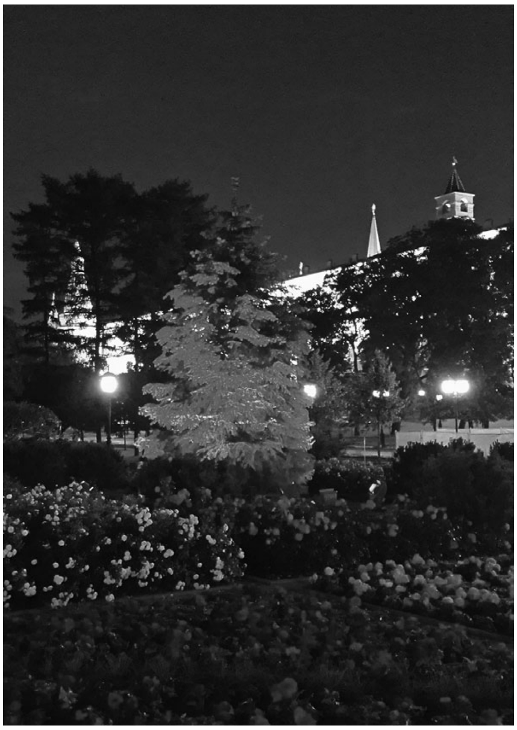
The garden was of a great importance in the creation of Moscow's central ensemble. As a part of the boulevard green belt, which arose in the early 1820^s around the Kremlin walls, the garden promoted a spatial unification of the territories around the Kremlin and its connection with the surrounding city.

Aleksandrovsky garden did not get its name straight away. Originally its name was the Kremlin gardens, which only became Aleksandrovsky since 1856, after the ascension of Alexander II. Earlier, people referred to "gardens", because the Aleksandrovsky garden consists of three gardens conceived in a uniform landscape planning style. The Top garden, 350 m in length, extends from Revolution square to Troitsky gate and was opened for the very first in the 1821. The Middle garden has length of 382 m and goes from Troitsky to Borovitsky gate. The shortest is the Bottom garden of 132 m length. It was opened last in 1823 and lies from Borovitsky gate to the Kremlin embankment. In Top and Middle gardens, three alleys are laid in parallel with Kremlin wall and Manezhnaya square.

At present Aleksandrovsky garden is one of the most popular places of the city; it is visited by almost everyone who comes to Moscow. Certainly, Aleksandrovsky garden is a favourite relaxation point for Muscovites. Moreover, it reminds of some of the major events in Russian history: of victories over Napoleon, in the Great Patriotic War, etc.

RECONSTRUCTION

A part of the grand reconstruction project of Aleksandrovsky garden became the modernisation of the landscape outlook and updating all of the park territory at the Kremlin walls. In the process, the best architects and leading designers studied historical pictures and archive materials, which became the basis for implementing ideas of the reconstruction to a pre-revolutionary look of the garden.



Instead of old trees and bushes, more than two hundred of new nursery plants were planted, including the best kinds of elite chestnuts, mountain ashes, birches, lindens and maples are presented. Coniferous trees we added as well: with blue and green fur-trees, Siberian firs and larches. A flavour of the winter Aleksandrovsky garden became a fifteen-year fur-tree, placed in the rosary centre. According to the new decoration project, almost 3000 bushes were planted: hawthorn, juniper, lilac and hydrangea, and about 78 thousand flowers: cannas, marigolds, petunias, kochias, begonias, balsamines and cinerarias. They were selected based not only on their colour scheme and bud size, but also on their aroma.

To support the plants under optimum favourable conditions, an automatic irrigation water pipe was installed, the total length of which amounted to 14 km allowing an irrigation of an area of 7.5 hectares.

CONCEPT OF ILLUMINATION AND LIGHTING INSTALLATION

The rearrangement of the installation of landscape illumination of the Top and Middle Aleksandrovsky gardens is accomplished within construction and mounting works of architecture and art illumi-

nation of buildings located on the designated "Protected Area around the Kremlin".

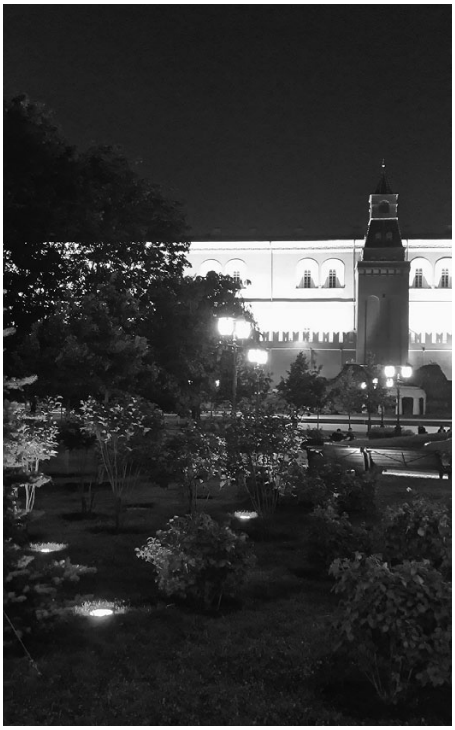
The layout of the light device's location was developed according to the plan of placing green plants, as well as with regard for location and features of small architectural forms and statues. The types and number of the light points were determined based on the main light accents conceived by the developers of the illumination concept.

The high-volume crowns of big trees were illuminated using architectural searchlights with *GRIVEN TRIDENT CYM 150* MHLs of 150 W power (MHL colour-changers[2]) installed at the ground level. The optics used in them were specially selected to achieve a maximum visual effect consisting of a wide coverage of foliage and branches, and this allows using a minimum number of the searchlights.

Bushes and low plants are illuminated with ground searchlights using *GRIVEN DUNE MC RGBW* light emitting diodes. The devices are skillfully built into the lawns and intended for colour-dynamics illumination. Their secondary optics secures a wide, uniform and soft "light coating".

The searchlights and luminaires used in the project of landscape illumination of Aleksandrovsky garden, were selected with regard for the necessary functionality and modified according to individual technological requirements. These requirements were formulated by specialists of a design company, who performed a detailed study of the functionalities proposed by leading manufacturers of lighting products. During the design process, natural tests were repeatedly performed. The results of the test modelling produced estimates of the necessary quality of visual effect, light distribution parameters and type of optics. After several iterations of the completion of optical part of the searchlights, an optimum solution was obtained when selecting the light emitting diode/secondary optics pairs for crowns of trees and bushes to be illuminated.

[2] An unlimited number of colours and shades with smooth transitions is reproduced. The principle of linear superimposing dichroic optical filters (a subtractive mixing system) is used.



Special attention was given to the selection of the white component included in the composition of the full-colour (*RGBW*) crystal. Correlated chromatic temperature (T_{cc}) and general colour rendering index (R_a) are key parameters, which should be taken into consideration when illuminating plants. In summer, it is necessary to work mainly with green, in autumn – with yellow and red colours, as well as with golden shades, and in winter branches are often covered with snow of amazing beauty and whiteness. All this was performed by a single light device. In doing so, high values of R_a and appropriate values of T_{cc} (of 4000 K order) were necessary, and a well-thought-out work of an artist programming light-and-colour scenarios, was certainly required.

In the design process, the interaction of the decorative lighting installation with numerous devices of general functional illumination was taken into consideration. MHL searchlight case configuration was perfectly combined with architectural style of the illumination poles, and the reproduced light scenarios did not contradict, and logically supplemented the light of the classical lamps installed on the light poles within the garden territory. The illuminance levels created by the lighting installation harmoniously correlated with values of the general illuminance diagram of the garden.

All the light devices used in the project of landscape illumination of Aleksandrovsky garden were unified under a general control system, which is capable of creating preset light scenarios and operating each light point independently in the real time mode.

According to the technical design specification, the lighting installation is able to operate in two modes: daily and festive. In accordance with the main intention, Aleksandrovsky garden is to a greater extent illuminated with white light, but white shades and other colour shades can change from the edges of the landscape area to the centre.

The result of the creative transformation of Aleksandrovsky garden has been an absolutely new perception of one of Moscow's main places of interest. Visitors of the Kremlin and people simply walking along its walls find themselves simultaneously in a modern botanical garden and in an ancient park. As darkness descends, the most beautiful elements of natural composition acquire unusual colours and shades, reviving in foliage colour play and in colourfully highlighted flower compositions.

The new light decoration of Aleksandrovsky garden has its own individuality and creates a unique mood of the capital centre at nighttime.

The development of the illumination concept, the design work package, equipment delivery, installation works and control system programming are made by Svetoservis company group.

In the article, materials from the resources: http://www.pastvu.com, http://kudago.com, http://arch-grafika.ru and http:// moscow.ru are used.

Sergei V. Chuvikin,
an engineer and expert in marketing. Graduated from the Moscow State Institute of Electronic Facilities in 1998 (specialty "Electronic mechanical engineering") and the Moscow Institute of Economics, Government and Right in 2004. The Head of projects of GRIVEN Russia Company

Light & Engineering
Vol. 23, No. 2, pp. 29-33, 2015

Svetotekhnika
No. 2, 2015, pp. 21-25

LIGHT REFERENCE POINTS IN A NIGHT CITY ENVIRONMENT

Marina A. Silkina

MArhI (State University), Moscow
E-mail: smakmv@mail.ru

ABSTRACT

The article considers problems of spatial orientation by means of light navigating visual and communicative systems as well as by structuring light information, utilitarian, architectural and landscape illumination. It also discusses the influence of visual communications is an important composition facility of comprehensive design of all illumination types on forming light-and-colour medium of a night city.

Keywords: city medium, light-and-colour medium, visual communications, light-and-information illumination, light advertising, orientation, navigation visual-and-communicative systems

Artificial illumination reveals the structure of a city during the hours of darkness and helps to orientate oneself in space. The informational value of the light medium has multiple layers: its basis is the light frame of a city formed by utilitarian illumination, which is supplemented with informational, architectural and landscape illumination. Together, these illumination types form light-and-colour medium of a modern city, which responds to the functional and aesthetic requirements of the inhabitants.

It would seem that visual and communicative components only relate to light information, but this is not exactly so. The informational value of a light medium, as well as of a spatial environment is provided by a number of interconnected components. Visual communications include three main areas: commercial systems (shop windows, signboards, light advertisement installations of various types, media screens, etc.); navigation systems (address signs, systems of pointers, information installations: maps, plans, public transport stops signs, underground entrances); social systems (information installations) [1]. Besides the informing function, they perform orientation functions, which allow locating the position of a person in space. These systems influence the architectural medium significantly in the daytime and form a light space in the night time. The mutual influence of the main groups of city illumination (utilitarian, architectural, information) [2, p. 167], as well as of the landscape, forms the visual image of a night city, and located points in space.

Historically, the evening illumination of a city consisted of the interactions of the utilitarian (oil and gas lanterns) and the information illumination (house number lanterns appeared in Russia in the second half of the 19 th century). Then, late in the 19th century, they were supplemented with commercial and advertising illumination. It was only in the first half of the 20th century that architectural and landscape illumination appeared. Thus, in forming the informative medium, we can trace the dominant role of utilitarian and navigation illumination and the secondary role of architectural, landscape and advertising illumination.

The architectural medium of a modern city is mainly filled with advertising components of visual and communicative systems, such as shop windows, signboards, advertising installations (billboard, poster pillars, roof installations and media screens). Navigation visual and communicative systems are rarely equipped with a special illumination in global practice: address signs with internal illumination typical for modern Moscow is more likely an exception to the rule, and direction signs are only highlighted in some cities (Moscow, Paris, Yerevan,

Fig. 1. A direction pointer sign. Yerevan, Armenia. Photo: © 2011, M.Silkina

Fig. 2. Times-square, New York, the USA. 2000. Source: [7]

Fig. 3. Moulin Rouge in Boulevard de Clichy. Paris, France. Photo: © 2012, M.Silkina

etc.) [1], Fig. 1. In the majority of world cities, the pointers are not illuminated additionally, and they can be viewed under general illumination. The navigation visual and communicative systems themselves appear to be almost imperceptible against general light-and-colour and advertising information background. Their influence on the light-and-colour medium is minimal [1], except for direction signs widely applied in Moscow (with names of streets) combined with advertising. In wider world practice such design solutions are not applied: advertising and city information are always separated [1].

A separate layer in the city navigation system comprises landscape illumination facilities designed as guiding lights. A trend of using light projections as a method for navigation is also planned. This method of information presentation is probably based on the experience of projective light installations.

The architectural illumination of buildings is usually viewed at a distance: space is needed for it to become fully visible. In European cities it is used minimally: as though light just catches out significant city spaces from the darkness, keeping to streets and squares without touching other structures of the city (Paris, Yerevan, Tessaloniki). The Moscow practice of light design unfortunately tends towards a "total" illumination of all main city streets illuminating buildings and constructions. Such an approach leads to a decorative excess, general illumination redundancy, inconsistency with the spatial context, and as a consequence, to visual chaos. Architectural illumination could after all become a composition instrument, which is capable of structuring the light medium. The influence of a commercial visual-communicative system on the light medium of any city is enormous. They exist regardless of utilitarian and architectural illumination [1]. As a rule, illuminated objects of visual communications are placed at the eye level and in this way form the main light and colour field of a city [1]. Irrespective of city illumination, shop display windows and signboards create a natural light "belt" at ground level and the first floors of buildings and constructions. In addition, advertising installations of various types and luminance, form a visual medium inappropriate for comfortable and safe living space [1]. In such a visual field of illuminated advertisements, navigation systems become almost lost, because they are either unlit or cannot compete with more actively lit information objects.

The world community faced the negative impacts of overabundant advertising in cites at the turn of the19th and 20th centuries, though the first signs of the chaos arose even earlier. Rationing was always applied as a regulation mechanism. Today, adjustment mechanisms have not changed. They have in respect to heights, size, colour and luminance

a) *b)*

Fig. 4. The light visual communication belt: a) Gare du Nord, Paris. Photo: © 2013, E.Grishin; b) Stoleshnikov by-street, Moscow. Photo: © 2013, M.Silkina

characteristics of the advertising elements. Dismantling of roof advertising installations in Moscow and St.-Petersburg has essentially improved visual quality of the city medium in both capitals. The rationing applied to the height, size and signboard luminance, will normalise the light and colour impact of signboards and shop display windows on the a night city. It will also make the light "belt" in the bottom part of buildings more active, which should primarily be taken into consideration when designing architectural illumination. Advertising illumination cannot be considered out of context of the light solution of the entire city medium, in isolation from its general light and colour composition [3]. Regardless of the fact that there is an accepted connection between a negative impact on the aesthetic perception of a city medium and light advertising, it is often a single light source also solving problems of utilitarian illumination, for example, in public transport stop shelters [1]. There are some fragments in the city structure, where advertising illumination is the main feature, for example, Times Square in New York (Fig. 2) and Boulevard de Clichy in Paris (Fig. 3). From the point of view of visual communications, these are atypical city territories. In such areas, the active work of signboards and advertising is the medium forming force. However, when this application is moved to a medium with other functional tasks, it can abound to visual chaos [4].

Thus the greatest influence (requiring a strict rationing) on the light medium of a city, is rendered by commercial visual communication systems (Fig. 4). They create a "visual noise" interfering with the perception of other medium components and with orientation in space. A space filled with visual communications can be structured with an architectural illumination taking into consideration the existence of the shop display window and signboard "belt" at the level of perceived medium "frames" and facade "pictures". However, influential commercial visually-communicative systems, may be navigation systems, should have a priority in perception, because their primary goal is the provision of safety, availability and comfort of the medium by means of understanding the spatial structure of a city [1].

Orientation in a city space is certainly a paramount consideration for comfort and safety both at night, and in the daytime. Any city has a certain functional and planning structure, which is manifested by a system of transport highways and public centers forming the functional spatial "skeleton" and filled with inter mainline territories [5]. At a level of visual perception, a city's structure is revealed by a system of medium dominants of the architectural and natural kind. These are reference points, which allow to be guided in a city space: historically, these may be a bell tower, the central square, horizontals of fortifications and aqueducts, or a mountain, the sea, etc. A modern city is so great and complicated that medium (natural and architectural) reference points prove to be insufficient. This leads to the appearance of extra-architectural facilities: navigation visual communication systems structuring visual information onto the medium.

At the end of the 19^{th} and at the beginning of the 20^{th} centuries, artificial illumination only revealed the network of streets and squares. The "map" [2, p. 159, 202] and the pattern of a city were read due to these light "way-guides". Buildings, constructions and medium fragments were only illumina-

Fig. 5. Revealing architectural dominants by illumination. a) A fortress. Tessaloniki, Greece. Source: [8]; b) Basilique du **Sacré** Cœur. *Paris, France. Photo: © 2012, M.Silkina; c) Tour d'Eiffel, Hotel des Invalides, Arc de Triomphe (light reference points) and a network of city streets (light frame). Paris, France. Source: [9]*

ted during large-scale holidays. Light advertising only strengthened the "glow" degree of city streets in places of public attraction (trade and pedestrian areas), which naturally formed light "magnets" in the medium. Later on, when developing city illumination, this principle remained. In the city medium, "light lacunas" of public spaces appeared, which were differentiated using colours: transport areas were illuminated with yellow light, pedestrian public – with white light, added to by the architectural illumination of building facades (France, Spain, the USA) [2, p. 148–150]. At the city perception level the "shop display window belt" element of the medium composition frequently became more distinct and clear than the rhythm (line) set by the utilitarian illumination [1].

At this level, two principal kinds of city illumination overlap each other showing the structure of a city and, an the same time, setting the light composition of a medium fragment. Architectural illumination lies in the following layer and as though it "reveals" space due to its ability to create medium reference points both by means of illuminating architectural objects, and as independent visual facilities. This type of illumination is extended not to the whole city or its centre, but only to the main city-forming structures (squares, embankments, avenues). It allows arranging an effective orientation in space of the night city without additional "light" efforts, where all is coordinated. Illumination of the existing dominant medium elements and formation of new light dominants themselves is a method of creating "beacons" in the darkness "sea". This is a "Ariadne's thread" if light with reference points "beaded" on it (Fig. 5).

Such illumination is attractive; it is not distributed over a city, but performs the role of a medium "magnet" revealing areas of social activity. N.I. Shchepetkov has divided light dominants into the real (illumination of existing landscape and architectural dominants) and the "virtual", which are created exclusively by means of light (laser rays, searchlight beams) [2, p. 168]. Certainly, the bigger the city, the more complex the system, in which many economic and social factors are involved, but for effective orientation in a medium, there is no necessity to illuminate everything. Architectural illumination can reveal the town's composition. In this case, utilitarian and aesthetic requirements are met, and illumination becomes "generalising" for utilitarian and light information purposes at a level of the city, "interior" and as a fragment of the medium [1]. When designing architectural illumination of buildings, it is necessary to take into consideration the natural light belt at a level of the ground and first floors [1]. It sets a composition rhythm of local, fragmentary illumination of architectural elements (light "splodges" [2, p. 256]) and provides integrity of the façade's perception. When using floodlight, the generalising influence of architectural illumination is revealed most completely, because it decreases the "fractionality" of the light medium and improves orientation in around the city.

Various components of city illumination are regulated at a level of urban light plans. Light and colour zoning essentially consist of three aspects: macrozoning (at a level of the general plan), mesozoning (within a functional area) and microzoning (the level of small planning forms: microdistrict, quarter, etc.). These zoning levels versions take part in the arrangement of spatial orientation. For example, a comprehensive scheme developed by N.I. Shchepetkov for Moscow (1999), includes the following layers of city illumination: "urbanized frame", which can be divided into utilitarian illumination of transport areas and pedestrian public areas; utilitarian illumination of a "natural frame"; a "texture" divided into utilitarian territory illumination in residential and production areas; architectural illumination of facades and decorative illumination of landscape elements. Moscow ("texture") is divided into three areas: a historical centre, "a buffer" area and modern building. Illumination of industrial areas and dominant light areas are considered separately. Zoning of territories, in this case by light, is a basis of orientation arrangement in the city. A plan of the colour zones for the historical centre was proposed by N.I.Shchepetkov (2000–2001). It is based on the following gradation: the Kremlin with Kitai-gorod is a two-part core surrounded with quarters of Bely Gorod, quarters of Zemlyanoi Gorod, buildings of the buffer area behind Sadovoye Koltso (ring) (these are "texture" elements; Boulevard Koltso, Sadovoye Koltso, radial transport streets, embankments, social and pedestrian spaces (these are "frame" elements) [2, p. 179–192]. This choice means every area is unified in light and colour, not only structures the centre, but also allows creating different light and colour images facilitating orientation in space.

Thus a compositional arrangement of the medium and of orientation in space is achieved.

While in the daytime "texture" zoning is most topical, at night time, the "frame" is most effective for orientation, as the most manifested lit structure, including the availability of visual communications.

To perceive means to select … [6, p. 111]: one of the main components of information perception is the need to "*recognise the form against noise*" [6, p. 140]. Understanding visual systems of communication "as an inherent and considerable composition aspect, which forms the light image of a city" [1] will help to achieve comprehensive city medium design solutions. Only as a result of the complete interaction of all layers of artificial illumination can effective orientation within the medium of a night city be possible.

REFERENCES

1. *Silkina M. A.*. Light visual communications in a city medium / Theses of reports of the scientific and practical conference "Light design – 2014". St.-Petersburg: the National Research University of Information Technology, Mechanics and Optics, 2014, pp. 20–21.

2. *Shchepetkov N. I.* Light design of a city. Moscow: Architecture-C, 2006. 320 P.

3. *Bystryantseva N.V., Van der Heide R.*. Formula of light: research of light medium of Volkhonka district / Culture territory. Quarters of Volkhonka. Moscow: Bely Gorod Project Open Company, 2014, pp. 50–57.

4. *Silkina M. A.* Influence of height of placing visually-communicative systems on the architectural medium image // International electronic scientifically-educational journal "Architecture and Modern Information Technologies" (AMIT), #2 (27) [a network resource]. URL: http://www.marhi.ru/AMIT/2014/2 kvart14/silkina/silkina2.pdf (addressing date: 18.07.2014).

5. *Gutnov A.E.* Evolution of town development. Moscow: Stroyizdat, 1984. 256 P.

6. Moles A. A theory of information and esthetic perception / Translation from France of B.A.Vlasyuk, J.F.Kichatov, A.I.Teiman; under editorship and with an afterword of R.H.Zaripov and V.V.Ivanov; introduction of B.V.Biryukov and S.N.Plotnikov. Moscow: Mir, 1966. 352 P.

7. URL: http://www.dailymail.co.uk/news/article-2217113/Times-Square-Amazing-images-capture-Crossroads-World-1904-modern-days.html (Addressing date: 18.07.2014).

8. URL: http://traveladventureeverywhere.blogspot.ru/2013/02/thessaloniki-voyage-to-thessaloniki.html (Addressing date: 18.07.2014).

9. URL: http://hdwallphotos.com/photoswall/paris-city-night-wallpaper-hd.html (Addressing date: 18.07.2014).

Marina A. Silkina,
a designer. Graduated from the Pyatigorsk State Technological University with design specialty in 2002. A senior teacher of the Chair "Design of architectural medium" of the MArhI (SA)

CRITERIA FOR COMPREHENSIVE EVALUATION OF THE QUALITY OF A CITY'S ARTIFICIAL LIGHT MEDIUM

Natalya V. Bystryantseva

RULD Creative association of light designers and Research University of Information Technology, Mechanics and Optics, St.-Petersburg
E-mail: svs.lighting@gmail.com

ABSTRACT

One of the professional creative tasks of a light designer is the creation of light medium of a city meeting certain artistic and functional features.

The article determines criteria for a comprehensive evaluation of the visual quality of an artificial light medium of a city and proposes a new criterion: "design properties of light medium of a city".

Keywords: light medium, medium of a city, light design, art features, functional features, comprehensive evaluation, criteria, new criterion

A city medium, whether it is a residential area, square, or a street, has a number of typical features in terms of urban layout, architectural and composition features, such as urban in-filling, which is dependent on the landscape features and on the public and personal activities of the inhabitants [1]. When designing illumination of a city medium, light designers consider different factors, among which the most essential are ***characteristics and functional attributes of city spaces*** [2].

The *first factor* is based on the concepts about the city, region, on a fragment of the city medium, their

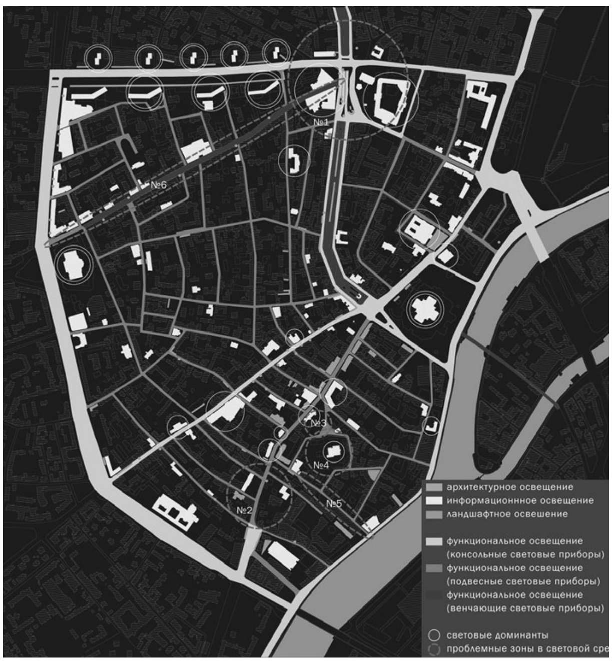


Fig. 1. "Existing light medium of Volkhonka area" [4]

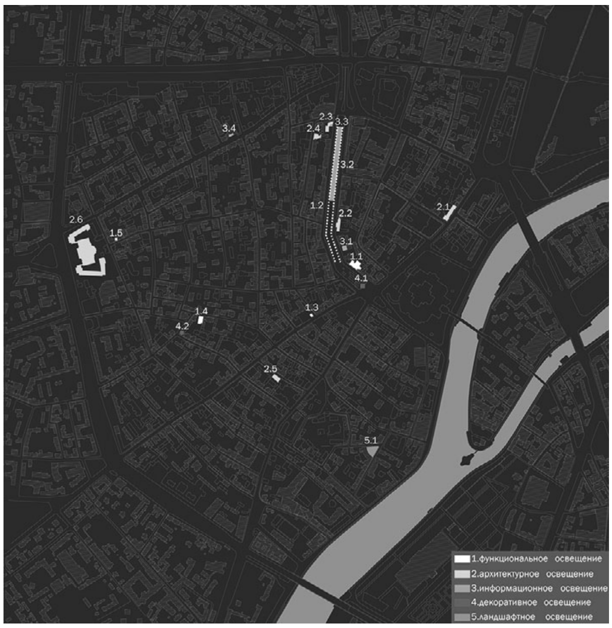


Fig. 2. "Research of light medium quality for Volkhonka area" [4]

Fig. 3. Illumination of the entrance area
(in Prechistenka street), 2012 © D. Podgursky

Fig. 4. Information stands in Gogol Boulevard,
2012 © N. Bystriantseva

type, size, structure and spatial arrangement, stylistic characteristics of the architectural environment and on the polychrome. In other words, characteristics of city spaces are driven by size and spatial concepts, which are formed by a specific society.

The *second factor* assumes an analysis of functional activity of a person in the city and of its socio-spatial organization, which determines quality and in-filling of the light medium created. This factor has not been widely applied in Russia so far.

It is rather difficult to draw a distinct boundary between many public processes, which occur on a territory, between various spatial ratios of streets and squares, gardens, green areas etc.. Each city is formed as a result of different functional interrelations: spaces of rest and leisure, communications and contacts, as well as the movement of people. Therefore, the **formation of light medium of a city fragment should begin from *a comprehensive evaluation* of its functional tasks and spatial arrangement. This should be the basis and the cause of the light composition solution**.

One of the features of city illumination theory and practice in Russia is that artistic and aesthetics concepts are used in respect to architecture, and not to the city medium as a whole. So the *artistry* of the light solution of a city medium depends mainly on the architectural illumination.

However, arranging the light medium of a city around architectural illumination often leads to super saturation: boundaries between the individual plasticity of buildings, the special nature of streets and their functional features are smeared. And because of this, public spaces can become indistinguishable from each. As a result, the main things are lost: a high quality of the comprehensive light environment of the evening city and a distinctive character of the city as a whole. [3].

An analysis of world practice and experience shows availability of different lighting solutions, in which illumination obtains an individuality reflecting the functional characteristics of the medium. This can achieved by following a proper hierarchy of illumination types within view of a person, instead of using a redundant luminance or an increased number of illuminated objects number.

As it is known, architecture and the city medium have different functional and art concepts and design requirements. Consequently, their solutions by means of artificial illumination should also be formed according to different criteria of their evaluation.

In 2011–2012, a research project of the Moscow city medium “Territory of culture. Quarters of Volkhonka” was undertaken, in which the light medium of the area of Volkhonka was investigated by the authors [4]. Working with volunteers and participants, it was proposed to estimate not only ***the technical quality*** of the illumination, but also its ***artistic quality*** relative to “a contextual and comprehensive arrangement of the light medium”.

As it is known, standards are developed for most types of illumination, where quality evaluation criteria are different and depend on the tasks performed by the artificial light. For example, in store window illumination, illuminance is normalised, and in architectural illumination, perception comfort is normalised, more specifically, absence of visual discomfort is normalised [5]. Perceptions, from both the viewpoint of a driver, and of a pedestrian should be ta-

Fig. 5. Borisoglebskaya church (against an office building), 2012 © N. Bystrjantseva

Fig. 6. Arbat square (oversaturation with information signa) 2012 © N. Bystrjantseva

ken into consideration, because they have completely different perception conditions of the illuminated facades. It is important for a driver that there are no excessively bright objects at the periphery of his/her sight, which interfere with keeping track of the traffic. The pedestrian's site is not directed lengthwise along the motorway, similar to the driver, but across the street, perpendicular to the building facades. The perception comfort also depends on the following factors: luminance distribution within sight; irregular illumination of objects surface and of spaces; light saturation of spaces; blindness and discomfort glare level; direction of the light beams; radiation spectrum and colour rendition quality of the light sources; illumination dynamics [6].

To evaluate and forecast light composition parameters of the evening medium of a city, N.I. Shchepetkov has proposed a system of criteria including the following: illumination levels determining luminosity and saturation of the space (a quantitative criterion); dominating chromaticity; kinetics of illumination and structure of the light field, which influence quality and volume of the light space formed (qualitative criteria) [7]. This range of the lighting criteria could become the basis for selecting light composition parameters, by means of which comfortable conditions of visual perception, modes and chromaticity of the illumination, a necessary scope of light spaces are provided. However, according to the author of this article, these criteria are insufficient for ***a comprehensive evaluation*** of a light medium as they do not take into consideration one of its main features: ***richness of content***.

The specialists consider that an evaluation of a light medium's content richness is a subjective thing. Therefore, it was especially important not only to research objects and fragments of a light medium from the viewpoint of comfort and safety, but also to determine a system of criteria of art quality light solutions.

Within the research project investigating Moscow's city medium, it was proposed to consider such factors as comfort, safety *and aesthetic properties* of the light medium concerning people [4]. It should be noted that the *aesthetic properties* term, which was used by the author within a report on the research results at a MArhI (SA) conference [3], obtained an doubtful evaluation since the "aesthetics" concept is rather many-valued [8]. Therefore, another terminology to a specific character of the considered problem is more appropriate.

Taking into consideration that the light medium of a city is formed based on functional and artistic concepts, this article proposes a new criterion: ***"design properties of the light medium of a city"*** (*DPLMC*), which, in our opinion, better reflects the specific character of visual quality of a light environment.

If comfort and safety are currently accepted lighting concepts taken into consideration in the standards and rules and described in the criteria system of N.I. Shchepetkov, N.V. Obolensky, G.V. Kamenskaya, V. Keller and V. Lukhardt [5–7, 9–11], then the ***DPLMC*** term needs clarification.

According to the author, ***DPLMC*** includes the following: ***informative efficiency, imaginative expressiveness, integrity of light composition, rationality of the light solution*** [12].

Informative efficiency is the creation of a system of accents and reference points in the light medium of a city using artificial illumination facilities based on functional fullness, significance, characteristic features and methods of arrangement in the city space. The information efficiency is responsible for a correspondence of a sense content of the light solution to the city environment, its functional and spatial characteristics and to features of the architectural medium.

Imaginative expressiveness is a reflection of city lifestyle, contemporary tastes and the specific character of a natural landscape in light and composition solutions, which create a uniform context of city perception and its social and culture code. All of this considers the light solution of a fragment of the city medium as a complete imaginative system, if though poorly structured. Nevertheless, this system has distinctly expressed aesthetic connections and relations between elements, which make it possible not only to recognise the image, but also to analyse it in respect of artistic composition. When addressing imaginative expressiveness, the following are taken into consideration: light culture of a city or of an area; importance of the ideas set in the light solution and trustworthiness of their expression.

Integrity of the light composition is an arrangement of the town-building structure featured by interrelation of light spaces within a fragment of the city or of the ensemble, as well as correspondence of the light solution based on the elements' hierarchy, architectural-and-planning arrangements of the city medium and on polychrome dynamics.

Rationality of the light solution is a reasonable choice of illumination facilities and methods, complying with the idea or concept; a correspondence of the light solution to utilitarian and practical tasks together with evaluation of its energy efficiency.

Fig. 7. Arbat street (a blinding effect of external illumination devices), 2012 © K. Karatayev

Based on the proposed criteria of comprehensive evaluation, a assessment of Volkhonka street illumination territory was performed. As a result, of the all variety of light solutions presented in Fig. 1, examples of a high-quality arrangement of the light medium were revealed (Fig. 2–5). Use of the criteria of a comprehensive evaluation of the light medium allowed revealing most the problematic sites of city spaces (the examples are given in Fig. 6–8) and determining methods of an optimum solution.

As a result, it became possible to formulate recommendations about solving the problems of the existing light medium and to develop further proposals for comprehensive illumination of public territories.

All of the above allows concluding that formation of light solution of a city fragment based on **a comprehensive evaluation** of its functional tasks and spatial characteristics, corresponds to the specific character of city illumination medium design.

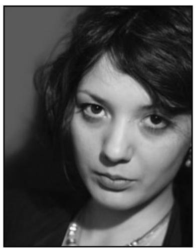
Fig. 8. In Ostozhenka street (dark yard territories), 2012 © S. Porohnja

The declared criteria of light medium evaluation allow determining in many respects the degree of appropriateness of the light medium to an information, social and medium context and creating **comprehensive light solutions** through integrating all components (illumination types) into a uniform art ensemble.

When reconstructing or creating light solutions based on the proposed criteria, the main factor will be an improvement of visual quality of a city's light medium rather than an increased number of illuminated objects.

REFERENCES

1. Gutnov A.E. "Evolution of town construction". Moscow: Stroyizdat, 1984, 256 P.
2. Shimko V. T. and Gavrilina A.A. "Typological fundamentals of art designing of architectural medium" Arckhitectura-C, 2004, 101 P.
3. Bystyantseva N.V. "Estetics of light medium". Proceeding of the Scientific and Practical Conference "Science, Education and Experimental Design". MARHI, 11–15 th April 2013.
4. Bystryantseva N.V., Van der Heide R. "Formula of light: research of light medium of Volkhonka territory / Territory of culture. Quarters of Volkhonka". Moscow: White City Project Open Company, 2014, 115 p.: pictures pp. 50–57.
5. Rules and Regulations СП 52.13330.2011 "Natural and artificial illumination. Actualized edition of Building regulations СНиП 23–05–95 *".
6. Architectural physics: Textbook for higher education institutions: / V.K.Litskevich, L.I.Makrinenko, I.V.Migalina, N.V.Obolensky, A.G.Osipov and N.I.Shchepetkov; Editorship of N.V.Obolensky. Moscow: "Arkchitectura-C", 2007, 448 P.
7. Shchepetkov N.I.. Light design of a city. Moscow: Arckhitectura-C, 2006, 320 p.
8. Ozhegov S.I. and Shvedova N.Yu.. Explanatory dictionary of Russian. Moscow: ITI of Tchnology, 2003.
9. Researches, development of recommendations and technical solutions of a comprehensive light decoration of main architecture memorials, squares and streets of Novgorod City: Report on the researches / The authors: Kamenskaya G.V., Zobov V.P., Podgornykh L.A., Petrova L.I., Kurnosov A.Yu., 1989.
10. Keller V., Lukhardt V.. Light in architecture. Light and color as facilities of architectural expressiveness / Translation from German of V.G. Kalish – Moscow: Gosstriisdat 1961, 184 P.
11. Matveyev A.B.. Fine arts, light design and esthetics // Svetotechnika. 1999, № 3, pp. 21–24.
12. Bystryantseva N.V. Criteria of Evaluation of Visual Quality of Artificial Light Medium of a City / Theses of reports of Scientifical-and-practical conference "Light design", SPb: ITMO University, 2014.



Natalya V. Bystryantseva,
an architect designer. Graduated from the Saratov State Technical University in 2004. A teacher of the TTOE Chair of the information technology, mechanics and optic University. The Head of the Creative Association of Light Designers "RULD". A competitor of the Chair "Design of architectural medium" of the MARHI (SA)

Fig. 1. A direction pointer sign. Yerevan, Armenia. Photo: © 2011, M.Silkina

Fig. 2. Times-square, New York, the USA. 2000. Source: [7]

Fig. 3. Moulin Rouge in Boulevard de Clichy. Paris, France. Photo: © 2012, M.Silkina

Fig. 5. Revealing architectural dominants by illumination. a) A fortress. Tessaloniki, Greece. Source: [8]; b) Basilique du **Sacré** Cœur. *Paris, France. Photo: © 2012, M.Silkina; c) Tour d'Eiffel, Hotel des Invalides, Arc de Triomphe (light reference points) and a network of city streets (light frame). Paris, France. Source: [9]*

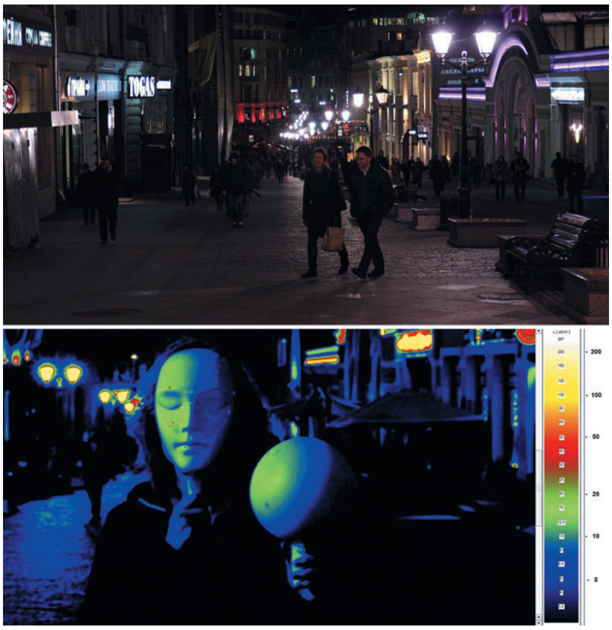


Fig. 1. Kuznetsky most street, a view downwards from Rozhdestvenka street. Lanterns are blinding because with the dark facades and a wide street, their light is insufficient, and shop display windows are few. The light of the lanterns has a certain light-simulating effect (lateral light) estimated using the white mask and the sphere

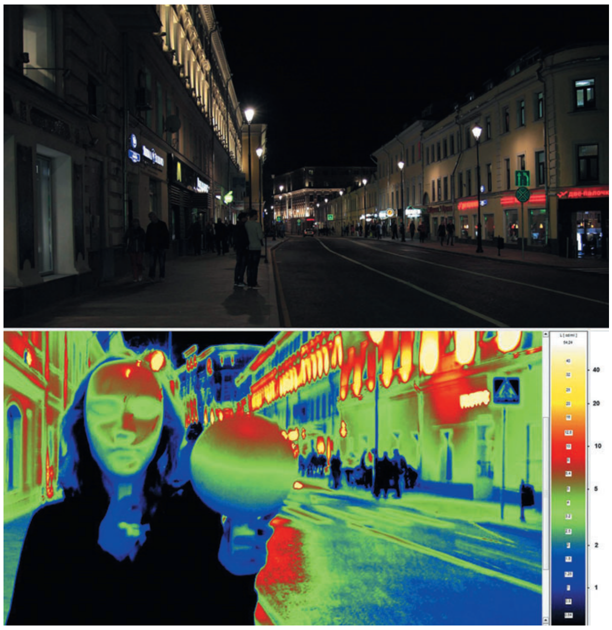


Fig. 2. Maroseika street. Dominating lantern light from the top forms shadows, however the feeling of a major light ensemble is not created

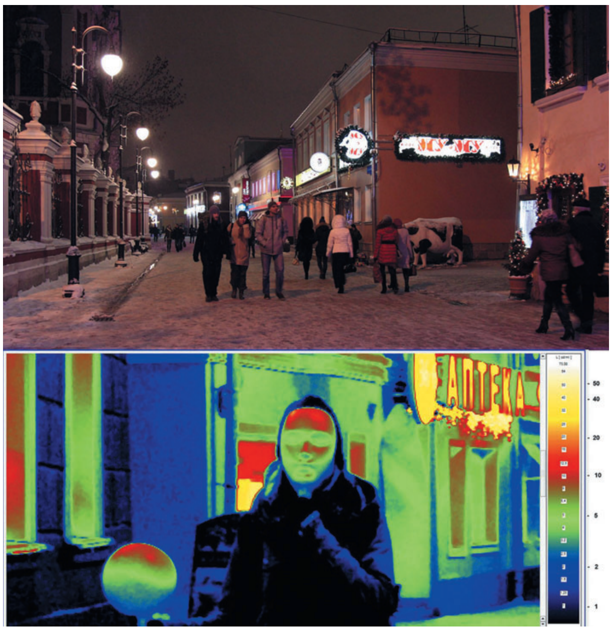


Fig.3. Klimentovsky by-street. Shadow forming during winter period

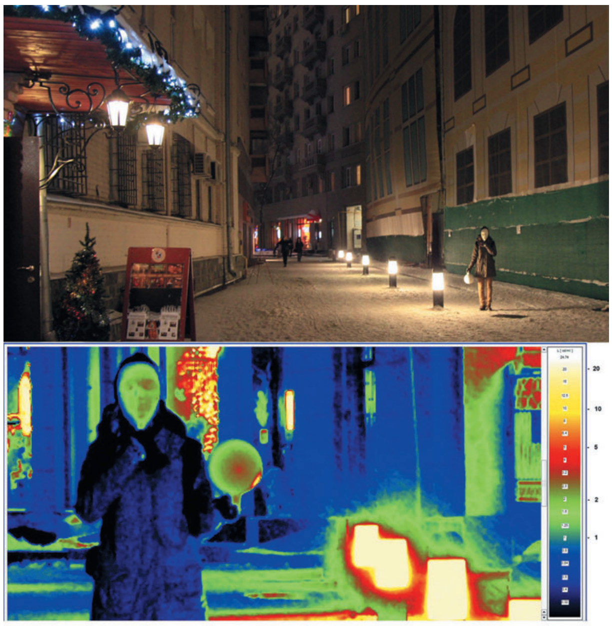


Fig. 4. Ordynsky cul-de-sac. An uneven light distribution, “footlights effect” with snow, a bad shadow forming effect and an unsettling atmosphere

Fig. 5. Pyatnitskaya street. the light ensemble has not taken place yet, but there is a dominant. Illumination is insufficient, light-simulating effect is weak (illumination is not counted)

Fig. 7. Vorobyovy Gory. Elements of light design of the pedestrian embankment

Fig. 8. St.-Petersburg. A pedestrian area (boulevard) in Malaya Konyushennaya street

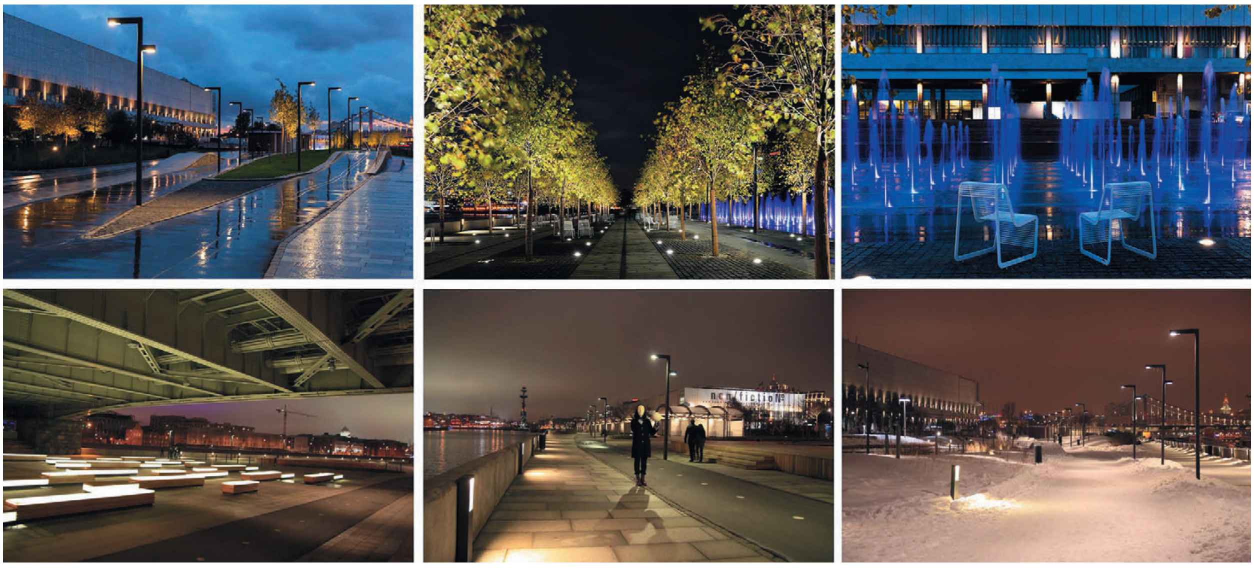


Fig. 6. Krymskaya embankment. Light design during different seasons at different points

Fig. 3. Illumination of the entrance area (in Prechistenka street), 2012 © D. Podgursky

Fig. 4. Information stands in Gogol Boulevard, 2012 © N. Bystriantseva

Fig. 5. Borisoglebskaya church (against an office building), 2012 © N. Bystrjantseva

Fig. 6. Arbat square (oversaturation with information signa) 2012 © N. Bystrjantseva

Fig. 7. Arbat street (a blinding effect of external illumination devices), 2012 © K. Karatayev

Fig. 8. In Ostozhenka street (dark yard territories), 2012 © S. Porohnja

Light & Engineering
Vol. 23, No. 2, pp. 43-48, 2015

Svetotekhnika
No. 2, 2015, pp. 59-60

PRINCIPLES OF CONSTRUCTING LIGHT FIELD MODEL FOR A ROOM WITH CURVILINEAR QUADRANGULAR LIGHT OPENINGS BY MEANS OF THE DOT CALCULATION

Vladimir A. Egorchenkov[1] and Eugene V. Konopatsky[2]

[1] The Kiev National Aircraft University, Ukraine;
[2] The Donbas's National Academy of Construction and Architecture, Makeyevka, Ukraine.
E-mail: aasmandrus@mail.ru

ABSTRACT

This work describes a technique of constructing a light field model for rooms with quadrangular light openings having curvilinear counters. Based on the dot calculation method, a dot set with coordinates of scanning dots is formed. Based on these dots, elementary solid angles with vertexes in a reference point are computed. Summation of these angles with their lighting indicators determines integral characteristic of the light field.

Keywords: modern architecture, quadrangular light opening, curvilinear counters, scanning dots, dot calculation, illuminance, light vector.

PROBLEM STATEMENT

The turn of the twenty-first century has been characterized by a wealth and variety of styles in urban architecture: from classicism to avant-garde. Today, one can see buildings of many configurations and of various non-standard volumes.

A new trend in modern architecture is the integration of houses with their surrounding landscape, without reducing the comfort of the inhabitants. Replacing straight lines and habitual cubic and angular houses with smooth configurations is becoming common; the sight of these houses brings to mind the dwelling of the Flintstones and hobbit houses.

Solutions for natural illumination systems in such buildings are peculiar. Looking carefully at architecture objects of gothic, baroque, rococo, ultra baroque, etc. styles, we see round, arch, oval, and other configurations of light openings. This is also true for much modern architecture.

Nowadays architecture has reached a level where its light openings can take various forms and outlines, and they can be placed arbitrarily in the space (Fig. 1). One of the primary problems for specialists is to find principles of simulating the light medium in such buildings, which would allow bringing parameters of the medium near to optimal values as much as possible. Architects should not only create the buildings to harmoniously fit into their environment, but also know what parameters are obtained in the rooms and to what extent they differ from the natural optimum.

Fig. 1. A bent house in Sopot, Poland

Classical methods of calculating light field parameters from any source [1] are based on computing the value of the radiated element solid angle using the integration method. This method is suitable for light openings of a private position and of a simple configuration. But for openings of an irregular shape, arbitrarily located in space, problems of determining integration boundaries arise. This circumstance reduces the accuracy of the calculations and increases computer operation time.

At present, a number of powerful software products for lighting design are available (Lightscape, 3 D Studio Viz, Radiance, Lara [2, 3], etc.). However all these programs have a disadvantage. If the light opening is in a general position plane, then to take into account its space position during the calculations, transformation matrices must be used (turn matrix, transition matrix etc.). This considerably increases the computing operation time and load on the central processor and random access memory. In addition, we did not manage to find information that these programs can work with all integral characteristics, only plane characteristics and light vectors.

THE SOLUTION PRINCIPLES

In this work, an attempt was made to construct a model of a room light medium, which would allow determining parameters of the light field from various configuration sources arbitrarily located in space. In doing so, modern facilities based on BN-calculation were used (the dot calculation of Balyuba-Naidysh) developed by Ukrainian scientists [4]. As distinct from other mathematical techniques in general and from vectorial calculus in particular, the dot calculation allows working directly with an object, in whichever space it would be, instead of with its projections. This feature is possible due to the use of special parameters, which are invariants of the parallel projection. Such an approach makes it possible to solve a needed task without use of transformation matrices.

The essence of the proposed method consists of the following. A basic element to determine integral characteristic of a light field is the solid angle of a space site, which radiates light to this point. The solid angle basis can be presented as a certain totality of points. In case parameters (coordinates) of these points are known, one can easily determine the solid angle using simple arithmetic operations.

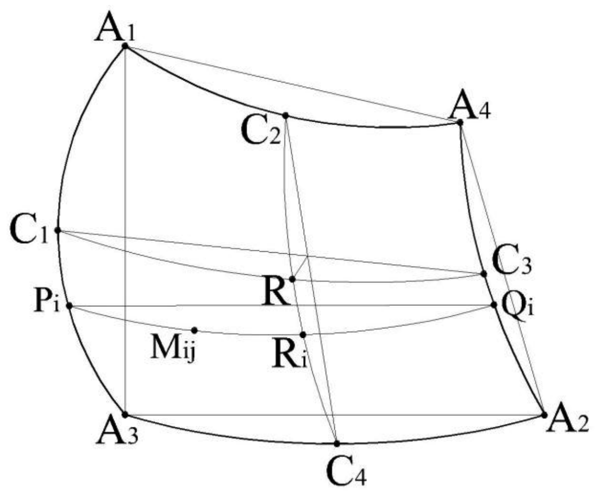


Fig. 2. A diagram of scanning a quadrangular light opening with curvilinear sides

A computer deals with numbers and operations with them. If a point is characterized using a totality of numbers, it is possible to simulate radiating sites of space by means of computer technologies. With this object in mind, one can use a Cartesian coordinate system, in which radiating site of space is set by a simplex of reference (characteristic) points accepted from architectural and structural considerations. For computer calculations, instead of continuous, a discrete point set from the considered geometrical object is necessary, which secures the needed calculation accuracy. The points forming a radiating surface can be presented as a system of their coordinate axes projections, which allow a coordinate calculation of geometrical configuration.

Let us take as an example a light opening (Fig. 2) in the form of a convex quadrangle with curvilinear counters (Fig. 1), with coordinates of angles vertexes and of four arcs: A_1 (x_{A1}, y_{A1}, z_{A1}); A_2 (x_{A2}, y_{A2}, z_{A2}); ... C_1 (x_{C1}, y_{C1}, z_{C1}); C_2 (x_{C2}, y_{C2}, z_{C2}); ..., as well as of the central point R (x_R, y_R, z_R). These coordinates are determined in relation to a point considered to be the coordinate origin. Here all parameters are determined based on the projection. After all, I am the architect who sets the configuration of the light opening and designates its size. If the central point approximately coincides with the geometrical centre, then scanning points will place uniformly.

To scan in the entire area of the curvilinear quadrangle, vertical $A_1 C_1 A_3$, $C_4 RC_2$ and $A_4 C_3 A_2$ sides should be expressed by point coordinates using the following equations of parabolas:

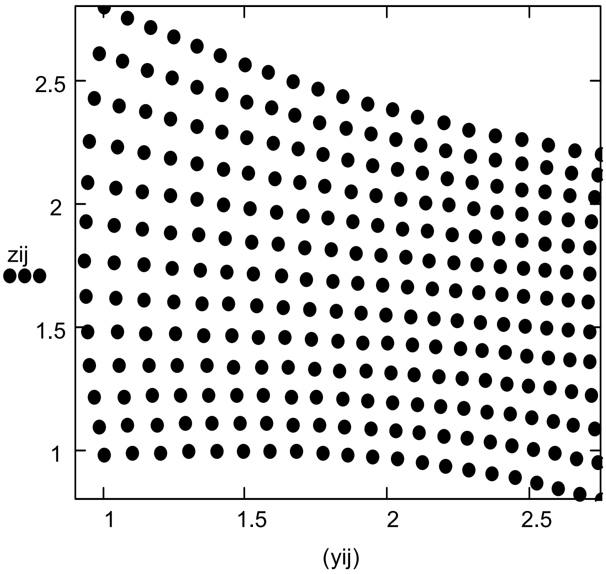


Fig. 3. Visualisation of a dot set for the light opening, which plane is inclined into the room by 25 ° from vertical (Fig. 1)

$$P_i = A_3(1-t)(1-2t)+4C_1t(1-t)+A_1t(2t-1);$$
$$Q_i = A_2(1-t)(1-2t)+4C_3t(1-t)+A_4t(2t-1); \quad (1)$$
$$R_i = C_4(1-t)(1-2t)+4Rt(1-t)+C_2t(2t-1),$$

where P_i, R_i and Q_i are current points of the correspondent arcs $A_1 C_1 A_3$, $C_4 RC_2$ and $A_4 C_3 A_2$;

To scan along another direction, the point equation of arc $P_iR_iQ_i$ is formed:

$$M_{ij} = P_i(1-\tau)(1-2\tau)+ \\ + 4R_i\tau(1-\tau)+Q_i\tau(2\tau-1), \quad (2)$$

where M_{ij} is a current scanning point within boundaries of a plain figure;

Then we change to parametrical equations in the coordinate configuration:

$$x_{ij} = x_{Pi}(1-\tau)(1-2\tau)+4x_{Ri}\tau(1-\tau)+x_{Qi}\tau(2\tau-1);$$
$$y_{ij} = y_{Pi}(1-\tau)(1-2\tau)+4y_{Ri}\tau(1-\tau)+y_{Qi}\tau(2\tau-1); \quad (3)$$
$$z_{ij} = z_{Pi}(1-\tau)(1-2\tau)+4z_{Ri}\tau(1-\tau)+z_{Qi}\tau(2\tau-1).$$

Here $0 \le t \le 1$, $0 \le \tau \le 1$ are parameters determining movement of point M_{ij} in vertical and horizontal directions. These are determined as follows:

$t = i/m$, $i = 0, 1, 2, 3,.. m$; $\tau = j/n, j = 0, 1, 2, 3,..n$.

An implementation of the proposed technique of forming a dot set carried out in a *MathCAD* medium with the correspondent parameters is presented in Fig. 3.

Luminous flux at some point of a room from the firmament is formed within a solid angle with the vertex in this point and is limited by the surfaces passing through counters of the light opening. Using the obtained scanning points, the whole solid angle of the window opening can be presented as a sum of elementary solid angles with vertex in a given point *N*, and pyramid sides pass through four neighbor scanning points (Fig. 4).

Coordinates of the scanning points, through which the sides of the pyramid pass, are determined from expression (3). Coordinates of the reference point, in which illuminance *N* (x_N, y_N, z_N) is determined, are set relative to the general coordinate origin. One can consider that within an elementary solid angle obtained in such a manner, luminance of the firmament is constant, and its value corresponds to the luminance value directed from the reference point to the middle of one of the diagonals (for example, $D_{\varepsilon v}$) of the obtained elementary quadrangle. The coordinates of this point are calculated:

$$D_{\mu/2} = \frac{M_{ij} + M_{(i+1)(j+1)}}{2}. \quad (4)$$

In order to determine illuminance in a plane, vector projections of solid angle σ, sr, will be determined using the known Vinner's formula:

$$\sigma^{D}_{\varepsilon\upsilon} = \frac{1}{2}\sum_{\lambda=1}^{p}\alpha_{ij}cos\beta_{ij}. \quad (5)$$

Angles α_{ij} are also determined using the dot calculation based on metric operators [4] according to formula (6). As an example, here determination of angular parameters for only one side is shown.

Value of $cos\beta_{ij}$ between the design plane and the side of an elementary pyramid is determined as the cosine of angle between their normals. Normal to the plane $M_{ij}M_{(i+1)}$ in the coordinate algorithm will be determined from expression (7).

(see eqn 6)

(see eqn 7)

As a result, cosine of the angle between the planes will be determined as follows:

$$cos\beta_{ij}^{(i+1)j} = \frac{x_{R1}x_{ij}^{(i+1)j} + y_{R1}y_{ij}^{(i+1)j} + z_{R1}z_{ij}^{(i+1)j}}{\sqrt{\left[x_{ij}^{(i+1)j}\right]^2 + \left[y_{ij}^{(i+1)j}\right]^2 + \left[z_{ij}^{(i+1)j}\right]^2}}, \quad (8)$$

where x_{R1}, y_{R1}, z_{R1} are coordinates of the point determining a single normal *NR* to the illuminated site. They are set so that the fragment would be perpendicular to the site, and its module $|NR|=1$. Cosines of angles for other sides of an elementary pyramid are determined in a similar way.

Then vector projection value of an elementary solid angle can be determined from the following expression:

(see eqn 9)

Illuminance of a reference point $E_{\varepsilon\upsilon}$, *lx*, from the firmament site within an elementary quadrangular pyramid is determined in accordance with the formula:

$$E_{\varepsilon\upsilon} = g_{\varepsilon\upsilon}^{D} L_z \tau_0 \sigma_{\varepsilon\upsilon}^{D}.$$

And general illuminance, lx from the whole light opening in reference point *N*, which is in the plane, will be equal to:

$$E_N = L_z \tau_0 \left(\sum_{\varepsilon=1}^{\nu} \sum_{\upsilon=1}^{\iota} g_{\varepsilon\upsilon}^{D} \sigma_{\varepsilon\upsilon}^{D} \right), \quad (10)$$

where $g_{\varepsilon\upsilon}^{D}$ is a coefficient of non-uniform luminance of the firmament towards centres of the elementary pyramid's foundation. The coefficient depends on the accepted model of the firmament (clear, overcast or semiclear) [5];

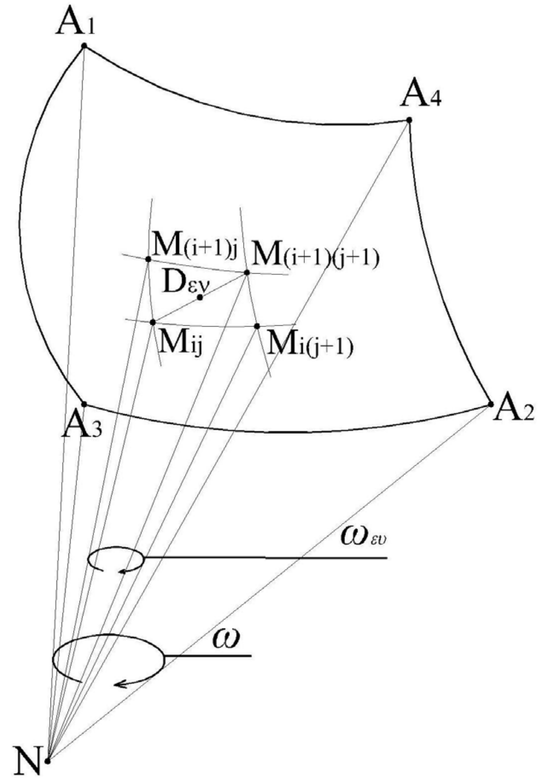


Fig. 4. Formation of the general and elementary solid angles

L_z is the zenithal luminance of the firmament, cd/m^2 [5];

τ_o is a coefficient taking into consideration light losses when passing through window fillings.

The value of the light vector module within an elementary tetrahedral pyramid will be determined as follows:

$$\alpha_{ij}^{(i+1)j} = arccos\frac{(x_{ij}-x_N)(x_{(i+1)j}-x_N)+(y_{ij}-y_N)(y_{(i+1)j}-y_N)+(z_{ij}-z_N)(z_{(i+1)j}-z_N)}{\sqrt{\left[(x_{ij}-x_N)^2+(y_{ij}-y_N)^2+(z_{ij}-z_N)^2\right]\left[(x_{(i+1)j}-x_N)^2+(y_{(i+1)j}-y_N)^2+(z_{(i+1)j}-z_N)^2\right]}} \quad (6)$$

$$\begin{aligned} x_{ij}^{(i+1)j} &= y_{ij}z_{(i+1)j} - y_{(i+1)j}z_{ij} + y_N\left[z_{ij} - z_{(i+1)j}\right] + z_N\left[y_{(i+1)j} - y_{ij}\right]; \\ y_{ij}^{(i+1)j} &= z_{ij}x_{(i+1)j} - z_{(i+1)j}x_{ij} + z_N\left[x_{ij} - x_{(i+1)j}\right] + x_N\left[z_{(i+1)j} - z_{ij}\right]; \\ z_{ij}^{(i+1)j} &= x_{ij}y_{(i+1)j} - x_{(i+1)j}y_{ij} + x_N\left[y_{ij} - y_{(i+1)j}\right] + y_N\left[x_{(i+1)j} - x_{ij}\right]. \end{aligned} \quad (7)$$

$$\sigma_{\varepsilon\upsilon}^{D} = \frac{1}{2}\left(\alpha_{ij}^{(i+1)j}cos\beta_{ij}^{(i+1)j} + \alpha_{(i+1)j}^{(i+1)(j+1)}cos\beta_{(i+1)j}^{(i+1)(j+1)} + \alpha_{(i+1)(j+1)}^{i(j+1)}cos\beta_{(i+1)(j+1)}^{i(j+1)} + \alpha_{i(j+1)}^{ij}cos\beta_{i(j+1)}^{ij}\right). \quad (9)$$

$$\left|\bar{\varepsilon}\right|_{\varepsilon\upsilon}^{D} = L_z \tau_0 g_{\varepsilon\upsilon}^{D} \tilde{\text{A}}_{\varepsilon\upsilon}^{D}. \quad (11)$$

Its origin is located in point N, and the direction coincides with direction $ND_{\varepsilon\upsilon}$. Coordinates of the vector final point are determined as follows:

$$E_{\varepsilon\upsilon}^{D} = \frac{\left|\bar{\varepsilon}\right|_{\varepsilon\upsilon}^{D} D_{\varepsilon\upsilon}}{\sqrt{(x_{\varepsilon\upsilon}^{D} - x_N)^2 + (y_{\varepsilon\upsilon}^{D} - y_N)^2 + (z_{\varepsilon\upsilon}^{D} - z_N)^2}} = \frac{L_z \tau_0 g_{\varepsilon\upsilon}^{D} \sigma_{\varepsilon\upsilon}^{D} D_{\varepsilon\upsilon}}{\sqrt{(x_{\varepsilon\upsilon}^{D} - x_N)^2 + (y_{\varepsilon\upsilon}^{D} - y_N)^2 + (z_{\varepsilon\upsilon}^{D} - z_N)^2}}. \quad (12)$$

And coordinates of the light vector from the whole light opening will be determined as a sum of coordinates of final points of vectors of all elementary pyramids:

$$XE_N^D = L_z \tau_0 \sum_{\varepsilon=1}^{\nu} \sum_{\upsilon=1}^{\iota} \frac{g_{\varepsilon\upsilon}^{D} \sigma_{\varepsilon\upsilon}^{D} x_{\varepsilon\upsilon}^{D}}{\sqrt{(x_{\varepsilon\upsilon}^{D})^2 + (y_{\varepsilon\upsilon}^{D})^2 + (z_{\varepsilon\upsilon}^{D})^2}};$$
$$YE_N^D = L_z \tau_0 \sum_{\varepsilon=1}^{\nu} \sum_{\upsilon=1}^{\iota} \frac{g_{\varepsilon\upsilon}^{D} \sigma_{\varepsilon\upsilon}^{D} y_{\varepsilon\upsilon}^{D}}{\sqrt{(x_{\varepsilon\upsilon}^{D})^2 + (y_{\varepsilon\upsilon}^{D})^2 + (z_{\varepsilon\upsilon}^{D})^2}}; \quad (13)$$
$$ZE_N^D = L_z \tau_0 \sum_{\varepsilon=1}^{\nu} \sum_{\upsilon=1}^{\iota} \frac{g_{\varepsilon\upsilon}^{D} \sigma_{\varepsilon\upsilon}^{D} z_{\varepsilon\upsilon}^{D}}{\sqrt{(x_{\varepsilon\upsilon}^{D})^2 + (y_{\varepsilon\upsilon}^{D})^2 + (z_{\varepsilon\upsilon}^{D})^2}}.$$

So angular height of the light vector (from the plane, in which reference point N is located) can be determined:

$$\varphi E_N^D = arctg \frac{ZE_{\varepsilon\upsilon}^{D} - z_N}{\sqrt{(x_{\varepsilon\upsilon}^{D} - x_N)^2 + (y_{\varepsilon\upsilon}^{D} - y_N)^2}}; \quad (14)$$

and azimuth of the light vector from axis Y:

$$\beta E_N^D = arctg \frac{XE_{\varepsilon\upsilon}^{D} - x_N}{YE_{\varepsilon\upsilon}^{D} - y_N}. \quad (15)$$

Mean spherical illuminance in a given point of a room within an elementary solid angle is determined under the following formula:

$$E_{\mu\hat{A}}^{4\pi} = 0{,}25 L_z \tau_o g_{\varepsilon\upsilon}^{D} \omega_{\mu\hat{A}}^{D}, \quad (16)$$

where $\omega_{\mu\hat{A}}^{D}$ is value of an elementary solid angle, str.

Value of the solid angle within the specified pyramid sides, is determined according to the following formula [1]:

$$\omega_{\mu\hat{A}}^{D} = 2\pi - \sum_{k=1}^{p} \left(\pi - A_{k,k+1}\right), \quad (17)$$

where p is number of sides of an elementary pyramid;

$A_{k,\,k+1}$ is a value of inner dihedral angle between the planes passing through the reference point and k and k+1 sides of an elementary pyramid.

To determine the latter, expressions of (7, 8) type are also used.

When substituting the angle values to formula (18), we obtain the solid angle value of an elementary pyramid:

$$\omega_{\varepsilon\upsilon}^{D} = A_{1,2} + A_{2,3} + A_{3,4} + A_{4,1} - 2\pi. \quad (18)$$

General value of the mean spherical illuminance can be obtained by a summation of illuminances from the all pyramids:

$$E^{4\pi} = 0{,}25 L_z \tau_0 \left(\sum_{\varepsilon=1}^{\nu} \sum_{\upsilon=1}^{\iota} g_{\varepsilon\upsilon}^{D} \acute{E}_{\varepsilon\upsilon}^{D} \right). \quad (19)$$

Here technique of constructing a light field model is presented using the parameter direct component only in a given point. However, a reflected component as well can be used with due regard for elements of the presented technique.

CONCLUSIONS AND PROSPECTS

The article proposes a new approach to create a model of the natural light medium for a room with light openings, which have curvilinear counters, and which are arbitrarily located in space. Such light openings are actively used in modern architecture. This work can be a basis for developing software when designing an optimum light medium in such buildings. The work is in its early stages and more research should be done in this direction. In particular, an interesting problem is the creation of a model of the light field in rooms with curvilinear surfaces. This problem can be also solved using the dot calculation.

REFERENCES

1. *Gershun A.A.*. Light field. In the book: "Selected works on photometry and light engineering", Moscow: Fizmatgiz, 1958, pp. 223–397.
2. *Larson G.W., Shakespeare R.* Rendering with Radiance: the art and science of lighting visualization. Morgan Kaufmann Publishers. San Francisco. California, 1998. P. 644.
3. *Bakharev D.V.* About design procedure of natural illumination // Svetotekhnika, 2006, № 1, pp. 57–59.
4. *Baluba I.G., Polishchuk V.I., Malyutina T.P.* Basis of mathematical apparatus of the dot calculation / Works of the Tavria State Agrotechnical Academy. Issue 4. Applied geometry and engineering graphics. V. 29. Melitopol: TDATA, 2005, pp.22–30.
5. *Darula N., Kittler R.*. A metod of calculation of natural illumination and modern trends of natural light evaluation // Svetotekhnika. 2006, № 1, pp. 28–34.

Vladimir A. Egorchenkov,
Ph.D., associate professor, graduated from Makeyevka Engineering and Construction Institute in 1972, up to 2014 he was in staff of Donbas's State Academy of Building and Architecture, at present he is a associate professor at Kiev National Aircraft University

Eugene V. Konopatsky,
Ph.D., associate professor, graduated from Donbas's State Academy of Building and Architecture in 2004, associate professor of the same academy chair of informative technologies and systems at present. The field of science is development of the theory of generalized trigonometry and goniometry, geometry simulation and modeling of quantity parametric processes and phenomenon

Light & Engineering
Vol. 23, No. 2, pp. 49-59, 2015

Svetotekhnika
No. 1, 2015, pp. 13-22

CONTROL OF PARAMETERS AND QUALITY OF LIGHT EMITTING DIODES AS WELL AS THEIR COMPOUND PRODUCTS IN HIGH-VOLUME PRODUCTION[1]

Alexander A. Bogdanov

Svetlana-Optoelectronics Company Group, St.-Petersburg
E-mail: avramenko@soptel.ru

ABSTRACT

Checking product parameters and quality is an important component of the manufacturing process. It intends to reveal defects in finished products and to check their reliability during the production process. The purpose of this article is to familiarise a broad range of specialists with the experience of Svetlana-Optoelectronics Company Group in the product check process for light emitting diodes and their compound lighting products, and with its ideas and proposals on the product quality control and quality confirmation.

Keywords: light emitting diodes, light-emitting diode industry, check of parameters, quality control, concept, goniophotometer, production localization

Svetlana-Optoelectronics CG is one of the oldest (established in 1998) and largest enterprise associations of the domestic light-emitting diode industry in Russia. It is one of very few domestic industrial groups implementing a full work cycle of light-emitting diode manufacture, including production of light-emitting crystals, LEDs themselves, as well as assemblage of a wide spectrum of lighting devices (LD) with different functions.

A conceptual moment of the CG's activity is a large-scale manufacture of a wide range of light emitting diodes (LED): from half-watt LEDs to multicrystal LED matrices of 100 W power. Prospective development can expect the implementation of 200 W matrices in 2015. All types of LED are intended for the most effective illumination functioning in each LD type. Therefore, the variety of LEDs produced, allows for the creation of a wide range of LD products for both general and special purposes.

As the result, Svetlana-Optoelectronics CG meets the needs of a wide range of partners: Russian Railways Open Society, State Corporation "Rosatom", Inter Russian Open Society, the Ministry of Education and Science of the Russian Federation, etc. In cooperation with them, the comprehensive introduction of energy-effective illumination systems using light emitting diodes (LEDIL) are taking place[2].

The current volume of the LEDIL market in Russia amounts to 16 billion rubles according to expert evaluations. Approximately 60 % of this is accounted for by state and municipal orders, financed from the state budget. Target objects of this class have a supreme importance, both from the societal point of view and from that of broad lighting safety. Therefore, the reliability and quality aspects of products, including LDs with LEDs used in these objects are extremely topical.

[1] Adapted from materials of a report at the 8th Moscow International Conference "*LED FORUM*" 12.11.2014, Moscow.

[2] Specific objects such as nuclear power stations should be emphasised. They demand the most careful attention to the quality of the products supplied of any purpose. These are enterprises of strategic value, and they are subject to state procurement practices, where strict conditions of observing and confirming standards and technological regulations are used.

The poor quality products using leads to high rates of replacement even within the warranty period, which is rarely exceeding three years. This situation is typical almost 60 % of all LDs with LEDs, which are mostly produced in China. They are sold at low prices, which is the main factor for the existing purchase system for state and municipal needs. However, at the declared three-year warranty period, almost 100 % of these products fail within one year, essentially multiplying the cost for service and replacement of the LDs. These failures interfere with users' health and safety all over the country. Fig. 1 illustrates this with a diagram of a model calculation of LED-production consumer benefit. The diagram takes into consideration three main groups of manufacturers of lighting with LED products on the Russian market: (1) Chinese manufacturers or domestic companies applying a complete rebranding (60 % of the market); (2) domestic producers using imported components with less than 50 % local production (30 % of the

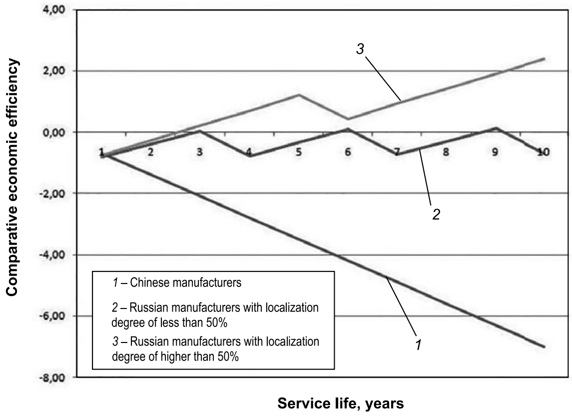


Fig. 1

Clean rooms and controllable mediums connected with them are intended to retain cleanliness of air in certain limits depending on requirements of the processes sensitive to a pollution.

APPLICATION AREAS OF CLEAN ROOMS

CLEAN ROOM is a room, in which concentration of the particles weighed in air is controlled (solid or liquid objects by size 0.1-5 micron). It is constructed and used so that to minimize accession, emission and retention of the particles indoors, and allows if necessary controlling other parameters, for example, temperature, humidity and pressure.
Light emitting diode production shop of of Svetlama-Optoelektronics company groups:

- Air temperature is 22 ± 2°C (a room of the seventh cleanliness classes). 22.5 ± 2°C (a room of the ninth cleanliness class);
- Air humidity in the of in the cleanliness seventh classes is – 50 ± 10%.

These conditions are necessary not only to provide a necessary level of cleanliness but also for correct work of the technological equipment and effective application of the materials

To designate air cleanliness degree in clean rooms and in controllable mediums connected with them, cleanliness classes are used

ISO Class N (Classification number)	Maximum admissible concentrations of particles (particles/m^3) with the sizes equal or bigger than the following values, micron					
	0.1	0.2	0.3	0.5	1.0	5.0
ISO Class 1	10	2	—	—	—	—
ISO Class 2	100	24	10	4	—	—
ISO Class 3	1000	237	102	35	8	—
ISO Class 4	10000	2370	1020	352	83	—
ISO Class 5	100000	23700	10200	3520	832	29
ISO Class 6	1000000	237000	102000	35200	8320	293
ISO Class 7	—	—	—	352000	83200	2930
ISO Class 8	—	—	—	3520000	832000	29300
ISO Class 9	—	—	—	35200000	8320000	293000

Fig. 2a

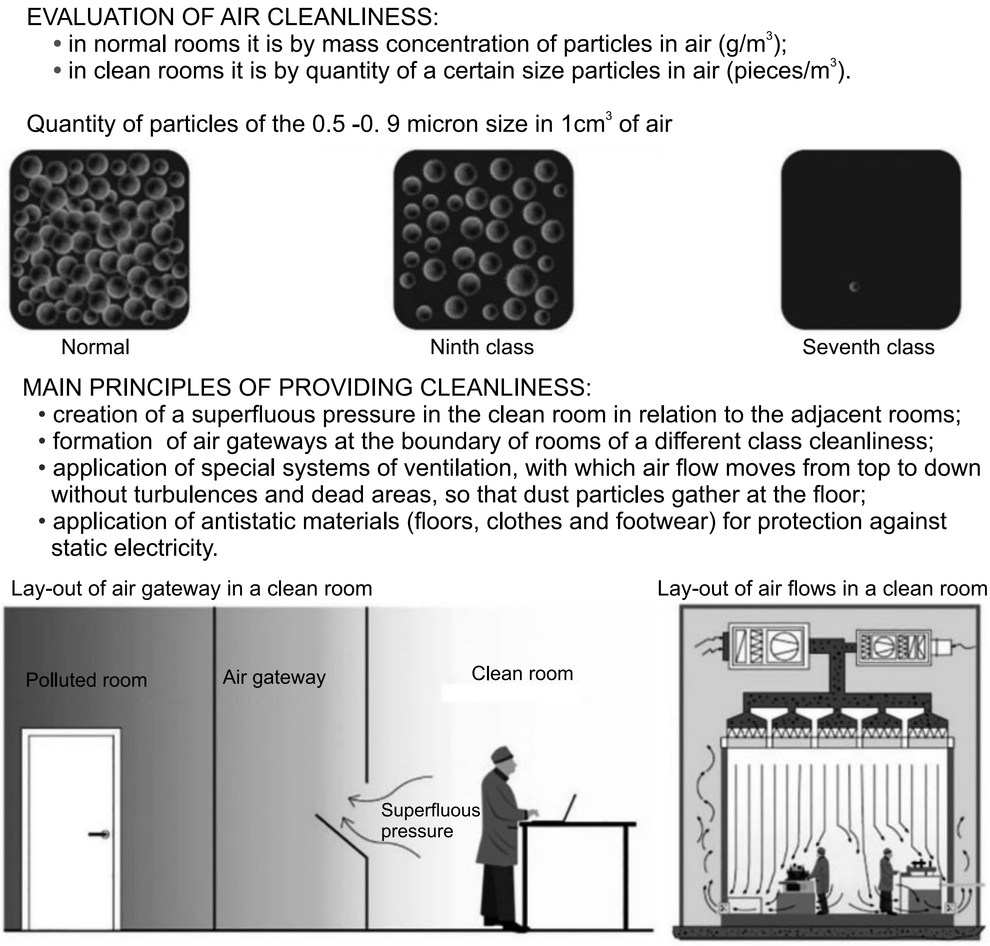


Fig. 2b

market); and (3) domestic manufacturers with more than 50 % local production (10 % of the market).

Fig. 1 shows that the use of high-quality products, primarily domestic with a minimum warranty service life and with a transparent mechanism of quality assurance, is more economically viable for the operating (service) companies than using cheap Chinese products.

In our opinion, both the users and the manufacturers can only access this benefit when the production is localised to the Russian Federation. In this case, localised is understood as the availability of a base of production, which allows manufacturing LEDs as a foundation to ensuring an appropriate product quality and long service life.

It can be argued that it would be best to have an entirely domestic LED production industry, in which manufacturers of the equipment, materials, as well as developers and the manufacturing process itself were clearly and logically coordinated with each other. But for the present, all Russian manufacturers mostly use imported assembly equipment, and there are no domestic manufacturers of similar equipment for assembling LEDs, let alone for growing the crystals. Therefore, localisation primarily refers to the availability of the modern high-efficiency automated equipment for manufacturing white glow LEDs at a manufacturing plant. It should be also noted that having local manufacture in the Russian Federation allows replacing LED products after their service life termination with more effective LEDs because of the continuous improvements in LED efficiency, and so benefit to the users will increase.

Undoubtedly, the quality of products is enshrined at the design stage and the development of production technology. One of the key aspects of any development is the division of labour. When a manufacturer tries to penetrate deep into the LED physical processes, which are not simple, he/she uses his/her resources ineffectively. It is better to cooperate with specialised research centres. The manufacturer should have a strong theoretical understanding, which allows on the one hand, sharing a common language with the scientists, and on the other hand,

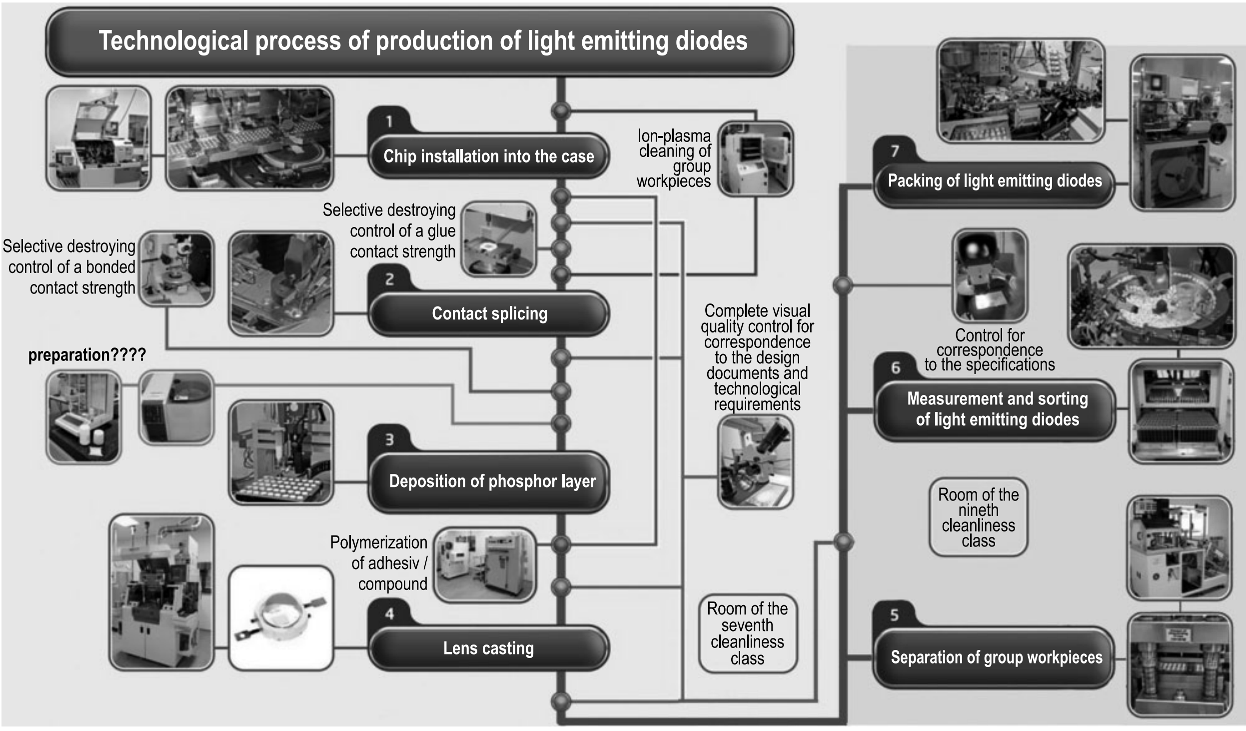


Fig. 3

MIL-STD-883H method 2011.8.		
Diameter of the wire	25 mcm	32 mcm
Minimum tear force for the bonded contact, g	3.0	4.5
EIA/JESD22-B116 (2.5-4D)		
Minimum average value of shear force for bonded contact, g	20.6-55	35.6-95.1

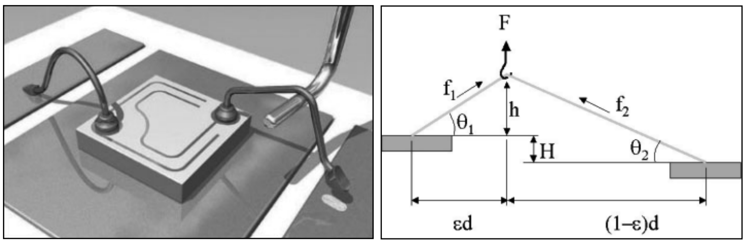


Fig. 4

checking the declared results. Without a correspondent metrological basis, appropriate developments are also impossible[3].

However, a simple transfer of well-known fundamental technological principles into production is impossible without a previously prepared manufacturing base, which takes into consideration specific characteristics of a product for serial production. Completing this task without significant investments into the means of production is impossible.

For assembling microelectronic products such as LEDs, a well prepared infrastructure is required, namely systems of steady, uninterrupted electric and water supply; ventilation and air-conditioning systems. The production building should have a suitable structure, with vibration-resistant foundation, with locking between the rooms, etc. Mass production of serial LEDs is impossible without meeting all these requirements. The main requirements of the manufacturing plant implemented by Svetlana-Optoelectronics CG, are given in Fig. 2.

[3] As measuring equipment is important at all main stages of the development process, its application should guarantee that the solution intended for serial production will be of an appropriate quality and reliability.

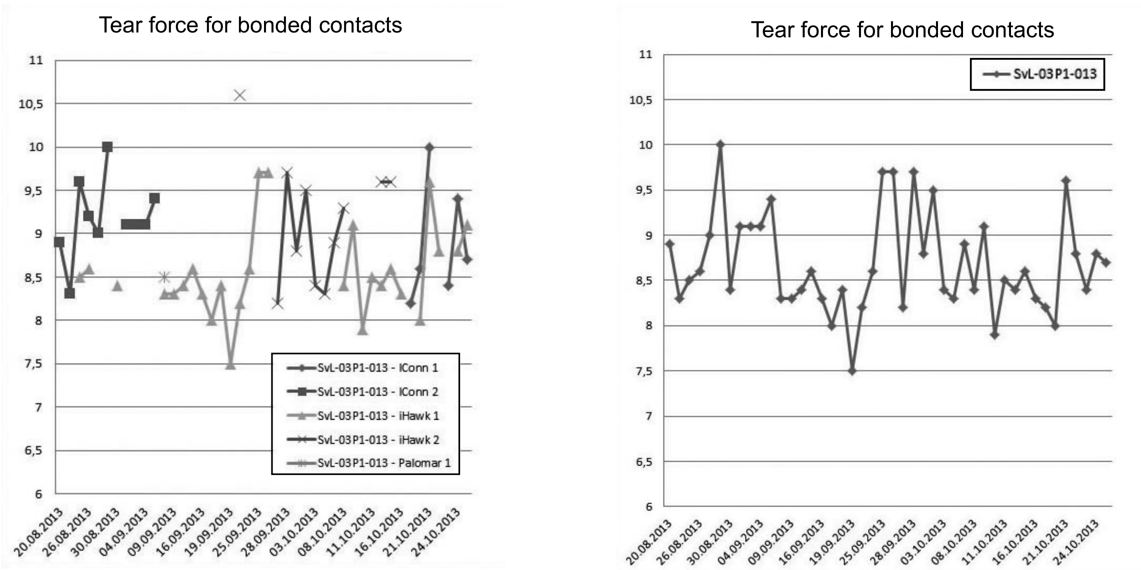


Fig. 5

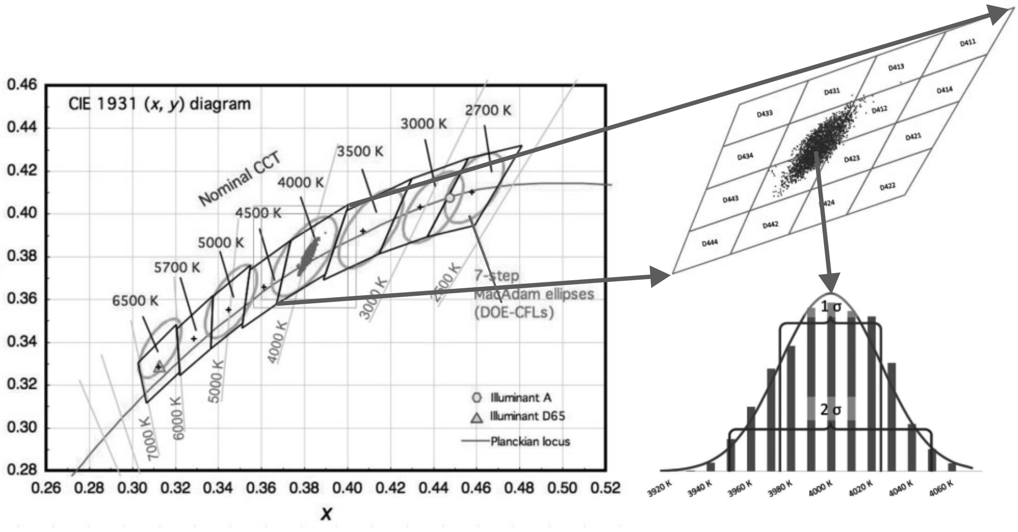


Fig. 6

The layout of the LED technological process is shown in Fig. 3. As it can be seen from the figure, to ensure proper product quality, all technological process should be subject to a system of checks, which are carried out directly within the production process. It is necessary to trace possible fluctuations on the fly against an established technology. In order to understand the importance of check operations, we will explore one such principle process.

Electronics is a science about contacts, and consequently the quality check of thermosonic bonding, which secures electric contacts between bonding pads of the light-emitting crystal and of the LED case, is crucial. Taking into consideration that at a real enterprise, the equipment can be of different types and brands, the checking process should be constant and systematic. Quality control of bonded junctions is based on two types of test: shear test and tear test. It should be noted that the tests are performed using international techniques *MIL-STD-883 H* and *EIA/JESD22-B116*, which do not have correspondent versions in Russia. A visualisation of the control process results is given in Figs. 4 and 5.

The experience of high-volume production gives evidence that these test methods guaranty a sufficient quality of thermosonic bonding, when a selective triple control for the operation shift is made. The second operation in order of importance is a dosed deposition of phosphor mixture on the initial packed light-emitting crystal of blue (dark blue) glow. The importance of a control operation at this stage, in term of obtained chromaticity coordinates,

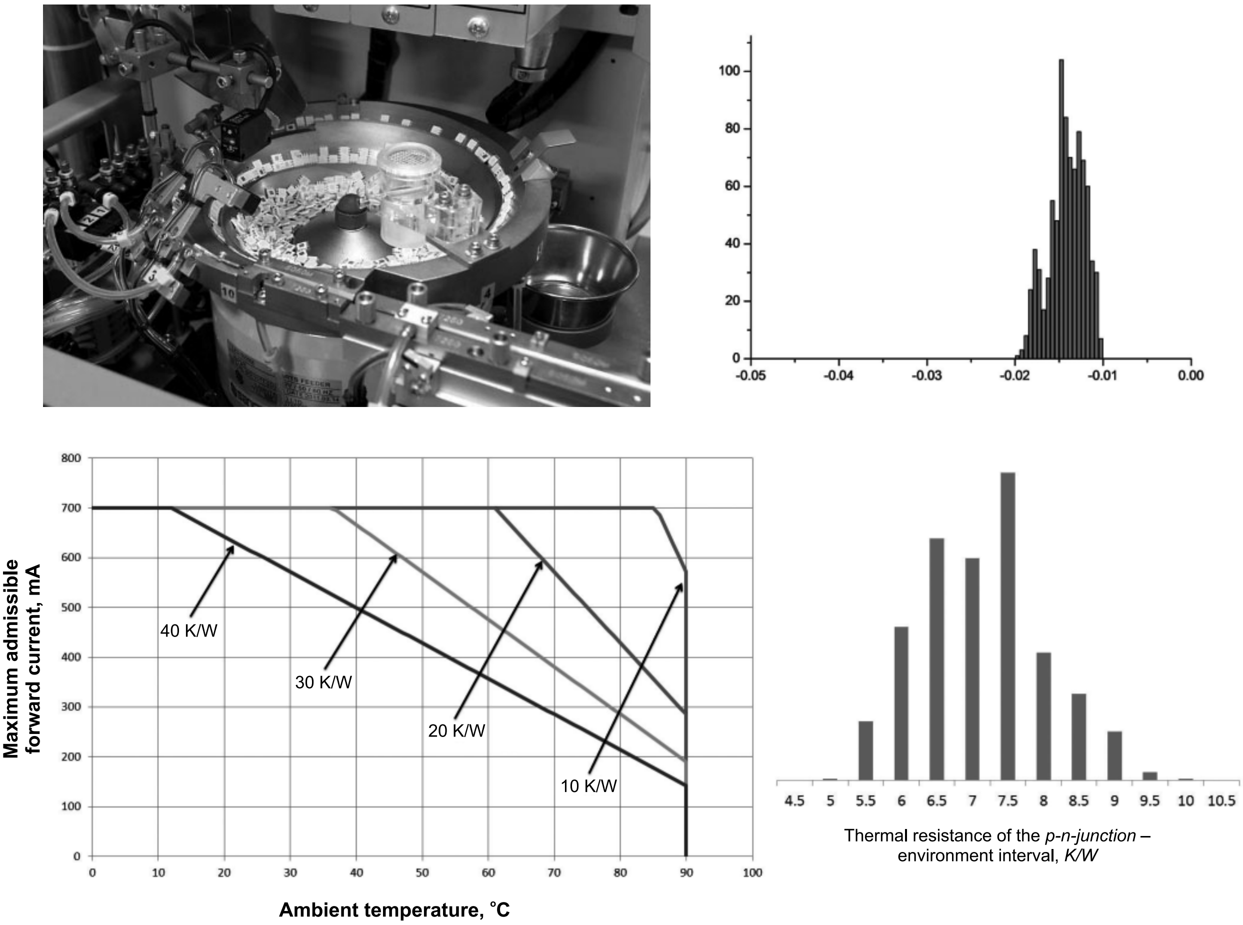


Fig. 7

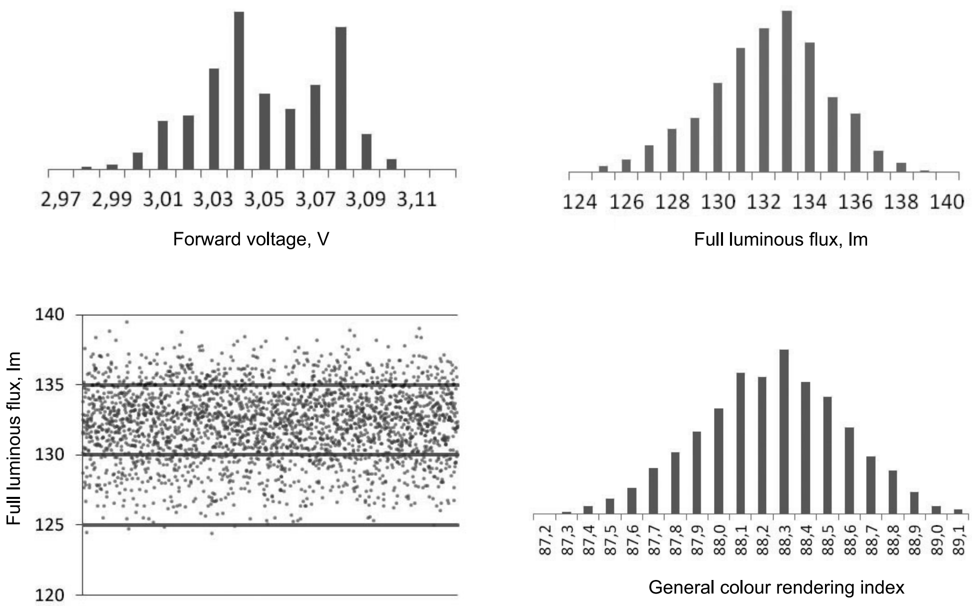


Fig. 8

is connected both with the fact that any correcting actions after forming the phosphor layer is impossible, and with a high performance of this technological process. Therefore, control of radiation chromaticity is made directly after formation of the phosphor layer for the all LEDs. Criteria for LED rejection are rather strict, and regulated by our own standard of white colour accepted at the enterprise. Results of this process are presented on a CIE 1931 chromatic diagram (Fig. 6).

It can be seen from the Fig. that such an approach secures sufficiently concentrated and uniform distributions, which give evidence of the high chromatic uniformity of the final products.

The final operation of any technological process is the output check of the product parameters. The evaluation methods of the output control results and the selection of controllable parameters can frequently be subjective. Not all manufacturers estimate at the output control value of thermal resistance as the heat transfer quality indicator for the manufactured LEDs. It is well established that the quality of heat removal from LEDs dictates their durable and reliable performance in LDs. The control of thermal characteristics in our technological process is performed using a method of evaluating the change in voltage temperature coefficient arising when supplying short voltage test pulses. This test allows precisely determining thermal resistance levels, both at normal environmental conditions, and empirical setting "corridors" of thermal resistance values for extreme temperature levels according to the intervals of the proposed climatic versions. Based on these data alone, it is possible to ensure a safe working LED. An example of this is given in Fig. 7. The availability of such LED information predicts and confirms the possibility of its application in real LDs, which are not always operated under normal environmental conditions, and usually manufactured in climate versions У1 or УХЛ1, that is operation even at – 60 and + 60 C° is possible.

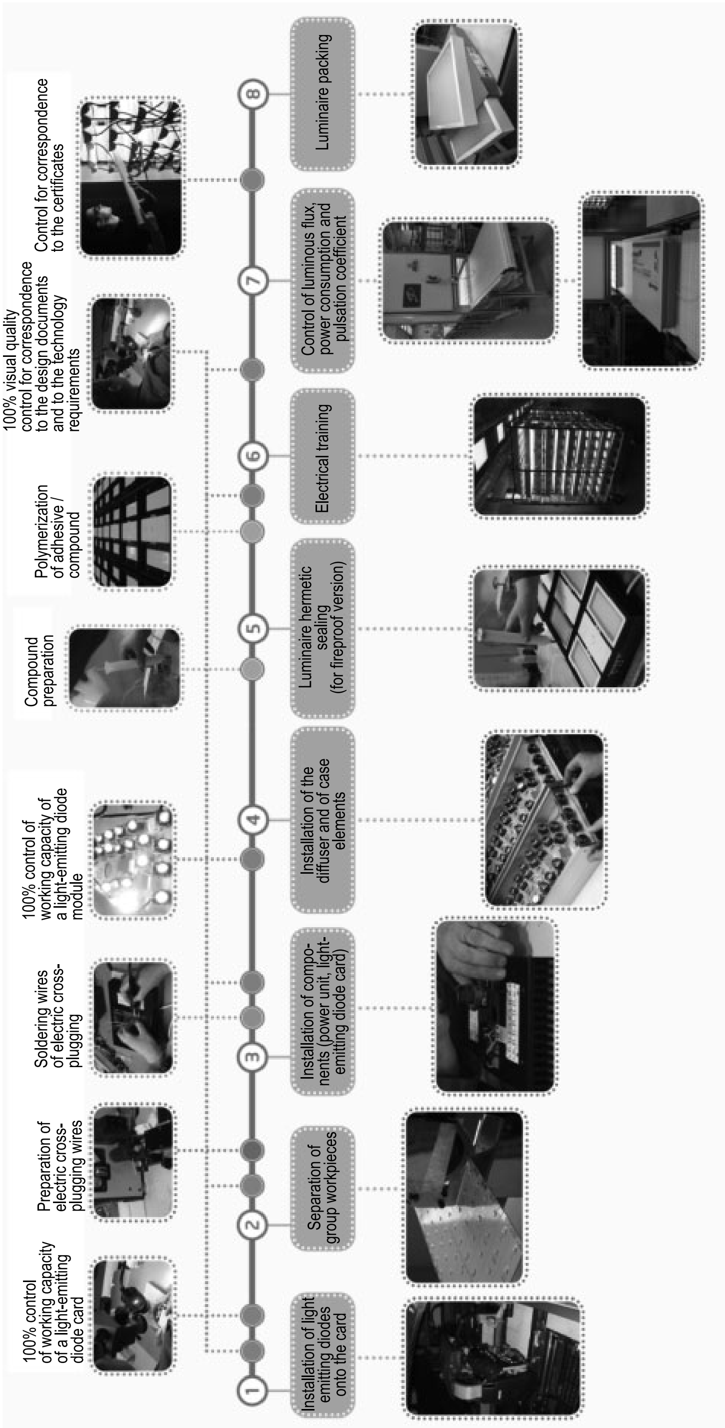
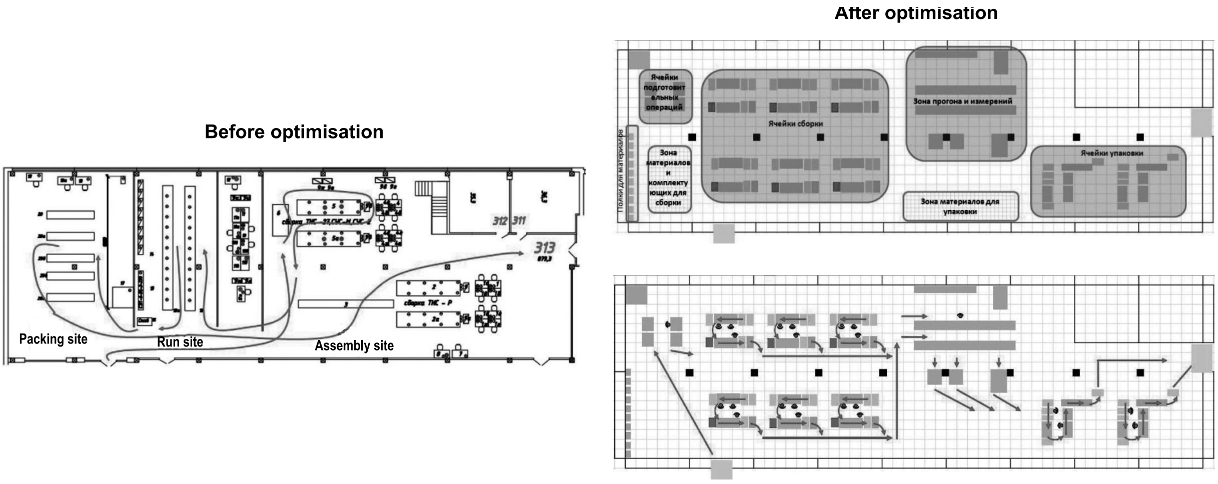


Fig. 9

Parameters, which are usually measured at the output control, such as direct voltage with a set working current, full luminous flux and correlated chromatic temperature (normally combined with determination of general colour rendition index), also demand an objective interpretation. Typical distributions of these parameters within serial production are presented in Fig. 8. It is matter of principle here that any of these normalised values is rated, and should always have an allowance. In case of high-volume production, a priority of the manufacturer (especially of LEDs) is the minimisation of admissible technological parameter spread. Theoretically, the spread of parameters should be such as most part of the LED estimated parameter distribution with-



Optimisation of a production site when implementing principles of lean production

Fig. 10

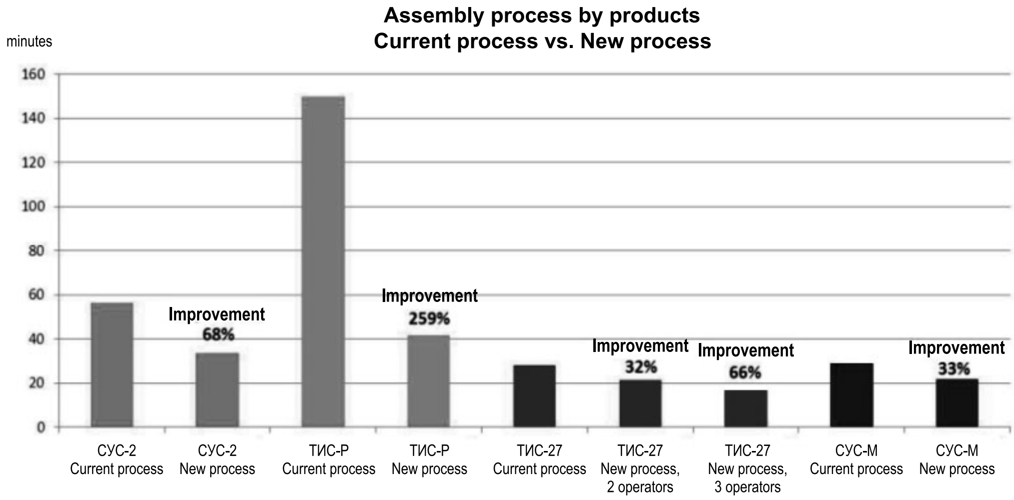


Fig. 11

in the allowance, were reliably equal or little more than the rating values. Otherwise this can lead to, for example, a shortage by luminous flux in final LDs, especially if they were designed for a large number of low-power LEDs.

The totality of technological process quality criteria when manufacturing the abovementioned LEDs is, in our opinion, a basis for securing reliable final product LDs with LEDs. It should be taken into consideration that the assemblage of an LD is a multistage technological process, of which one aim is not to harm the quality of the LEDs used and the other components.

A schematic diagram of the assembly of an LD with LEDs and parameter check processes implemented at Svetlana-Optoelectronics is given in Fig. 9. In view of the traditional character of technological approaches applied in this process, which are designed to meet the ISO system quality procedure and requirements, we will consider solutions, which in our opinion are innovations for the domestic industry. Namely, we will consider an experience of introducing the principles of "economical production" (*lean production*) at a manufacturing enterprise, the main aim of which is to decrease production costs. The types of losses, which this approach can eliminate, are as follows:

1. *Overproduction* i.e. manufacturing of products, which are unnecessary; production in a greater volume earlier or faster than is required at next stages of the process.

2. *Excessive reserves/capacities* i.e. superfluous quantity of half-finished products, materials, raw materials, i.e. excessive costs, unused materials.

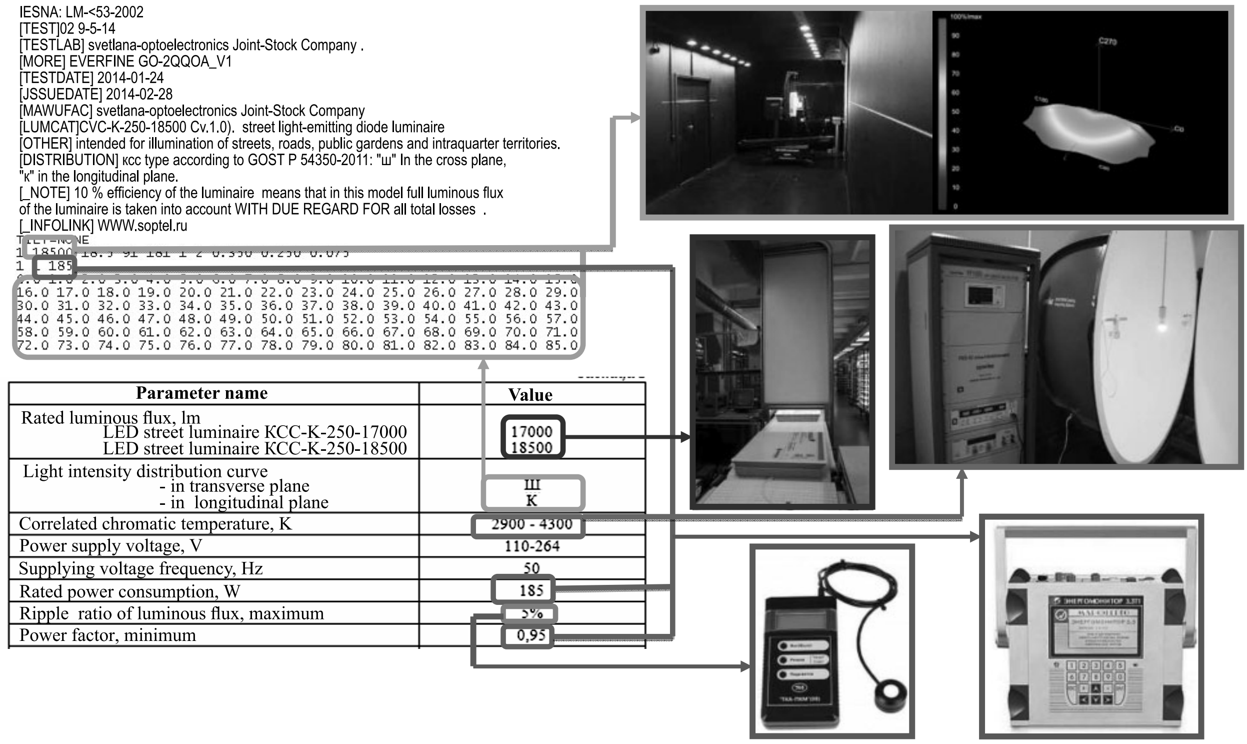


Fig. 12

3. *Excessive processing,* i.e. efforts, which do not add any value to a product/service from the consumers' point of view.

4. *Unnecessary movements* i.e. any movement of people, of tools or equipment, which does not add a value to end products or services.

5. *Defects*, i.e. products demanding a check, sorting, recycling, decrease of quality grade, replacement or repair.

6**.** *Idle periods,* i.e. operation breaks connected with waiting for people, materials, equipment or information.

7. *Unnecessary transportation*, i.e. movement of products (including unfinished) or of materials within the enterprise.

The most evident illustration of the results of the work arranged using the *lean production* principles, is the increased of labour productivity through elimination of irrational movement and creation of convenient interchangeable production cells, which flexibly and quickly respond to the current production situation. Fig. 10 shows the layout and lines of inter-operational routes of an assembly shop before and after rearrangement using the *lean production* principles. A comparison of target indicators for decreasing the period of assembly operations for four types of lighting devices before and after the shop reorganisation is presented in Fig. 11. It is seen from the Fig. that it was possible to decrease time for manufacturing all of the products, and for some of them (a luminaire for beam illumination) by more than by 200 %. This result indirectly influences the LD quality reached not by intervention into the product structure, but by optimisation of production.

At the same time, it would be incorrect to say that the quality of LD with LED only depends on the optimisation of the technological process logistics. As well as in LED production, final quality criteria are output control operations confirming observation of the declared properties. LDs are finished devices ready to use, which should first of all be safe. Therefore, the first operation of the output control is a complete LD check for correspondence to the electrical safety requirements.

Of all the variety of LD indicators normalised and checked in a high-volume production process, luminous flux and power consumption should be emphasised. 100 % of the products are obligatory objects to be controlled using these parameters.

Again, as well as with LEDs, we consider necessary to pinpoint the fact that the declared values should be ratings and that an objective allowance band for these should be present. In our opinion, based on long-term experience developing and producing LD with LED, as well as on a practical

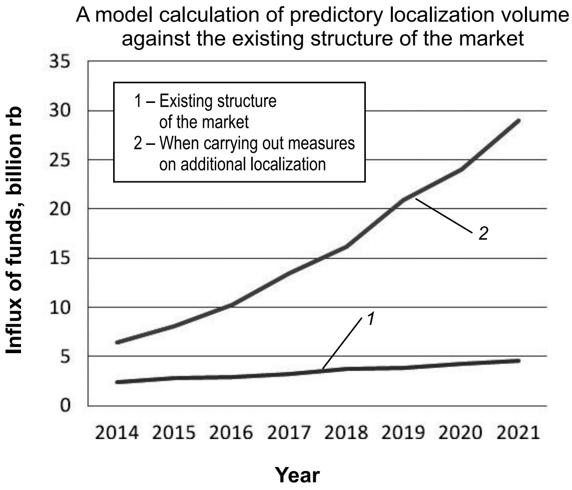


Fig. 13

implementating design solutions, allowance for the main rating values cannot be more than ± 10 %.

The question which now arises is, how can, for example, luminous flux be measured under conveyor production conditions? Using a goniophotometer each time? This is no possible due to the long duration of such measurements. Instead, an indirect measurement normalisation of goniophotometer registration should be used when carrying out the check operations. That is, creating an optimum number of control and measurement stands registering LD illuminance level data at several points with a simultaneous measurement of power consumption. Their number depends on the LD solid of light distribution, but normally it should be no less than five. There is no other method, and therefore any of a high-volume lighting product enterprise should have such a system of control and measuring equipment, including a goniophotometer.

Use of a goniophotometer is also a unique method, which allows obtaining trustworthy information about LD solid of light distribution for its further use as a mathematical model (*ies*-file) to design illumination systems. There are no other methods. At the same time, it is well known that nearly always in *ies*-files of unfair LD manufacturers, efficiency of the latter is more than 100 %, and power and luminous flux, according to *ies*-files, does not correspond to those specified in other product documents (for example, in the operation manual). As an example, Fig. 12 vividly shows an objective interrelation of key LD parameters presented in the accompanying documentation. In our opinion, it is necessary that information presentation were uniform for all manufacturers and were inevitably controlled by a correspondent authorized supervising body. Clearly traced documents are warrants of manufacturing high-quality products and of the reliability of the results obtained as quality criteria. Any manufacturing enterprise, which has implemented all these procedures, can easily take part in fair procedures of certification, whether it be a voluntary certification, a certification under technical regulations of the Customs union, or certification system "*TÜV International Certification*".

Against the above described and correctly determined and checked values, one specific problem arises (twice as problematic for LED products). The ambiguity of the situation is that one of main advantages of devices with LEDs is their long service life. As to the LEDs themselves, standard documents exist as service life evaluation recommendations using extrapolation methods. However, there are no similar documents for LDs. Another circumstance is that the products are almost never operated at normal (room) environmental conditions. They work in a real environment. How can this fact be taken into consideration and checked? Currently, there are no suitable methods.

The roadmap of development and research in the field of semiconductor illumination of the US Department of Energy serves as confirmation of this fact. It is said in p. 4.3.1 that at present there are no reliable methods to determine service life *even* by luminous flux decrease. And it is specified there that measurement of dynamics of luminous flux decrease for devices with LEDs, is not a sufficient basis to determine service life of a product as a whole.

In our opinion, there is only one way out of this situation: the manufacturer guarantees product quality and undertakes warranty certificates on the service, even within the whole life cycle[4]. Clearly, such a solution is only possible if the manufacturer's production localisation is greater than 50 %, and if the following technological principles securing the production quality are observed:

• High degree of automation and mechanisation of the technological processes with minimum influence of human factor.

• Use of equipment, which is highly precise certified.

[4] For this reason exactly, the warranty period for equipment at nuclear power stations is set at seven years, and the possible increase to 15 years is being discussed.

• Highly experienced personnel. Systems training and additional training of the personnel. Personnel certification.

• Complete protection against static discharge.

• Daily verification of the process equipment and of the technological processes themselves. Correction of the control programs in case of non-compliance with the requirements of the technological and design documents revealed during the verification.

• Periodic inspection of the technological process throughout the day, quality control and check of correspondence to the technological documentation requirements.

• Control of the process specifications, electro vacuum hygiene and of the process equipment.

• Development of the technological process checking methods, checking the process and research of the material characteristics.

• Measurement of the material's physical parameters, control correspondence of glue and wire contacts to national and international standards, using the test equipment.

• Mathematical processing test measurement results, introduction of the information to the database and its analysis.

• Development of technical control and test methods.

• Correction of the technological process using the results of finished product testing.

• Formation of a database of physical properties and technological features of materials to provide a choice when optimising the production and introducing new projects.

Therefore, it should be noted that without due investments in the production plant and in minimising dependence on foreign suppliers, rolling-down of the LED industry to the screwdriver type is inevitable. A simple import of ready products from China with a subsequent rebranding is more probable.

The only means of avoiding this is strengthening the domestic production by creating conditions and requirements to provide product quality at the production stage, which is only possible by means of increasing the degree of localised production.

The results of a model calculation of the localisation volume forecast against the background of the existing market structure (Fig. 13) show that domestic production can provide a real competition to foreign manufacturers if the localisation degree is higher than 50 %. With further growth of the localisation degree, a natural replacement of foreign products on the interior market will occur. This will be accompanied by an increase in investment into domestic production from 5 to 40 billion ruble. Such a tendency, together with consolidated support from key ministries and departments, and from the professional community of LED device manufacturers will be able to provide a scaling effect, which will contribute to growth in gross national product and of the energy efficiency of the Russian economy.

Besides the economic benefit itself, increasing the degree of production localisation also has other significant consequences for the country as a whole:

– Creating new workplaces, including highly qualified ones;

– Development of all industries involved in the main manufacture of lighting products with LEDs;

– Increase of economic, energy and ecological sustainability of the country.

It is important to note that the above is not limited exclusively to illumination. Taking into consideration the possibility to introduce it into other industries, the formation of a complete system becomes possible, which will eventually secure an appropriate quality for almost any product.

Alexander A. Bogdanov,
Ph.D., senior lecturer. Deputy Director of the Department of strategic projects of Svetlana-Optoelectronics CG (he is responsible for expert evaluation of the projects based on light emitting diode illumination systems). He frequently takes part as an expert in leading Russian and International conferences on light-emitting diode subjects. He also is a trustee of the Noncommercial partnership of manufacturers of light emitting diodes and systems (NP MLEDS)

Light & Engineering
Vol. 23, No. 2, pp. 60-63, 2015

Svetotekhnika
No. 1, 2015, pp. 40-42

WHITE LIGHT-EMITTING DIODE RADIATORS OF CIRCULAR OPERATION FOR SIGNAL LIGHTS ON BOATS AND FOR WATERWAY NAVIGATION SIGNS

Nina A. Galchina, Alexei L. Gofshtein-Gard, Lev M. Kogan, Alexander A. Kolesnikov, Naum P. Soshchin, and Boris K. Flegontov

OPTEL Scientific–and-practical Center Open Company, Optron Open Company and the Moscow State Academy of Water Transportation, Lyuminofor Research-and-production Company, Fryazino; The Moscow State Academy of Water Transportation» Federal Budgetary Enterprise of the higher vocational training, Moscow
E-mail: levkogan@mail.ru

ABSTRACT

White light-emitting diode radiators of circular operation are developed for signal lights on boats and for navigation signs of waterways. The structure of the radiators is described and their key parameters are given: luminous intensity in the horizontal plane is equal to 95–120 cd (without Fresnel lens), the radiation angle in the vertical plane is 40 °, which secures visibility of the lights when lit from boats or navigation signs at a distance of up to 10 km.

Keywords: light emitting diode, light-emitting diode radiator, luminous intensity, correlated chromatic temperature, radiation angle, radiation indicatrix, lens

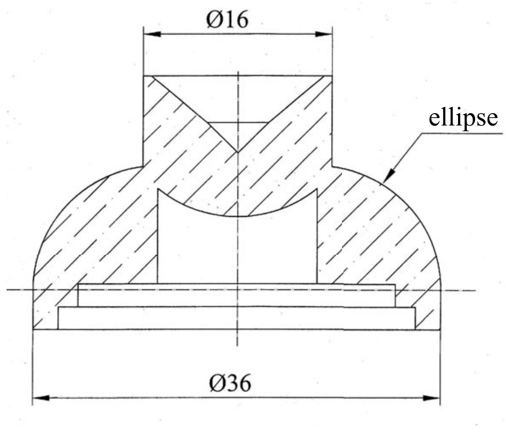


Fig. 1. Polymeric case of the radiator

In order to increase navigational safety, equipping boats and navigation warning signs on waterways with signal lights of increased visibility based on energy saving LED radiators is necessary. Three types of white lights are required for boat light alarm system: masthead, aft and circular[1]. Their LED radiators should have certain circular radiation indicators. A special transparent polymeric case was developed for them (Fig. 1) [1].

Its bottom part (refractive index n = 1.5–1.6) is an ellipsoid, its big axis is located in the horizontal plane of the radiator passing through the illuminating surface of the phosphor. Eccentricity of the ellipsoid is equal to 0.50–0.55, and the centre is displaced from the radiator centre by 0.35–0.4 of its long semi-axis length. This part of the case has a central cylinder cut, which is topped by a spherical surface, convex towards the phosphor.

[1] Masthead light is a white light located in the diameter plane of a boat. The light radiates a continuous light by a horizon arc of 225°. It is located so as to be visible from the direction in which the boat is heading by no less than 22.5° behind the beam line of each board.

Aft light is a white light located at the aft part of a boat. It radiates a continuous light by a horizon arc of 135° and is located so that its light is visible from the right astern direction no less than 67.5° from each board.

Circular light is a white light providing a continuous light by an arc of horizon of 360°.

Fig. 2. Appearance of a radiator of the У-217 Bl type (for boat lights)

The top part of the case is made as a cylinder with a built-in conic reflector. The diameter of the cylinder is equal to 0.44–0.48 of the diameter of the bottom part of the case, and diameter of the cylinder cut in the bottom part of the case is equal to 0.8–0.9 of the diameter of the top cylinder part.

To manufacture white LEDs we used blue crystals (of *InGaAlN* heterostructure) of 1.52×1.52 mm size of *SemiLEDs* Company.

The LEDs are placed on a metal printed-circuit board and contain four crystals connected in series.

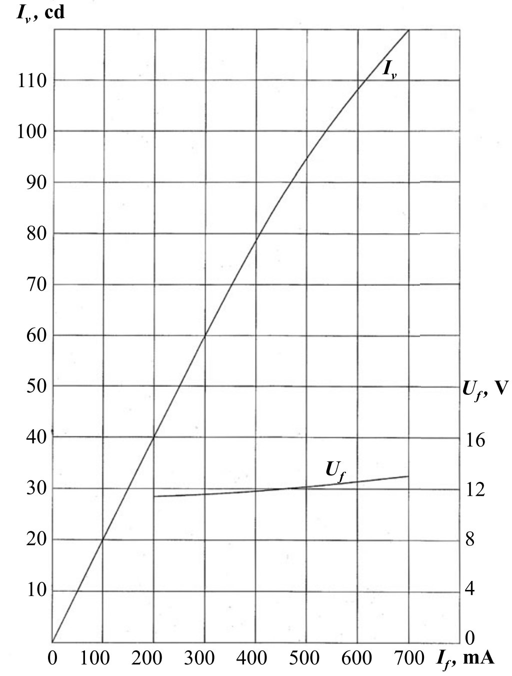


Fig. 3. A radiator of У-217 Bl type: luminous intensity I_v and forward voltage U_f dependence on forward current I_f

The light-converting LED unit includes a ceramic reflector, silicone with *n* = 1.53–1.54 and a phosphor placed far from the crystals [2]. The phosphor is made from aluminum-yttrium garnet [3].

The LED radiator for the boat lights (of У-217 Bl type) (Fig. 2) contains a heat sink for heat removal. The radiator has the following parameters:

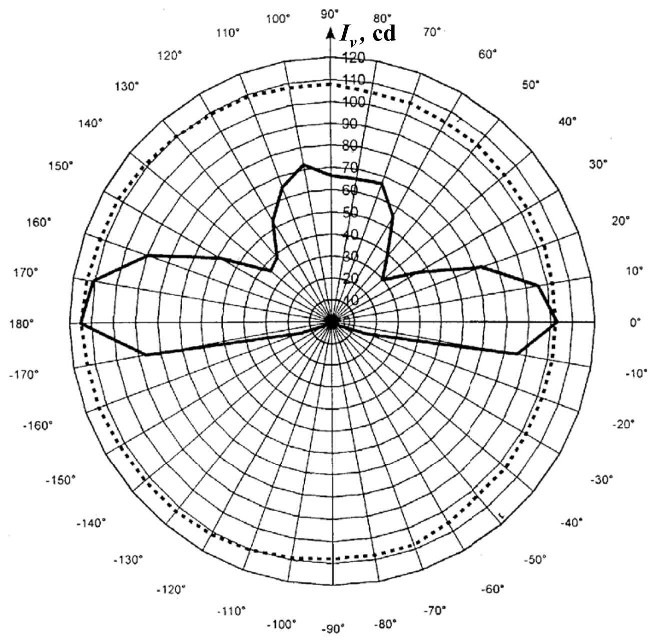


Fig. 4. Luminous intensity spatial distribution of the У-217 Bl type radiator in the horizontal plane at working forward current

– Forward current is equal to 700 mA, input voltage is (12.5–13.0) V, electric power consumption is 9 W;

– Correlated chromatic temperature (CCT) is 4000–5000 K; chromaticity coordinates x and y are 0.37–0.38 and 0.43–0.44 respectively;

– Maximum luminous intensity in the horizontal plane I_v is (95–120) cd (without a Fresnel lens);

– Radiation angles in the horizontal and vertical planes are 360 ° and about 40 ° respectively.

The У-217 Bl type radiator is used without an additional cylindrical Fresnel lens and is protected against environment exposure with a translucent cap integrated in the light structure.

I_v dependence on forward current I_f is close to linear, and usually amounts 102–115 cd (Figs. 3 and 4). Here the abovementioned radiation angle in the vertical plane allows supporting visibility of the light when the boat is rolling, and the visibility range is more than 10 km at atmospheic transparency of 0.84.

A white LED radiator of circular operation (У-244 Bl type) was also developed for use in navigation signs on water storage basins and lakes (Fig. 5). For the manufacture of this LED, blue crystals (of *InGaAlN* heterostructure) were also used. These LEDs were produced as those in the previous case, but they only contain two crystals connected in series.

In this case, radiation indicators are similar in to those given in Fig. 4.

The radiator is used without an additional cylindrical Fresnel lens, but with a translucent protection cap.

The working parameters of the У-244 Bl type radiator are as follows: forward voltage is 6 V; I_f= 500 mA; I_v = (50–55) cd; CCT = (4000–5000) K; light visibility range is 8 km (at atmospheric transparency of 0.84). The radiation angle in the vertical plane is about 40 °, which ensures light visibility on water storage basins and lakes when navigation signs are rolling.

Fig. 5. Appearance of the У-244 Bl type radiator (for navigation sign lights of water storage basins and lakes)

Red and green LED radiators are also developed (У-244 В and У-244 I types).

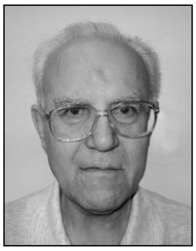
The authors are grateful to I.T.Rassokhin for his help in the work.

REFERENCES

1. *Kogan L.M., Gofshtein-Gardt A.L., Rassokhin I.T., Flegontov B.K.*. Energy saving light-emitting diode radiator for circular signal lights / Patent of Russia № 100303, 10.12.2010. Bul. A 34.

2. *Kogan L.M., Galchina N.A.*. Structure of a light emitting diode with phosphor / Patent of Russia № 2416841, 20.04.2011. Bul. A 11.

3. *Alexei L. Gofshtein-Gardt, Lev M. Kogan, Igor T. Rassokhin, Naum P. Soshchin, and Andrei N. Turkin “High Power White Light Emitting Diodes and Modules with Light Flux up to 1500 lm”, Light & Engineering,#3, 2014, pp.29–36.*



Alexei L. Gofshtein-Gardt,
an engineer, graduated from Moscow Institute of Electron Mechanical Engineering in1965, at present he is a leader technologist of SPC OPTEL Moscow Open Company

Lev. M. Kogan,
Dr. of Technical Science, graduated from Moscow Energy Power Institute in1956, at present he is a Scientific Head of SPC OPTEL Moscow OpenCompany, and Member of International Academy of Information

Naum P. Soshchin,
Ph.D., graduated from physical chemical faculty of Moscow Chemical Technology Institute named by D.I. Mendeleev, at present he is a head of laboratory at Phosphor SPC Open Company

Boris K. Flegontov,
engineer, graduated from the Leningrad High Engineering Marine Collage named by admiral Makarov. At present time he is the head of laboratory on navigation safety at Moscow State Academy of Water Transport

Nina A. Galchina,
engineer, graduated from Moscow Energy Power Institute in 1971. At present time she is the engineer-technologist of SPC OPTEL Moscow Open Company

Alexander A. Kolesnikov,
engineer, graduated from Moscow Engineering Physical Institute (MIFI) in 1971, the main metrologist of SPC OPTEL Moscow Open Company

PROBLEMS OF SPECTRORADIOMETRIC MEASUREMENTS

Oleg M. Mikhailov

The S-Petersburg State Institute of Cinema and Television
E-mail: mom1938@mail.ru

ABSTRACT

Modern methods of photometric and colorimetric measurements are increasingly moving towards use of spectral concentration of a photometric value to determine both integral effective values, and to measure colorimetric values of self-luminous and non-self-luminous radiation sources applied in lighting installations and lighting devices. This is linked to decreasing use of incandescent lamps and to the expansion of energy efficient modern radiation sources in illumination technology. This article is dedicated to the problem of spectral measurements of optical radiation in a wide spectrum interval.

Keywords: energy photometry, visual measurements, correlation adjustment, efficiency, error, spectral concentration of power and energy, computer transformation, light-emitting diode (LED), radiation chromaticity, electroluminescence, radiation spatial distribution

1. READERS' NOTE

The choice of subject for this article is influenced by the author's research direction, as well as by an interest expressed by readers towards this topic. The subject under consideration is a basic activity of the majority of companies and educational institutions in energy photometry, which is in turn an integral part of light engineering as an illumination science.

The purpose of this article is to engage readers in a discussion and to encourage them to speak out about this problem.

2. LIGHT-EMITTING DIODES (LEDS), TRADITIONAL SOURCES, ENERGY SAVING AND EFFICIENCY

Luminous flux effective value (Φ_v), in lumens differs from energy flow, in watts ($\Phi_e = \int \Phi_e(\lambda)d\lambda$) and amounts to:

$$\Phi_v = k_m \int_{380}^{780} \Phi_e(\lambda)V(\lambda)d\lambda,$$

where K_m is maximum spectral luminous efficiency ($K_\text{m} = 683 lm/W$), $\Phi_e(\lambda)$ is spectral concentration of energy flow. $V(\lambda)$ is relative spectral radiation luminous efficiency for day sight of the CIE standard photometric observer.

Thus, luminous flux is an effective value formed as a result of exposure of the eye to electromagnetic radiation, whereas surrounding objects are not influenced by light. They are objects of electromagnetic radiation. The changes, which occur in an object, depend on its properties and on spectral concentration of the radiation power. Energy power (radiation flow) is caused not only by the visible interval of electromagnetic radiation; it covers a big spectral range. To evaluate (not to measure light characteristics) an illumination system or lighting installations, methods based on visual perception are used frequently. At the same time, it is not possible to evaluate radiation power using visual sensations.

Illuminance on a set plane measured in lx, can be the same for a gas-discharge lamp, for an incandescent lamp and for a LED. When measuring illuminance with an integral luxmeter, essential differences in spectral distributions of these light sources can lead to errors connected with the correction quality of the measuring device according to $V(\lambda)$ curve.

LEDs radiate too little in violet and long-range red areas of the visible spectrum (less than 440 nm and more than 680 nm). Therefore, they have a different colour transmission in comparison to the CIE standard radiators. You can fail to recognise your car by colour in an underground parking lot illuminated with LED luminaires.

In Russia, as well as all over the world, transition is propagated from thermal radiation sources to electro-fluorescent sources (LEDs and gas-discharge compact lamps). Inorganic LEDs have specific optics and physical properties and need less power at a lower cost for their operation, and their service life largely depends on the electron ballast. At the same time, they are economically are inferior to the traditional incandescent lamps and even to the compact fluorescent lamps (CFL) because of their higher purchase price.

Electro-fluorescent radiation sources are modern high-reliable solid-state devices without a vacuum structure, in which electric field energy is directly transformed to radiation, and this determines their low power consumption.

The main characteristics of light devices based on LEDs are as follows: spectral composition of radiation, radiation power, luminance dependence on the frequency, voltage and on electric current; consumed electric power, light efficacy and service life. Radiation colour of the phosphor and LED radiation spectrum depend on the applied activator, its concentration, as well as on the excitation mode. A key limitation of LED service life is ageing (degradation) of the phosphor in the operation process, which leads to luminance reduction and to a change in colorimetric characteristics. Spectral composition of the radiation (or its colour) can be any, including white colour of any shades. “New” radiation sources based on LEDs and “old” sources, for example, CFLs, similar to traditional incandescent lamps, should be subject to comprehensive testing for transmission of chromatic differences, reproducibility of radiation parameters and economic application feasibility in devices of different functions.

Growing energy cost and stricter requirements for ecological safety continue to force electrical energy savings for city and household illumination. In comparison with traditional radiation sources, inorganic light emitting diodes have a high efficiency of transforming electric energy to energy of radiation. Organic radiating diodes have a sufficient luminance flux and a long service life at little radiation flow. At the same time, such light sources are ecologically safer compared to the solid-state diodes, the production of which is damaging from an ecological point of view. Organic radiating diodes for illumination systems are very new. Distinct from inorganic light emitting diodes, they can be manufactured based on their uniformly luminous, not blinding surfaces with a high colour rendition index.

Reproduction of most colours, including brown, gold, purple and other similar colours, when illuminating an object using lighting devices based on LEDs, is very ineffective. The colour rendition concept itself, as well as correlated chromatic temperature, requires new terminological validity.

All these factors are based on the fact, that determining parameters of lighting devices with LEDs, should be performed using verifiable spectral devices and spectroradiometric measurement methods. This is a comparatively new phenomenon in routine light and chromatic measurements, where methods of measuring effective values by means of photometers and colorimeters, were typical and universal. Relative spectral sensitivity of photodetectors for such devices should be corrected in accordance with the effective relative spectral curve of a measurement task.

3. A NEED FOR CORRELATION ADJUSTMENT; ERRORS OF LIGHT AND CHROMATIC MEASUREMENTS

Correlation adjustment of a photodetector’s relative spectral sensitivity is necessary in the event of measuring various integral effective values. Classical effective values are luminous values. In addition, curves of photobiological danger for the retina in IR and dark blue spectrum regions exist. There are also ultra-violet efficiencies, photosynthesis and addition functions in colorimetry. Most correlation adjustment methods use installation which selectively cut off colour filters made of different materials into the photodetector optical circuit. The methods of calculating filter type and their thickness based on a known sensitivity of the optical radiation receptor using modern computing techniques are easy to perform. However, the calculations themselves are rather awkward, as they must take into consideration

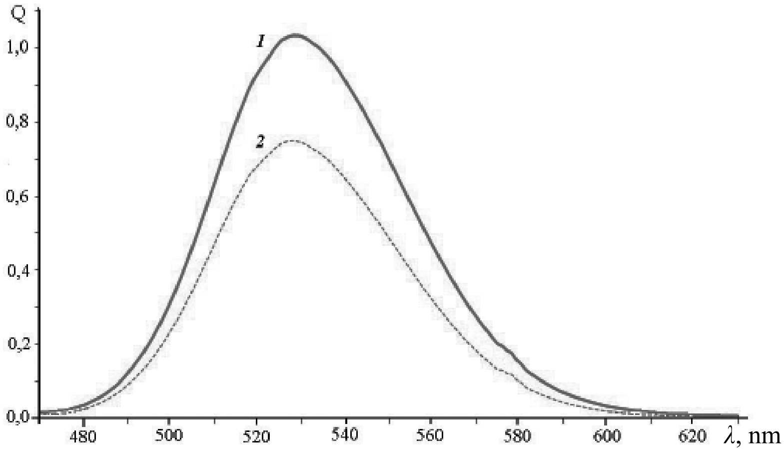


Fig. 1. Spectra of photoluminescence investigated films of $SrGa_2 S_4$: Eu (strontium tiogallate) after annealing in sulfur vapour during electron-beam processing (1) and without it (2)

photodetector sensitivity spreads, cooking classes, for example, of glass filters and overall dimensions of output fixtures. A correcting filter can be formed using three methods:

- The subtractive method (B): colour glasses are superimposed on each other and block the whole radiation beam subtracting non-working spectrum areas;
- Additive method (A): coloured glass are placed nearby and block different areas of the beam and so summarise useful spectrum areas;
- Combined method (C): a combination of the first two methods, when to the filter formed by method *B,* two pieces of glass of different colour using method *A* are added. These block some controlled parts of the beam.

Special difficulties and problems arise in the process of quality control when correcting relative spectral sensitivity of a photometer according to a set curve of the measurement task. The existing evaluation methods using five lamps and in accordance with values Δ, f_z and f_1' under modern conditions are not always correct [1,2]. A wide development of quasi-monochromatic radiators (radiating diodes, organic diodes and semiconductor lasers) allow using the spectral evaluation or checking by means of quasi-monochromatic radiation of colour radiating diodes.

Unlike any other measurements, the error of light and chromatic measurements is connected not only with classical provisions of the error theory, but also dependent on the calibration method and on the type of measured dependence. Radiation or its colour is measured in all its natural variety, and the calibration is made in accordance with CIE standard radiation. The calibration error can be easily calculated, and measurement error of specific radiation, especially of complex or single-curved composition, is sometimes unpredictable. Only spectroscopically pure radiations and radiation chromaticities of a black body at different temperatures can serve as radiation chromaticity standards. The error of the integral measurement method for products with a spectrum distinct from the standard radiator spectrum will be quite large because of the uncertainty of evaluating correction quality of the applied photometer or colorimeter.

Now the possibility arises to make precise measurements of integral effective radiation by determining the relative spectral distribution of the investigated radiation and by a computer calculation of effective flux using the CIE tabular data. In doing so, the correlation adjustment quality is not taken into consideration, because it is almost ideal, but the measurement error, for example of light values, will depend entirely on the measurement accuracy of spectral concentration of the required characteristic. Under modern conditions, one should use a stable high sensitivity receiver of optical radiation (ROR), advanced computer equipment and an obligatory experimental file of measurement results of non-coherent radiation. Experiments have confirmed a possibility to measure light parameters using spectroradiometric methods. The output of a modern spectral radiometer is connected to a computer with the software, where tabulated curves of addition functions for colorimetric and photometric values to be calculated are included. It is easy to determine illuminance E_V in a mode of "as if error-less" measurement of a light value in any reasonable spectral interval of the visible range by measuring E_e (λ), which is the spectral distribution of irradiance.

Besides this, there are some ideas of new physical models of radiation reference sources, for example of the "light lumen".

The "light lumen" is a radiation source, the spectral distribution of which repeats the curve of relative spectral luminous efficiency of a human eye *V (λ)*. Modern achievements in nano- and chemical technologies allow proposing an unexpected and somewhat disputable method of modelling a radiation source of a set spectral composition, named "light lumen". The essence of the proposal is that using reproducible methods of arranging electrofluorescent radiation sources, a light source is formed, the radiation spectral concentration $\Phi_e(\lambda)$ of which approaches seems to approach the relative spectral luminous efficiency *V (λ)* [3].

Strontium tiogallate doped with europium is a potential composition for manufacturing effective phosphors, which emit green radiation, and work at a low voltage.

Spectral characteristics (Fig. 1) of the investigated samples show, that after processing a material with a large luminance of the photoluminescence can be obtained. Further technological operations (radiation, gamma and electron-beam modifying) allow changing the radiation curve type and shifting the wave length value at the radiation maximum by ± 50 nm.

The novelty of this development is clear, and its practical importance requires comprehensive discussion.

4. SPECTRAL MEASUREMENTS

Spectral measurements include: a measurement of spectral concentration of radiation parameters, the spectral sensitivity of photodetectors and photoreceptors, spectral transmission and reflection factors of materials, in gaseous and condensed mediums.

Determination of spectral characteristics of materials and mediums is performed using specialised spectrophotometers based on precise scanning monochromators or CCD spectrometers intended for routine measurements. Disperse devices of the same type can be used to measure the spectral characteristics of radiation sources by comparing with a reference source of the spectral distribution of the required characteristic. Some (surmountable) difficulties can arise when recording a value of the spectral concentration of power (energy) of pulse, laser and multiline radiation. To a significant extent, they are caused by a spectral resolution (two decimal places of nanometer), time (transitional pulse characteristic to picoseconds) and by spatial resolution (indicatrix type, polarisation). Here, two circumstances should be noted: radiation dispersion by the dispersive system (including the highest orders of decomposition) and self-absorption of own radiation by plasma in the pulse discharge. To record short duration radiation pulses a radiation receptor with a response time not exceeding 10^{-10} seconds is needed. It is very difficult to deal with diffuse radiation. One should use mechanical aperture diaphragms, shutters and replacement of the receiver, or similar to the case of excluding the higher orders of diffraction grating decomposition, use cutting off bandpass filters. In case of a pulse discharge, spectral distribution of radiant intensity and radiation energy spectral distribution differ. This phenomenon is connected with complex the physical processes in the discharge. A certain increase of spectral measurement accuracy is influenced absolutisation of the obtained data and operational stability of the measurement object, because it is impossible to obtain a full spectrum for one pulse (Fourier transformation isn't considered).

Integral measurements of radiation by wavelengths in various sites of the optical spectrum always face a problem, which is resolved by certain agreements at an international level. In the IR spectrum interval, a usage coefficient is applied. In the visible area it is a system of light values. In the UV interval it is purposeful effective flows (bactericidal and erythema efficiency, as well as photosynthesis). Application of non-selective receptors for spectrum recording secures a reliable and accurate measurement of any kind of radiation. As to weakening and modification of the influencing radiation within specific measuring tasks, they are unrelated to these results. Methods of absolutisation of these radiometric and spectroradiometric measurements need to be discussion. The most correct methods of self-calibration and simulation of black bodies have clear benefits and certain disadvantages [4, 5]. Breaking the UV radiation down to areas A, E, N and IR to near and far areas limits the use of reliable and accurate methods. П-shaped distribution is never reached by the available facilities, and computer processing of spectral measurements easily manages this task. Blind acceptance of the breakdown to the areas leads

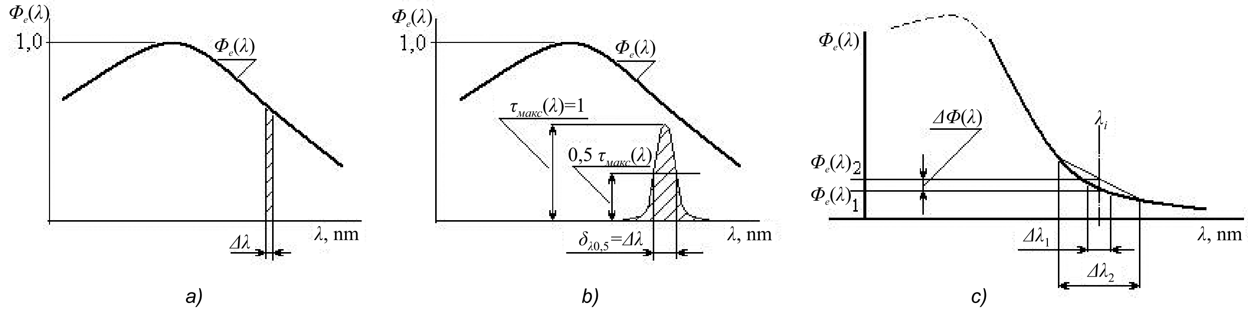


Fig. 2. Features of spectral measurements: spectral resolution (a), interference filter (b) and influence of the slit width (c)

to serious errors in he measured values of energy photometry, because the radiation "does not know" that it is divided artificially. True exposures of radiation on objects and on medium are recorded with significant errors.

The sensitivity of a receptor S (λ) can be estimated using quantum efficiency *Q*, i.e. relation of the number of photoelectrons to the number of quanta falling on the sensitive surface:

$$Q = \frac{I \cdot h \cdot c}{\Phi_e \cdot n \cdot e \cdot \lambda},$$

where *I* is receptor reaction; *h* is Planck's constant; *c*is light speed; *n* is refractive index of air; *e* is electron elementary charge; λ is wave length; Φ_e is radiation flow. Making necessary transformations, for quantum efficiency equal to one, we obtain a formula for spectral sensitivity at a set wavelength: $S(\lambda) = I/\Phi_e = \lambda / 1239.5[A/W]$.

Some photodetectors, for example silicon and germanium photo diodes, have quantum efficiency equal to one in a certain spectrum area. For some reason, not all photons work for photo effect. Some of the photons are reflected from the boundary (photodetector surface is inner sensitive layer). In this case $S(\lambda) = \alpha(\lambda) \cdot \lambda / 1239,5[A/W]$. In especially located several receivers of the same type, due to an increase in the extinction factor (a part of unreturned radiation) by means of multiple use of the reflected radiation [5], value α (λ) is forced to tend to one. In this case, absolute spectral sensitivity (**self-calibration phenomenon**) *S*(*λ*) is determined using the upper expression. It is necessary to measure current in the electric circuit of the receptor and the radiation wave length only. If an absolute positioning at one site of spectral sensitivity is known, it is easy to transition to the whole sensitivity interval by wavelength, measuring relative spectral sensitivity of the radiation receptor used. An important circumstance when making broadband spectral measurements in energy photometry, is red boundary of photo effect, i.e. the wave length, for which sensitivity of the radiation receptor leads to measurement errors.

The methods of equispectral and equisignal photometry and radiometry should also be discussed. The first one is more often used when measuring spectral sensitivity of photodetectors, the second – when measuring spectral concentration of radiation parameters. This is caused by the fact that in the first case, it is necessary to exclude the influence of diffuse radiation, and in the second case it is connected with a seeking to work on a linear site of the characteristic "receiver output signal/input radiation influence".

Measurement of photodetector spectral sensitivity remains a labour-consuming and complex step in the general problem of energy photometry. The reasons for this are as follows. First, there is a need to measure devices of different classes (thermoelements, photocells, photomultipliers, photodiodes, charge-coupled devices, etc.). Secondly, it is due to the use of special equipment (vacuum, heat). Thirdly, because of difficulties in metrological support, including the need for reliable fixtures modifying the radiation in different sites of the spectrum. The differences in sensitivity of many photodetectors can reachs several orders of magnitude. At the red boundary of device sensitivity, a tricky problem of its measurement arises. It is connected with spectral resolution of the dispersive device (Fig. 2).

In the selection of measurement standards, preference should be given to requirements of equispectral photometry. The reliability and accuracy of sensitivity measurement are confirmed by such factors as retention of an informative parameter in the case of multiple measurements, a comparison of measurement results and coincidence of the obtained data when using different devices and methods of determining absolute values. Self-calibration is used as one of the determination methods. Absolute spectral sensitivity in the spectra with constant quantum efficiency is determined using two measurement operations. At first, the reflection factor of the sensitive site, and then the current in the receiver circuit are measured without using comparative measures. A spectral device including a receiver with a constant quantum efficiency (trap detectors [5]), allows measuring the spectral distribution of spectral concentration of any type of radiation power and makes absolutisation of relative spectral characteristics of light devices possible [6].

CONCLUSION

From the mid seventies of the last century onwards, spectral measurements of optical radiation sources and receivers, spectrophotometry of non-radiating materials and mediums are widely developed in Russian domestic instrument engineering. A standard basis of metrological support for these types of measurement at the state level has also been developed. At present, methods of spectral radiometry are widely used in the routine measurements not always securing measurement unity. Modern spectral devices are constructed using the "express measurement" principles for production of technological operations and as check devices of chromatic medium evaluation. Receivers of the charge coupled device matrices, a special software and primitive optical systems are used in these. The problem of metrological support for such devices demands a new level of equipment for their research and testing with a special requirement of standard spectral resemblance with measurement unit.

REFERENCES

1. Publication of CIE 53–1982.
2. Characterization of the Performance of Illuminance Meters and Luminance Meters, CIE Standard CIE S 023/E:2013.
3. Oleg Mikhailov, Egor Markov, Konstantin Tomsky. Dependence of a screen image quality on the radiation source. Palmarium Academic Publishing, ISBN: 978–3-639–74532–0, Saarbruecken, Germany, 2014, 79 p.
4. Oleg Mikhailov, Maxim Sychev, Konstantin Ogurtsov. Photometry and metrics of displays. Palmarium Academic Publishing, ISBN: 978–3-639–77091–9, Saarbruecken, Germany, 2014. – 211 p.
5. Fox N.P. Trap Detectors and their properties. 1998. Metrologia, 28, pp. 197–202.
6. Stolyarevskaya R.I., Bartsev A.A., Belyaev R. Methodology of LED Luminaire BLH Radiance Measurements, Proceedings of CIE "Lighting Quality and Energy Efficiency", 19–21 September 2012, pp.215–222.

Oleg Mikhailov,
Dr. of engineering, professor, graduated from the Leningrad Institute of Precise Engineering and Optics in 1963. His specialty is mechanical engineering. He is a well-known scientist in energy and pulse photometry, colorimetry and metrics of optical radiation. A qualified specialist in securing unity of optical-and-physical measurements. He has contributed greatly to the development of energy photometry of coherent and non-coherent radiation. Until 2003, he was the main metrologist and the head of the department of energy photometry and of construction of optical systems in the State Optical Institute of S.I.Vavilov. Since 2003 to 2009 he was the chief specialist in the tests for correspondence of laser products, general light engineering products, lights of sea rescue facilities, ergonomics and safety of road traffic. He works at the Chair of light engineering of the S.Pb. State Institute of Cinema and Television since 2010. He has published 240 scientific papers and reports

Light & Engineering
Vol. 23, No. 2, pp. 70-77, 2015

Svetotekhnika
No. 2, 2015, pp. 39-44

INFLUENCE OF AMBIENT TEMPERATURE ON COLOUR PROPERTIES OF LOW-PRESSURE FLUORESCENT LAMPS

Przemysław Tabaka

Lodz University of Technology, Poland
E-mail: przemyslaw.tabaka@wp.pl

ABSTRACT

The article presents results of laboratory measurements of colorimetric parameters of various fluorescent lamps of different powers in ambient temperature ranging from +25⁰ C to –25⁰ C in steps of 5⁰ C. Based on registered spectral distribution of radiation, correlated colour temperature and colour rendering index have been determined. Straight fluorescent lamps of 8 W, 18 W and 36 W powers were measured. In terms of 18 W fluorescent lamps, different lamp colour's codes (640, 827, 840) were considered. Additionally, one straight frost-proof fluorescent lamp of 840 colour's code and one 18 W compact fluorescent lamp integrated with a conventional magnetic choke have been measured. All straight fluorescent lamps cooperated with a conventional magnetic choke.

Keywords: fluorescent lamp, ambient temperature, correlated colour temperature, general colour rendering index, colour's code

1. INTRODUCTION

Fluorescent lamps are among the most popular low-pressure lamps. They are widely used as interior lightning in offices, conference and administration rooms, corridors, schools, shops, supermarkets, shopping centres, restaurants, hotels, sports and recreational centres, galleries and museums, hospitals, doctor's consulting rooms, waiting rooms, warehouses, industrial space, households (kitchens, bathrooms, cellars), garages. These lamps are also used as exterior lightning for the purpose of pedestrian lightning (e.g. underground passages), parking lot lightning, lighting at public transport stops, bus and train platforms, as well as signboards, billboards and advertising coffers.

Fluorescent lamps are characterised by a special feature, which has been pointed out in the literature [4, 5, 6, 7]; their luminous flux is dependent on the ambient temperature. However, the literature lacks analysis of colour temperature in terms of changing ambient temperature of those light sources. This paper deals with the influence of ambient temperature on colour properties of low-pressure fluorescent lamps.

2. METHODS FOR DETERMINING COLOUR PROPERTIES OF FLUORESCENT LAMPS

Manufacturers of fluorescent lamps usually provide their colour properties by means of a three-digit code, which is preceded by a symbol of the lamp and information about the power of the light source (Fig. 1 a). The symbol of the lamp (one or two-character) is assigned individually by each manufacturer. The first number of the colour code (item 2 Figs. 1a and 1c) provides information about the general colour rendering index (R_a), the two following items (item 1 Figs. 1a and 1c) give information about the colour temperature. The symbols are a standard adopted by manufacturers to determine the colour properties of fluorescent lamps. An example of a three-digit code of straight fluorescent lamps available on the market is presented in Table 1. As the first digit of the code only provides

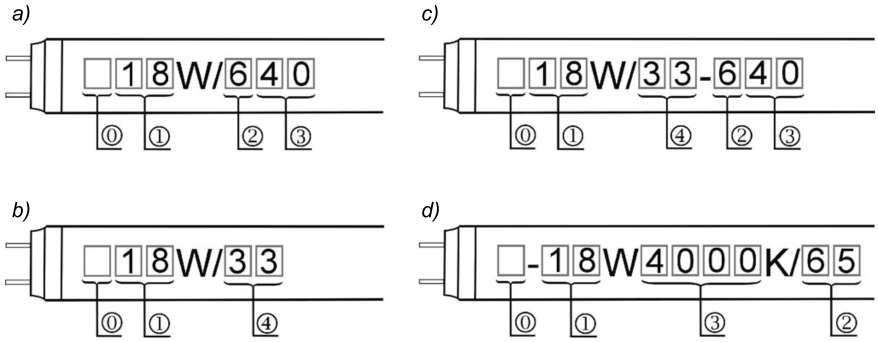


Fig. 1. Examples of different methods for determining colour properties of straight fluorescent lamps: a) international, b) old one, c) old one combined with international, d) individual one adopted by one of the manufacturers; item: ⓪ - designation as a fluorescent lamp, ① - lamp's power, ② - general colour rendering index, ③ - correlated colour temperature, ④ - old one (two-digit) designation of a lamp's colour

Table 1. Example of components of an international three-digit code determining light colour and colour rendering index of straight fluorescent lamps available on the market

General colour rendering index (R_a)					
Item② from fig. 1 a and 1 c	5	6	7	8	9
value	50÷59	60÷69	70÷79	80÷89	90÷100
Correlated colour temperature (T_{cc})					
Item③ from fig. 1 a and 1 c	27	30	35	40	50
value	2700 K	3000 K	3500 K	4000 K	5000 K
Item ③ from fig. 1 a and 1 c	54	60	65	80	
value	5400 K	6000 K	6500 K	8000 K	

Table 2. Examples of the same colour designation in the old one and international system

Old system *)	1)	25	30	20	-	10	11
	2)	25	29	33	35	54	-
	3)	125	129	133	135	154	
International standard		740	530	640	535	765	860
Old system *)	1)	12	21	26	31	32	41
	3)	-	-	-	-	193	-
International standard		950	840	835	830	930	827
1) for OSRAM light sources only, 2) for GE and PHILIPS light sources 3) for SYLVANIA light sources *) – the example does not include a complete list							

the range including the colour rendering index, to obtain the accurate value it is necessary to refer to the catalogue.

Some manufacturers still use the old system to determine the colour of a lamp (Fig. 1b).

Table 2 presents the most common designations of colour's codes together with their international equivalents.

In some instances, colour properties of fluorescent lamps are described by means of a pair of num-

Table 3. Terms used by manufacturers to determine the most popular colours of light sources

Colour temperature range	Name of colour
2700 ÷ 3000 K	warm white
3000 ÷ 4500 K	White
4000 ÷ 5500 K	cool white
5500 ÷ 6500 K	Daylight

Table 4. General information on the researched low-pressure mercury vapour lamps

lamp	tamp power	colour	tube diameter	tube length	symbol
straight	08 W	840	16 mm	288 mm	1
straight	18 W	827	26 mm	590 mm	2
straight	18 W	640	26 mm	590 mm	3
frost-proof	18 W	840	26/38 mm**	1125 mm	4
compact	18 W	Warm white	-	-	5
straight	18 W	Daylight	26 mm	590 mm	6
straight	36 W	840	26 mm	1199,4 mm	7
** lamp tube of 26 mm diameter additionally protected with a 38-mm glass shield					

bers separated with a hyphen (Fig. 1c). The first number before the hyphen relates to the old system of colour designation, whereas the second number relates to the international system. However, sometimes manufacturers use their own individual manner of designation to characterise properties of fluorescent lamps (Fig. 1 d).

Manufacturers frequently use the following terms to describe the most popular colours of light sources: warm white, white, cool white and daylight. Such a descriptive presentation of colours is very convenient from the customer's point of view, who is not familiar with technical terms operating in lightning technology. However, on the other hand, such presentation of colour is ambiguous. The colour temperature ranges associated with these names of colours tend to overlap (Table 3). It is quite common to see two straight fluorescent lamps with identical colour temperature of e.g. 4000 K, but the colour described either as white or cool white, depending on the manufacturer.

3. SUBJECT AND SCOPE OF STUDY

Several straight fluorescent lamps of 8 W, 18 W and 36 W powers as well as one integrated compact fluorescent lamp of 18 W power have been measured. For 18 W straight fluorescent lamps, different colours have been considered. All the lamps (including compact lamps) were coordinated with a conventional magnetic choke. Additionally, one straight frost-proof fluorescent lamp of 18 W has been measured. General information on the researched light sources is presented in Table 4. For the purpose of this study, the researched light sources have been given symbols from 1 to 7.

In terms of individual lamps the following have been registered: changes of spectral distribution and luminous intensity in the function of ambient temperature ranging from+25 ^{0} C to −25 ^{0} C in steps of approximately 5^0 C.

In low-pressure fluorescent lamps primary radiation is processed by a luminophor into secondary radiation of longer wavelength. Due to this fact, additional measurements were carried out for a special fluorescent lamp of 40 W, the interior of which (for didactic purposes) was half covered with phosphor. This enabled an observation of the influence of ambient temperature on the changes in the spectral distribution of primary radiation.

Approximate look of the selected fluorescent lamps tested is presented in Fig. 2.

Table 5. Determined correlated colour temperatures of the researched light sources in different ambient temperatures

T [^{0} C]	Correlated colour temprature T_{cn} [K]						
	source 1	source 2	source 3	source 4	source 5	source 6	source 7
25	3923	2740	4022	4007	3015	5747	3980
20	3878	2734	3892	4022	3032	5686	3948
15	3877	2739	3857	4057	3040	5625	3896
10	3843	2692	3827	4099	3100	5637	3721
5	3787	2658	3805	4112	3140	5567	3616
0	3787	2534	3764	4109	3143	5362	3571
-5	3744	2555	3744	4066	3133	5349	3405
-10	3745	2390	3641	4008	3105	5288	3326
-15	3648	2270	3570	3972	3095	5190	3157
-20	3598	2296	3427	3936	3086	5374	3095
-25	3545	2290	3476	3888	3050	5216	3016

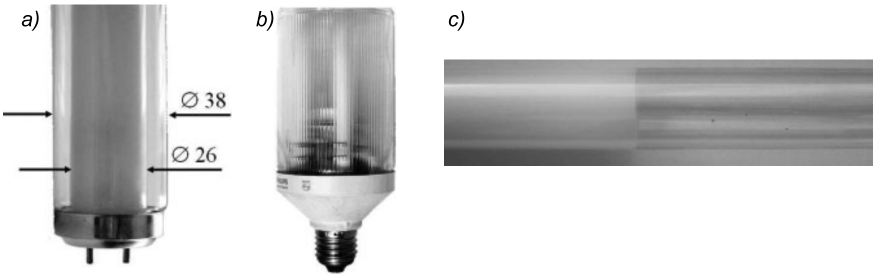


Fig. 2. Photographs of selected light sources which underwent experimental measurements: a) fragment of a frost-proof fluorescent lamp, b) compact fluorescent lamp with prismatic diffuser, c) fragment of a special lamp

4. MEASURING SYSTEM

Laboratory measurements, which tested the influence of ambient temperature on colorimetric parameters of fluorescent lamps, have been conducted on a system, the structure of which is presented in Fig. 3.

Circuits of individual lamps (a fluorescent lamp with the necessary choke) were fed on voltage stabiliser *(2),* which provided constant rms voltage with an accuracy of 0.1 %. By means of an autotransformer *(3)* the value of 230 V was set, which was checked by the voltmeter *(4).*

Room temperature of 25^0 C was taken as a reference temperature.

In order to register the spectral distribution of the researched sources, optical fibre of 50 mm diameter was placed inside the chamber (*8*). One end of the optical fibre was directed at the light of the measured source (*7*) and the other end was connected to the CCD spectrometer (*11*), which was placed on the outside of the chamber. Communication between the spectrometer and PC was realised by means of the interface USB 2.0.

5. CHANGES IN SPECTAL DISTRIBUTION OF RADIATION

Spectral distribution of radiation in different ambient temperatures at a frequency of 1 nm was registered. Results of measurements for individual lamps are presented in Figs. 4–6.

Spectral distributions are of particular importance because they contain essentially all the information

Table 6. General colour rendering indices of the researched light sources at different ambient temperatures

T [^{0} C]	General colour rendering indexes R_a [-]						
	source 1	source 2	source 3	source 4	source 5	source 6	source 7
25	81.1	81.3	64.8	80.6	81.1	76.2	83.8
20	78.0	81.2	64.2	80.8	78.2	75.1	83.1
15	76.0	78.4	63.3	80.3	80.5	71.0	81.3
10	67.8	76.1	62.1	79.7	80.0	70.0	80.0
5	66.3	74.3	61.4	79.4	78.0	69.4	79.4
0	66.3	71.2	61.0	78.9	79.0	68.7	77.3
-5	64.2	70.9	60.1	78.8	78.1	68.0	76.5
-10	64.1	68.3	59.4	77.5	78.0	67.9	74.2
-15	64.0	66.4	59.0	75.2	78.5	67.1	73.1
-20	64.2	62.3	58.1	74.1	76.7	66.6	71.1
-25	63.2	61.7	53.6	73.0	79.9	69.4	69.8

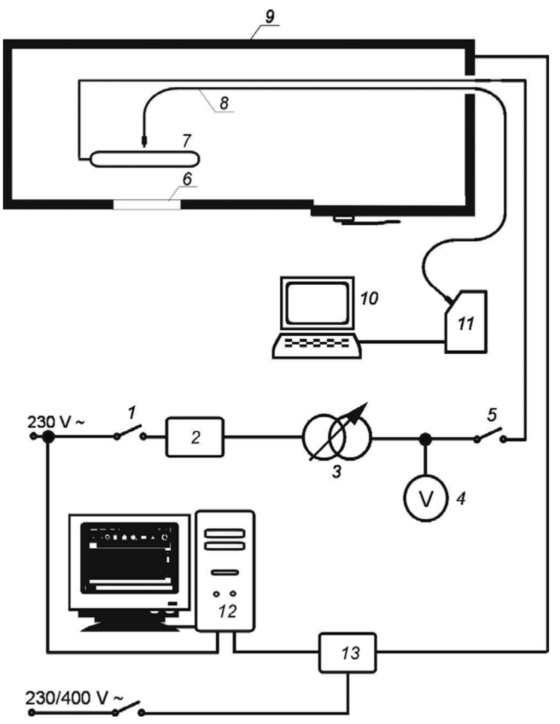


Fig. 3. Schematic diagram of a measuring system designed to determine light characteristics of low-pressure fluorescent lamps in the function of temperature:
1, *5* – power switch, *2* – voltage stabiliser, 3 – autotransformer, *4* – voltmeter, *6* – circular glass unit enabling observation, *7* – researched light source, *8* – optical fibre, *9* – test chamber made of sandwich panels, *10* – PC registering spectral distribution of radiation, *11* – spectometer, *12* – computer controlling the chamber, *13* – chamber control unit

about the qualitative characteristics of the radiation emitted by the light source.

Due to the multitude of data (for each of the eight light sources 11 spectral distribution curves have been registered) it has been decided to present results of four lamps (symbols *1, 4,* and *5* and a "special" lamp), three each for the following temperatures +25^0 C, 0^0 C and –25^0 C. Larger number of spectral distribution curves would reduce the clarity of the drawings.

6. CHANGES IN COLOUR TEMPERATURE AND COLOUR RENDERING INDEX

The most common parameter in lighting technology, which characterises the colour of radiation emitted by a light source, is correlated colour temperature measured in Kelvin. This is the temperature of a blackbody at which it emits radiation of identical chromaticity (colour i.e. identical hue and saturation) as the light source investigated. According to its definition, this term should only be used in relation to light sources the chromaticity coordinates of which belong on the Planck curve. In case of lamps, which chromaticity coordinates do not belong to the blackbody radiation curve (Fig. 7) a term of correlated colour temperature (T_{cc}) should be used – this is the temperature of a blackbody, whose colour is mostly proximate to the colour of the analysed light source.

In order to determine correlated colour temperature, isotemperature lines (Judd's lines [1]) are used. In the colorimetric diagram *u*, *v* (CIE 1960) they are perpendicular to the curve of a blackbody (to be more precise they are perpendicular to the tangent to the curve of a blackbody at the point of intersection of the line and curve).

According to the standard [2] the length of each of these lines is 0.04 units starting from the point, which defines the centre of the line and at the same time lies on the Planck curve, to the points that define the ends of the line. In practice, that means that when determining the correlated colour temperature, the trichromaticity coordinates cannot be placed at any distance from the blackbody curve. Coordinates defining both ends of the isotemperature lines (whose parameters are given in [2]) can be determined by solving the system of equations (1). A set of points on the chromaticity diagram obtained in that manner will define the area where chromaticity points may be in relation to which using the term of correlated colour temperature makes sense.

$$\begin{cases} v - v_i = t_T(u,v)\cdot(u-u_i) \\ (u-u_i)^2 + (v-v_i)^2 = 0{,}04^2 \end{cases}, \qquad (1)$$

where u_i, v_i – coordinates of a point, which marks the centre of the isotemperature line; $t_{T\,(u,\,v)}$ – slope of the isotemperature line.

In nature, there are no colours with chromaticity points outside the spectral curve, thus when defining correlated colour temperature, the trichromaticity coordinates should lie within the area outlined by the curves 3 and 4 and straight lines 1 and 2 (Fig. 8.) – highlighted area with the exception of the shaded area.

When manufacturers of electrical light sources provide information about their products, either in catalogues or on the packaging, they do not use the term of correlated colour temperature. The term of colour temperature is very convenient and it is used with reference to almost all light sources including those whose chromaticity is different from the chromaticity of a blackbody. For this reason, before presenting of the results, the author has decided to explain this issue in more detail.

By means of quotation (2) relative values of individual spectral distribution of radiation of the re-

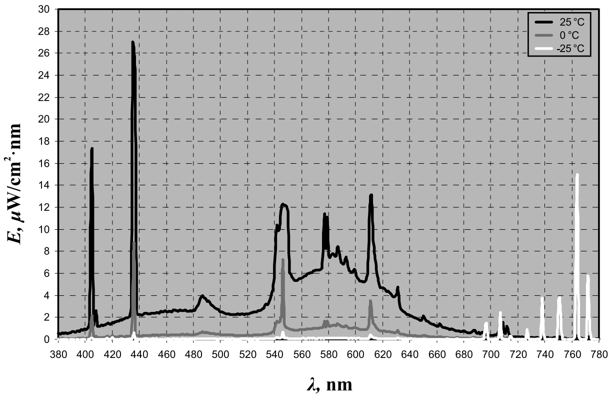


Fig. 4. Spectral distribution curves of a straight fluorescent lamp of 8 W power and 840 colour (source *1*) in terms of different values of ambient temperature

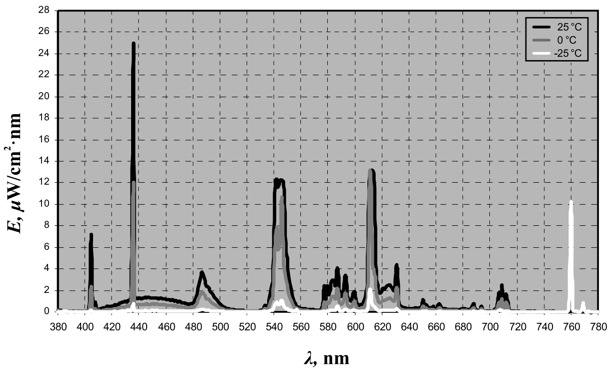


Fig. 5. Spectral distribution curves of a straight frost-proof fluorescent lamp of 18 W power and 840 colour's code (source *4*) in terms of different values of ambient temperature

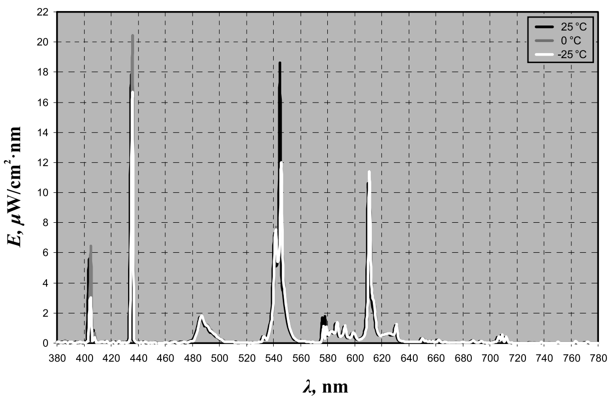


Fig. 6. Spectral distribution curves of a compact fluorescent lamp of 18 W power and warm white colour (source *5*) in terms of different values of ambient temperature

searched light sources *S* (l) for particular ambient temperatures were determined. The values were subsequently used for calculation of the correlated colour temperature (Tab. 5.) and general colour rendering index (Tab. 6.)

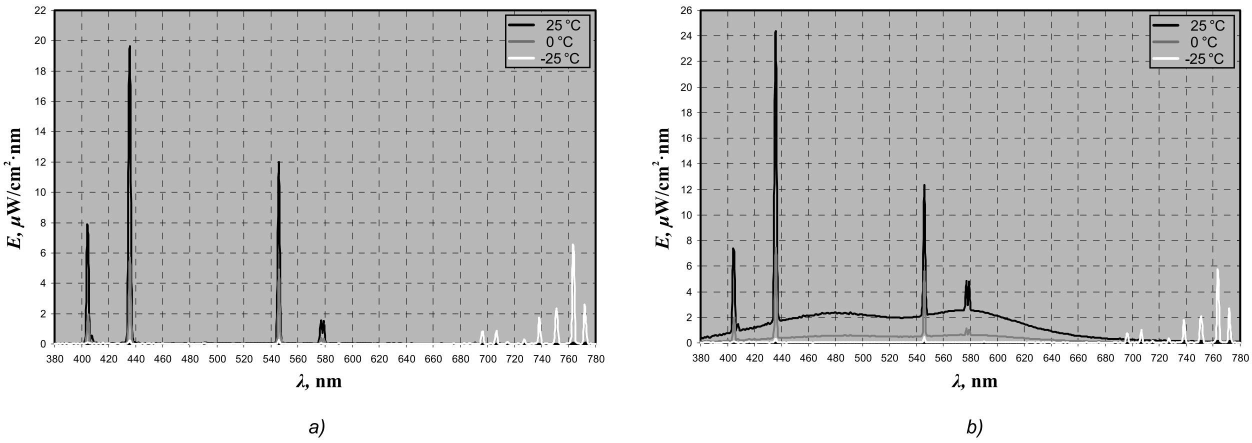


Fig. 7. Spectral distribution curves of a special straight fluorescent lamp of 40 W power in terms of different ambient temperature values: a) part of the tube free of phosphor , b) part of the tube covered with phosphor

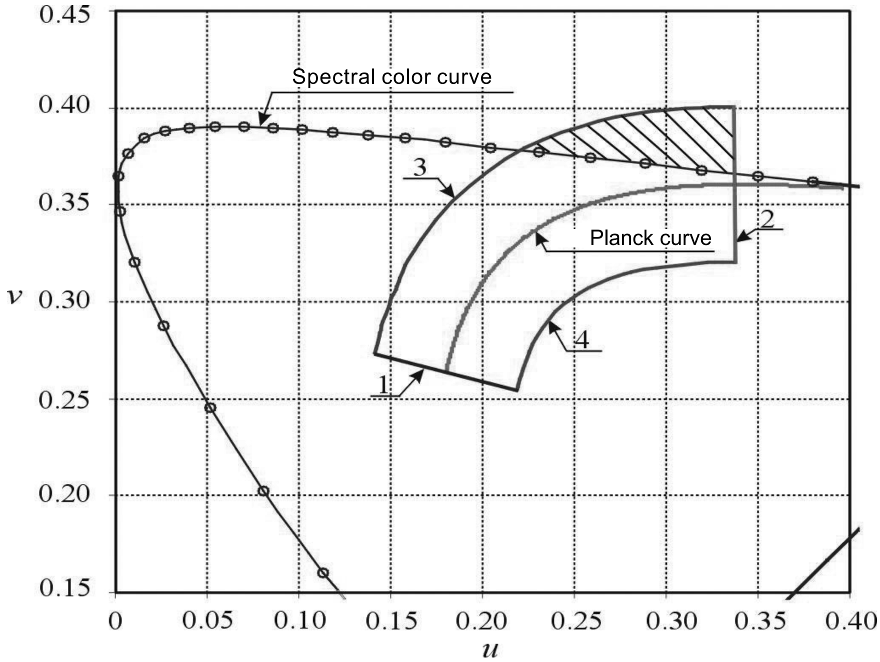


Fig. 8. A fragment of a colour diagram in the *u*, *v* coordinate system with drawn: Planck curve, spectral curve and area of chromatic coordinates (restricted by lines: 1, 2, 3, 4) for which the use of correlated colour temperature term is appropriate

$$S(\lambda)=\frac{100E(\lambda)}{E(560)}, \quad (2)$$

where $E(\lambda)$ – spectral distribution of radiant exitance, $E(560)$ – value of exitance for a wavelength $\lambda = 560$ nm.

7. RESULTS

Based on the experiments, it can be concluded that the colour properties of low-pressure mercury lamps are a function of ambient temperature. Along with the drop of temperature, in case of all the researched fluorescent lamps, changes in spectral distributions were observed. Maximum discharge energy radiation in mercury vapour at low pressure shifts from the short-wave region in the direction of longer wavelengths. This results in the colour change of the light emitted by the lamps (lowering the correlated colour temperature in freezing cold conditions). There are two reasons for this – firstly, changes in the properties of phosphor, and secondly, the drop of pressure inside the discharge tube. Therefore, ambient temperature change is accompanied by new technical conditions in the lamp itself.

There is yet another parameter, colorimetric, which is closely connected with the spectral distribution of radiation, the colour rendering index. In case of all types of lamps examined, a decrease in its value has been observed.

Out of the tested low-pressure fluorescent lamps, sources 4 and 5 are the least sensitive to changes in ambient temperature. These were equipped with an additional translucent shield, which reduced the heat loss of the fluorescent lamp.

REFERENCES:

1. Helbig E.: Grundlagen der Lichtmesstechnik, Geest und Portig Leipzig 1972.
2. PN-91/E-04042/03 Optical radiation measurements – Colourimetry – Methods for determination of spectral and colorimetric characteristics of light sources.
3. Ferholski W., Stanioch W.: Kolorymetria trójchromatyczna, WNT, Warszawa 1973.
4. Tabaka P.: Badania porównawcze zamienników tradycyjnych żarówek, Przegląd Elektrotechniczny R.85 no. 9/2010 pp. 315–321.
5. Wiśniewski A.: Elektryczne źródła światła, Oficyna wydawnicza Politechniki Warszawskiej, Warszawa 2010.
6. Zaremba K.: Wpływ budowy świetlówek na ich mrozoodporność w warunkach ruchu powietrza, Zeszyty Naukowe Politechniki Białostockiej 1999, Elektryka bulletin no. 15.
7. Żagan W.: Podstawy techniki świetlnej, Oficyna wydawnicza Politechniki Warszawskiej, Warszawa 2005.

Przemysław Tabaka,
had got Ph.D. in the field of electrical circuits with specialisation in lightning techniques. In 2002 he graduated from the faculty of Electrical, Electronic, Computer and Control Engineering. Since 2004 he has been employed as assistant professor in the Institute of Electrical Power Engineering of Lodz University of Technology. He is a member of the Polish Electricians Association and Polish Committee on Illumination.

PHOTOVOLTAIC SYSTEM UTILISATION FOR RURAL AREAS IN NORTHERN CYPRUS

Cumali Sabah, Murat Fahrioglu, and Ali Muhtaroglu

Middle East Technical University-Northern Cyprus Campus, Department of Electrical and Electronics Engineering, Kalkanli, Guzelyurt, Turkey
E-mail: C. Sabah, sabah@metu.edu.tr

ABSTRACT

Photovoltaic system as the renewable energy source became much important particularly together in LED based illumination systems application.

This paper presents an analysis and review study of solar energy data with seasonal variation in Northern Cyprus, which has one of the highest solar energy potential in Europe. Also numerical and simulation studies are applied to analyze and review of solar energy potential in Northern Cyprus. Measurements taken at two different sites of the northern part of the island are compared and evaluated to simulated results in this paper, and furthermore some actual production data from a photovoltaic farm is presented for further evaluation of the solar energy potential of the island.

Keywords: photovoltaic; solar energy; Northern Cyprus, TRNC

1. INTRODUCTION

In recent years, the world economic growth and population increase caused the need for more energy as it is an essential element for the socio-economic development of developing, as well as developed countries [1]. Therefore, the usage of energy is of great importance [2, 3]. Nowadays, it is an indisputable fact that people are obliged to meet their continuously increasing energy needs with new, inexhaustible, and environmentally friendly electric power sources [4].

Renewable energy resources play an important role around the world in diversifying the energy portfolio from both economic and environmental points of view [1,5]. Environmental and energy security concerns, as well as the strategic need to utilise the available energy resources efficiently, have motivated nations, governments, technology providers, and academics to shift focus from conventional resources to renewable energy [6–8]. Renewable energy resource can be defined as a sustainable energy resource that is available over the long term at a reasonable cost, and that can be used for any task without negative effects [9]. According to the Renewable Global Status Report 2012, by the end of 2011, total renewable power energy capacity worldwide exceeded 1,360 GW, up 8% over 2010; renewable comprised more than 25% of total global power-generating capacity (estimated at 5,360 GW in 2011) and supplied an estimated 20.3% of global electricity. Non-hydropower renewable exceeded 390 GW, a 24% capacity increase over 2010. [10,11].

In general, solar energy is the main alternative to fossil energy resources [12–14]. The sun is the world's most abundant and permanent energy source which emits energy at a rate of 3.8×10^{23} kW, of which, approximately, 1.8×10^{14} kW is intercepted by the earth [15–17]. In 2005, it was reported that the mean value of the solar constant outside the Earth's atmosphere is equal to 1368 W/m^2 (from measurements made in a spacecraft) [18,19]. In principle, there are many ways to harvest the energy from the sun. Many researchers and experts believe

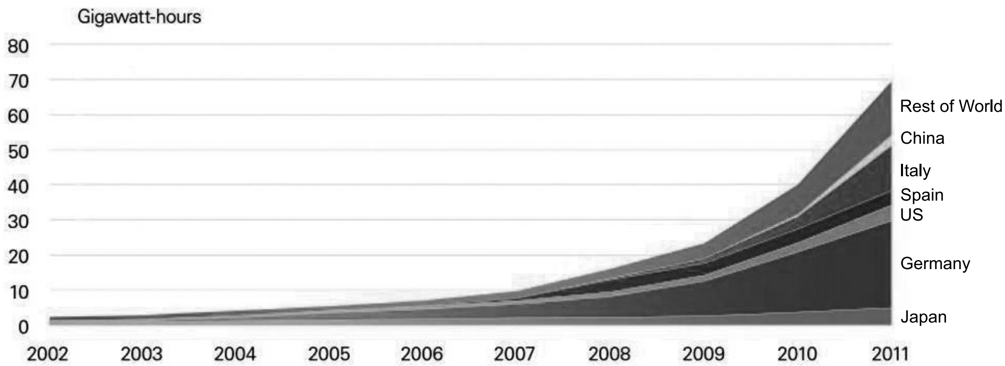


Fig. 1. Solar PV generation installed capacity [25]

that the sun is one of the preeminent candidates to provide a fully established solution for energy generation. In general, the photons arriving on the earth's surface can be converted either directly into electricity (photovoltaic) or heat (solar thermal methods), which then can be used for heating, cooling or electricity generation [15–17]. In addition, solar energy can also be used directly for lighting. In that sense, utilisation of solar energy for direct conversion into electricity is a critical strategy especially at the time of high fossil fuel costs and degradation of the atmosphere by the use of fossil fuels. Most of this energy makes it below the atmosphere, and is free, clean, and plentiful in most places on earth throughout the year [20]. Therefore, photovoltaic (PV) panels can be considered as the fundamental elements of renewable energy resource once their manufacturing cost is decreased to an affordable level compared to other available energy resources [21,22].

Recently, there has been a considerable increase in the utilisation of solar energy worldwide since it is abundant, cheap, effective, safe, and clean. The most widely known technique for generating electric power from solar radiation is using a PV system, which is proven and easy to use for electricity generation. PV panels on the roofs of buildings capture the energy from the sun to generate electricity cleanly and quietly. The rapid development of the industry and the continuous reduction of costs gradually establish a sustainably developed of energy system. The growth of solar power generation installed capacity is depicted in Fig. 1. According to [25], capacity has grown almost ten-fold over the past five years. Solar power generation enjoyed spectacular growth in 2011. Its overall share of renewable power remains low (6.5%), but 2011 marked the arrival of solar power at scale, contributing 20% of the growth of renewable power in 2011 as shown in Fig. 1 [23–25].

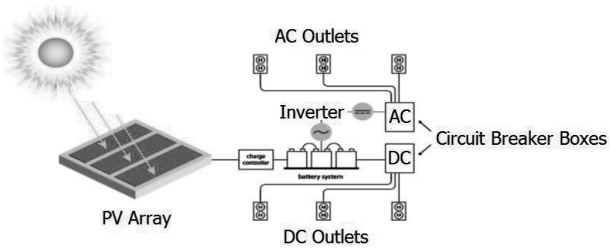


Fig. 2. Schematic view of a stand-alone PV installation [23]

In this paper solar measurements taken at two different locations in Northern Cyprus will be analysed and compared to simulation results. Actual solar energy generation data from the only PV farm (Serhatköy) in Northern Cyprus will also be shared to evaluate how solar measurements translate into actual production.

2. PHOTOVOLTAIC SYSTEM FOR RURAL AREAS

PV systems are generally classified according to their functional and operational requirements and they can be installed as grid-connected or stand-alone systems. The main component in grid-connected PV systems is the inverter, or power conditioning unit. On the other hand, stand-alone PV systems operate independently from the electric utility grid. The load requirements of these systems are provided by PV panels, DC/AC load, charge controller, inverter, and batteries. Basically, the charge controller is used to control the current flow from the array to the battery and the inverter is used in the conversion of DC into AC electricity. Fig. 2 shows the schematic

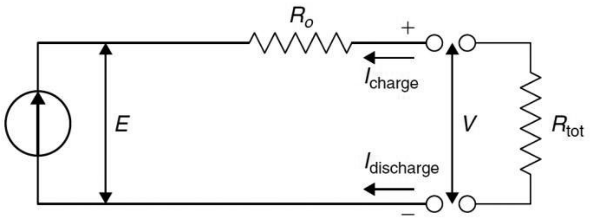


Fig. 3. Schematic diagram of used PV system battery [28]

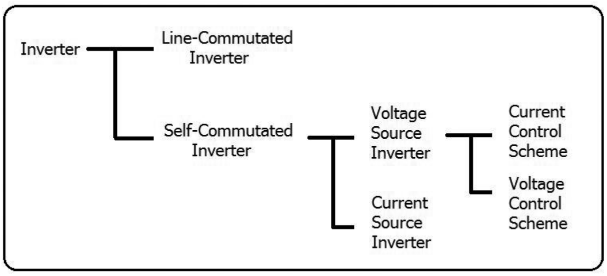


Fig. 4. Classification of inverter types

view of a stand-alone PV system. In addition, such systems are explained and can also be seen in detail in [23, 27–32].

Generally, the electrical load requirements with stand-alone PV system are provided by photovoltaic panels. As a common rule, these systems can be installed and operated as a single power plant with a lifetime of over 20 years with high assurance capability. In this system, panels and batteries (independently from the grid) can generate direct electricity (DC) [31]. Besides, the use of PV system to electrify rural areas has both social and economic benefits. The power generated using this system can be used to operate motor and pumps used for irrigation, storing consumable agricultural products, and many other usages. As for the social benefits are concerned electricity allows school going children to study at night, women to do some entrepreneurial activity, and so on. It contributes to better health as it allows switching from inferior biomass fuels to clean electricity thereby enhancing indoor air quality. It also gives rural people a lot of opportunities to access telecommunications and mass media [32].

2.1. Storage device or battery

The charge controller is used to control the current flow from the array to the battery. The main function of the charge-controller is to protect the battery from over discharge and also from overcharge [31].

Batteries are classified by their nominal capacity (q_{max}), which is the number of ampere hours (A_h) that can be maximally extracted from the battery under predetermined discharge conditions. The efficiency of a battery is the ratio of the charge extracted (A_h) during discharge divided by the amount of charge (A_h) needed to restore the initial state of charge. Therefore, the efficiency depends on the state of charge and the charging and discharging current. The state of charge (SOC) is the ratio between the present capacity of the battery and the nominal capacity; that is [28];

$$SOC = \frac{q}{q_{\max}} \tag{1}$$

The type of batteries which are used in stand-alone solar systems is generally the lead-acid [31]. The main advantage of lead acid battery is its low cost and its high safety and efficiency; but the life span (250–750 cycles) of these batteries are low and it has low specific energy [32]. In general, the battery can be viewed as a voltage source, E, the terminal voltage, V, in series with an internal resistance, R_o, as shown in Fig. 3.

The lifespan of a battery in a solar PV system ranges from three to five years; its life span depends greatly on the load connected to the system, charging and discharging pattern, temperature and ageing properties [32]. The PV batteries prices are higher than the prices of classic car batteries, yet their advantages are longer lifespan and lower discharging rates. Consequently, the maintenance costs of the PV system are lower [30].

2.2. Inverter

A power electronics based inverter is used to convert the direct current (DC) into alternating current (AC) electricity. The structure of the inverter can be single or three phase. Some inverters have good surge capacity for starting motors, others have limited surge capacity. The PV system designer should specify both the type and size of the load the inverter is intended to service [30]. Inverter technology is the key technology to have a reliable and safe grid interconnection operation of the PV system. It is also required to generate high quality power to AC utility system at a reasonable cost. To meet with these requirements, modern power electronic technologies are used in PV inverters. There are various types of inverters as shown in Fig. 4 [29].

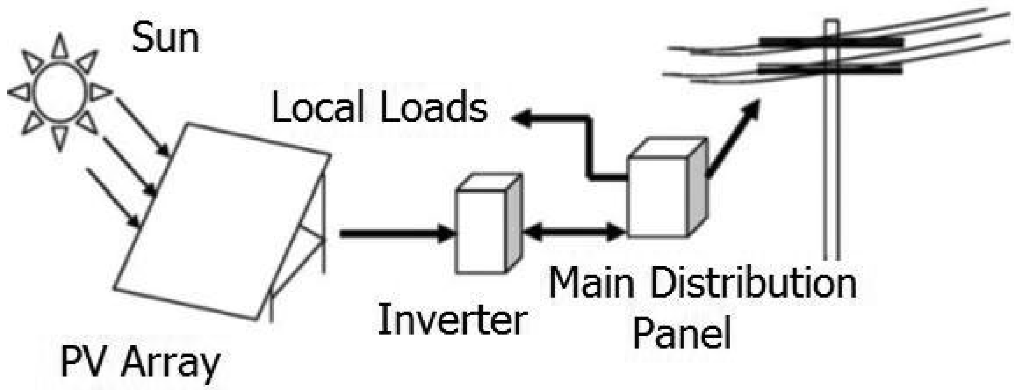


Fig. 5. Grid-connected PV power system with no storage [24]

The inverter is characterised by a power-dependent efficiency η_{inv}. Besides changing the DC into AC, the main function of the inverter is to keep a constant voltage on the AC side and convert the input power, P_{in}, into the output power, P_{out}, with the highest possible efficiency, given by [28]:

$$\eta_{inv} = \frac{P_{out}}{P_{in}} = \frac{V_{AC} I_{AC} \cos(\alpha)}{V_{DC} I_{DC}}, \qquad (2)$$

where $\cos(\alpha)$ is the power factor, I_{DC} and V_{DC} are the current required by the inverter from the DC side and is input voltage for the inverter from the DC side, respectively.

It is also important to grasp the installation environment of the inverter for the PV power system, and to take into consideration the influence of the inverter on the surrounding environment. The most important installation conditions of the inverter are the ambient temperature condition, the requirements for being waterproof and dustproof, the actual audible noise level of the inverter, and applicable regulations for power quality (or electro-magnetic compatibility) [27, 30].

2.3. Power distribution network (PDN)

The major elements of a grid-connected PV system that does not include storage are shown in Fig. 5. The inverter may simply fix the voltage at which the array operates, or (more commonly) use a maximum power point tracking function to identify the best operating voltage for the array [29].

3. THE CURRENT STATUS OF ENERGY IN NORTHERN CYPRUS

Two different sets of data will be provided from two different sources located in the Güzelyurt, which is in the north-western part of Cyprus (Location: 35°11’42” North, 33°6’42” East, as shown in Fig. 6). Data collection originates from both Middle East Technical University-Northern Cyprus Campus (METU-NCC) at Kalkanli and Serhatköy PV Farm, which are two different rural areas in Güzelyurt. METU-NCC has been collecting solar measurements for about two and a half years [33].

Serhatköy PV Farm was funded by the European Union and is operated by the Cyprus Turkish Elec-

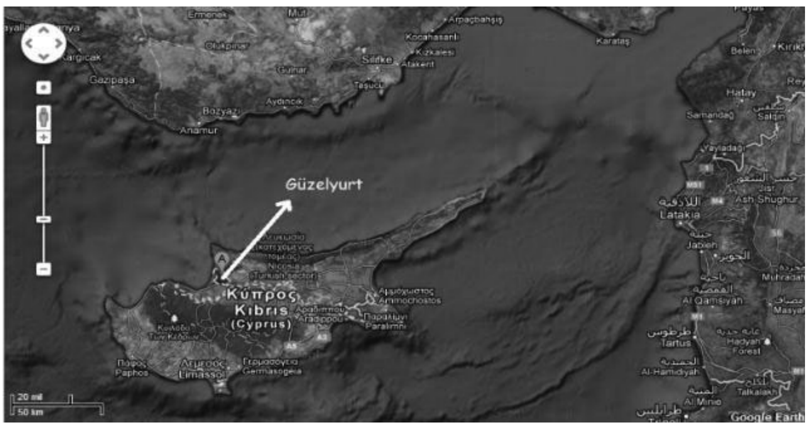


Fig.6. Location of the selected region of Güzelyurt by Google Earth

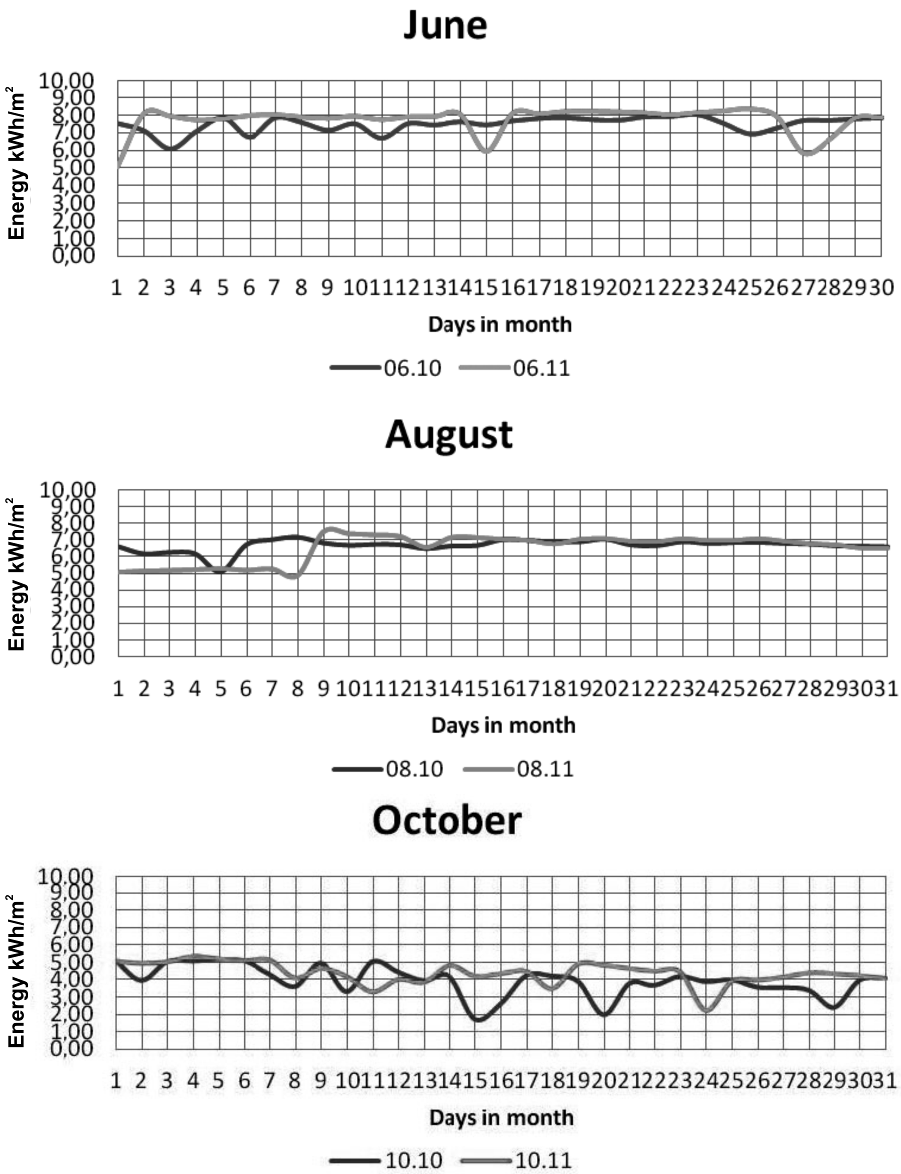


Fig. 7. Measured solar enegry at METU-NCC for June, August, and October 2010 and 2011

tricity Authority (KIB-TEK). Energy generation, transmission and distribution in the north side of the island are under the responsibility of Cyprus Turkish Electricity Authority (KIB-TEK). Total electricity generation capacity of KIB-TEK is 346.3 MW, and it is entirely dependent on oil and petroleum products (mainly Fuel Oil No. 6) [26]. The only PV plant is in a small village called Serhatköy in the Güzelyurt area. More detailed information on this PV plant is provided in later sections.

4. SOLAR ENERGY ANALYSIS IN NORTHERN CYPRUS

The quantity of solar radiation intake on the surface of the earth is influenced by numerous factors, such as geographical latitude of the given place, season of the year, time of the day, purity of the atmosphere, cloudiness, orientation and surface inclination, etc. [36].

Global horizontal irradiation maps show that TRNC is one of the countries, which has the greatest solar energy potential. The average total solar radiation is approximately $1960\frac{kWh}{m^2}$. TRNC has an important solar energy market. Solar energy potential, the number of sunny days and the amount of radiation in TRNC is significantly higher than in many European countries, according to the European Photovoltaic Geographical Information System ambient temperature data [35–37].

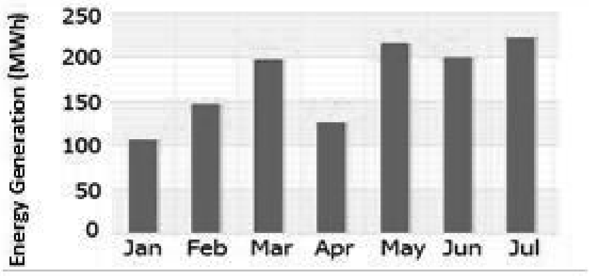


Fig. 8. Electrical energy generation at Serhatköy PV Farm for the first seven months of 2012

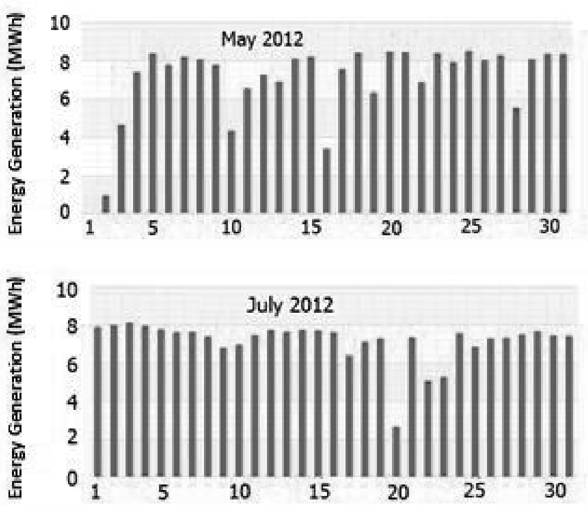


Fig 9. The daily electrical energy generation at Serhatköy PV Farm for May and July of 2012

The measured solar energy values can be used for developing solar energy models which describes the mathematical relations between the solar energy and the meteorological variables such as ambient temperature, humidity, and sunshine ratio [20]. Fig. 7 shows measured solar energy at METU-NCC in 2010 and 2011 for June (06.10, 06.11), August (08.10, 08.11) and October (10.10, 10.11). In June, irradiation is mainly between 7 and 8 kWh/ m^2, whereas this number drops to being just around 7 kWh/ m^2 in August as the sunlight hours are diminishing. By the time October arrives the measurements drop to be around 4 kWh/ m^2. The sunlight hours are shorter, and also the rainy season starts around October. The sharp dips in the graph are cloudy and rainy days.

The other data source is Serhatköy PV Farm. The PV Farm has 6192 PV panels each 206 watt on 9256 m^2 of land. They are made of multi-crystalline solar cells [26, 34]. According to KIB-TEK, total electricity generation in Northern Cyprus was approximately 1,468,095 GWh in 2011. The electricity genera-

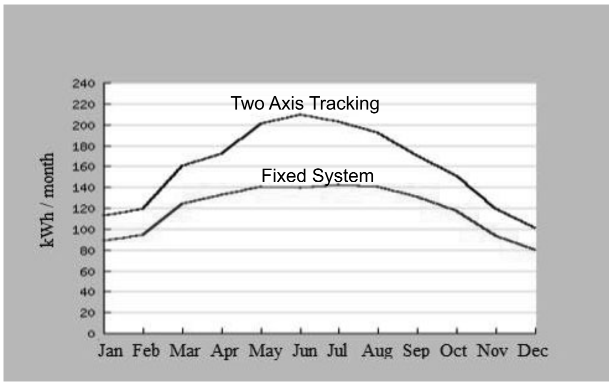


Fig. 10. Monthly energy output from fixed-angle PV system

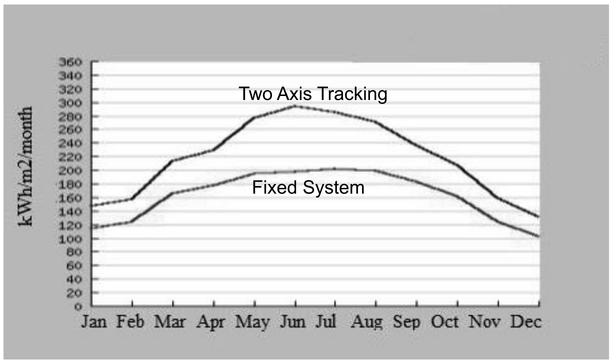


Fig. 11. Monthly in-plane irradiation for fixed angle

tion in Serhatköy PV Farm started in May 2011 and its total generation was 910 GWh form May till December. This PV farm is a small installation that was set up for PV generation demonstration and research purposes. Also, monthly weather conditions affect the electricity generation of PV farm. Fig. 8 shows the generated electrical energy for the first seven months of 2012 [34] and Fig. 9 shows the daily generated solar energy for May, and July 2012 can also be found in the same Figure. Summer months, as expected, have the highest numbers and rainy month of April has a lower amount of solar energy.

5. SOLAR ENERGY YIELD ESTIMATION IN NORTHERN CYPRUS

A simulation was designed for the city of Güzelyurt in Northern Cyprus. Table 1 and Figs. 10 and 11 are obtained, and designed according to the Joint Research Centre European Commission Photovoltaic Geographical Information System (PVGIS) data for this area. Firstly, the geographical location is considered, and then two different types of systems (namely Fixed and 2-axis tracking systems) are simulated by the indicated parameters as follows [35]:

Table 1. The geographic and system design values for indicated location

	Fixed system, inclination = 31 °, optimum given orientation			
Month	**Ed (kWh)**	**Em (kWh)**	**Hd (kWh/ m²)**	**Hm (kWh/ m²)**
Jan	2.86	88.8	3.69	114
Feb	3.37	94.2	4.40	123
Mar	4.00	124	5.32	165
Apr	4.42	133	5.91	177
May	4.52	140	6.28	195
Jun	4.65	139	6.56	197
Jul	4.57	142	6.48	201
Aug	4.52	140	6.42	199
Sep	4.35	131	6.08	183
Oct	3.79	118	5.20	161
Nov	3.10	93.1	4.11	123
Dec	2.57	79.7	3.32	103
Year	3.90	118	5.32	162
Total for year		1420		1940

- Location: 35°11'42" North, 33°6'42" East;
- Elevation: 118 m a.s.l.;
- Nominal power of the PV system: 1.0 kW (crystalline silicon);
- Estimated losses due to temperature: 12.2% (using local ambient temperature);
- Estimated loss due to angular reflectance effects: 2.6%, other losses (cables, inverter etc.): 14.0%, combined PV system losses: 26.5%;
- Ed: Average daily electricity generation from the given system (kWh);
- Em: Average monthly electricity generation from the given system (kWh);
- Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/ m²);
- Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/ m²).

The system is designed with consideration of the values detailed in Table 2. Geographic, PV panels and system information are examined. Electricity energy generation capacity of the system is indicated. The diagrams are created by months. In addition, fixed system and 2-axis tracking system for PV installation design were also added to diagrams as shown in Figs. 9 and 10. Total energy for the year based on average monthly electricity generation from the given system are 1420 kWh (Fixed) and 1910 kWh (2-axis). The total average sum of global irradiation per square metre received by the modules of the given systems are 1940 kWh/ m² and 2610 kWh/ m² for fixed and 2-axis tracking system respectively. The data shows that 2-axis tracking PV system can generate more electricity.

Actual measurements show the data collected in Serhatköy is similar to the simulated results for the 2-axis simulation even though Serhatköy has a fixed axis system.

6. CONCLUSION

The island of Cyprus has one of the highest solar energy potentials in Europe. Measurements and actual production data collected in Güzelyurt region in the North-Western part of the island support this high potential. Measurements taken on campus for METU-NCC were taken with a pyranometer and new equipment (a sun tracker and a pyrheliometer) is being added to improve the quality of the measurements. Actual production data is only available in Serhatköy, however, with encouraging results

Table 2

	2-axis tracking system			
Month	**Ed (kWh)**	**Em (kWh)**	**Hd (kWh/ m²)**	**Hm (kWh/ m²)**
Jan	3.61	112	4.73	147
Feb	4.26	119	5.63	158
Mar	5.16	160	6.88	213
Apr	5.73	172	7.61	228
May	6.47	201	8.94	277
Jun	6.98	209	9.80	294
Jul	6.53	202	9.19	285
Aug	6.19	192	8.74	271
Sep	5.68	170	7.89	237
Oct	4.86	151	6.68	207
Nov	3.96	119	5.30	159
Dec	3.24	101	4.24	132
Year	5.23	159	7.14	217
Total for year		1910		2610

from the measurements it is hopeful that more PV farms will be set up in different regions on Northern Cyprus.

ACKNOWLEDGEMENTS

The support of KIBTEK, METU-NCC Sustainable Environment and Energy Systems Graduate programme is greatly appreciated. Also appreciated are the efforts of Furkan Dinçer for his valuable discussions. Campus Research Fund of METU-NCC also helped out by providing the equipment necessary to make the solar measurements on campus. Also appreciated is the help of SEES graduate student Mehmet Yenen in gathering the solar data from METU NCC.

REFERENCES

1. Genc, M., S., Celik, M., Karasu, I.: “A review on wind energy and wind–hydrogen production in Turkey: A case study of hydrogen production via electrolysis system supplied by wind energy conversion system in Central Anatolian Turkey”, Renewable and Sustainable Energy Reviews, 16, pp. 6631–6646, 2012.

2. Hrayshat ES. Analysis of renewable energy situation in Jordan. Renewable and Sustainable Energy Reviews, 11, pp. 1873–87, 2007.

3. Dincer F.,: “The Analysis on Photovoltaic Electricity Generation Status, Potential and Policies of the Leading Countries in Solar Energy”, Renewable & Sustainable Energy Reviews, 15, (1), 2011, pp. 713–720.

4. Dincer F.: “Overview of the photovoltaic technology status and perspective in Turkey”, Renewable & Sustainable Energy Reviews, 15, (8), pp. 3768–3779, 2011.

5. Rustemli, S., Dincer, F.: “Economic Analysis and Modeling Process of Photovoltaic Power Systems”, Przegląd Elektrotechniczny, 87, (9 a), pp. 243–247, 2011.

6. Aghaei, J., Alizadeh, M., I.: “Demand response in smart electricity grids equipped with renewable energy sources: A review”, Renewable and Sustainable Energy Reviews, 18, pp. 64–72, 2013.

7. Ipakchi A, Albuyeh F. Grid of the future. IEEE Power Energy Magazine, 7, (2), 2009, pp. 52–62.

8. Sioshansi R, Short W., Evaluating the impacts of real-time pricing on the usage of wind generation. IEEE Transactions on Power Systems, 24, (2), pp. 516–24, 2009.

9. Manzano-Agugliaro, F., Alcayde, A., Montoya, F., G., Zapata-Sierra, A., Gil, C..: "Scientific production of renewable energies worldwide: An overview", Renewable and Sustainable Energy Reviews, 18, pp. 134–143, 2013.

10. Al-Badi, A., H., Albadi, M., H.: "Domestic solar water heating system in Oman: Current status and future prospects", Renewable and Sustainable Energy Reviews, 16, pp. 5727–5731, 2012.

11. Renewables Global Status Report 2012. (http://www.ren21.net), Accessed: 04.08.2013.

12. Cruz-Peragon, F., Palomar, J., M., Casanova, P., J., Dorado, M., P., Manzano-Agugliaro, F.: "Characterization of solar flat plate collectors", Renewable and Sustainable Energy Reviews, 16, pp. 1709– 1720, 2012.

13. Banos R., Manzano-Agugliaro F., Montoya F.G., Gil C., Alcayde A., Gomez J., Optimization methods applied to renewable and sustainable energy: a review, Renewable & Sustainable Energy Reviews, 15, pp. 1753–1766, 2011.

14. Ssen Z, Solar energy in progress and future research trends, Progress in Energy and Combustion Science, 30, pp. 367–416, 2004.

15. Tyagi, V., V., Panwar, N., L., Rahim, N., A., Kothari, R.: "Review on solar air heating system with and without thermal energy storage system", Renewable and Sustainable Energy Reviews, 16, pp. 2289– 2303, 2012.

16. Thirugnanasambandam M., Iniyan S., Goic R., A review of solar thermal technologies, Renewable and Sustainable Energy Reviews, 14, pp. 312–322, 2010.

17. Panwar N.L., Kaushik S.C., Kothari S., Role of renewable energy sources in environmental protection: a review, Renewable and Sustainable Energy Reviews, 15, pp. 1513–1524, 2011.

18. Hassan, H., Z., Mohamad, A., A.: "A review on solar-powered closed physisorption cooling systems", Renewable and Sustainable Energy Reviews, 16, pp. 2516– 2538, 2012.

19. Oliver J.E., The encyclopedia of world climatology (Encyclopedia of earth sciences series), Springer (2005).

20. Khatib, T., Mohamed, A., Sopian, K.: "A review of solar energy modeling techniques", Renewable and Sustainable Energy Reviews, 16, pp. 2864–2869, 2012.

21. Asim, N., Sopian, K., Ahmadi, S., Saeedfar, K., Alghoul, M., A., Saadatian, O., Zaidi, S., H.: "A review on the role of materials science in solar cells", Renewable and Sustainable Energy Reviews, 16, pp. 5834–5847, 2012.

22. Parida B, Iniyan S, Goic R., A review of solar photovoltaic technologies, Renewable and Sustainable Energy Reviews, 15, pp. 1625–36, 2011.

23. Bhutto¸A., W., Bazmi, A., A., Zahedi, G.: "Greener energy: Issues and challenges for Pakistan – Solar energy prospective", Renewable and Sustainable Energy Reviews, 16, pp. 2762– 2780, 2012.

24. Bahadori, A., Nwaoha, C.: "A review on solar energy utilisation in Australia", Renewable and Sustainable Energy Reviews, 18, pp. 1–5, 2013.

25. bp.com/statisticalreview, BP Statistical Review of World Energy June 2012, Accessed: 11.19.2012.

26. Ozerdem, O., C., Biricik, S.: "Overview of Energy System and Major Power Quality Problems in North Cyprus", International Journal on "Technical and Physical Problems of Engineering" (IJTPE), 3, (8), pp. 71–75, 2011.

27. Ishikawa T., Grid connected photovoltaic power systems: survey of inverter and related protection equipments, Task V: Grid Interconnection of Building Integrated And Other Dispersed Photovoltaic Power Systems, (www.iea-pvps.org), pp.1–64, 2002.

28. Kalogirou S. Solar energy engineering: processes and systems. Academic Press; 2009. pp. 469–517.

29. Eltawil, M., A., Zhao, z.: "Grid-connected photovoltaic power systems: Technical and potential problems – A review", Renewable and Sustainable Energy Reviews, 14, pp. 112–129, 2010.

30. Meral, M., E., Dincer, F.: "A review of the factors affecting operation and efficiency of photovoltaic based electricity generation systems", Renewable and Sustainable Energy Reviews, 15, pp. 2176–2184, 2011.

31. Mirzahosseini, A., H., Taheri, T.: "Environmental, technical and financial feasibility study of solar power plants by RETScreen, according to the targeting of energy subsidies in Iran", Renewable and Sustainable Energy Reviews, 16, pp. 2806–2811, 2012.

32. Raman, P., Murali, J., Sakthivadivel, D., Vigneswaran, V., S.: "Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India", Renewable and Sustainable Energy Reviews, 16, pp. 3320–3325, 2012.

33. M. R. Pathirana, A. Muhtaroglu, "PV Solar Technology Status and Feasibility in Northern Cyprus", Proceedings of Global Conference on Global Warming (GCGW), July 2012.

34. Cyprus Turkish Electricity Authority (KIBTEK), Serhatköy PV Farm Data Reports, 2012.

35. http://re.jrc.ec.europa.eu/pvgis/, Accessed: 11.19.2012.

36. Pavlovic, T., M., Milosavljevic, D., D., Mirjanic, D., Pantic, L., S., Radonjic, I., S., Pirsl, D.: "Assessments and perspectives of PV solar power engineering in the Republic of Srpska (Bosnia and Herzegovina)", Renewable and Sustainable Energy Reviews, 18, (2013), pp. 119–133.

37. http://solargis.info/, Accessed, 03.25.2012.

Cumali Sabah,
Assoc. Prof. Dr. in Electrical and Electronics Engineering, received B.Sc., M.Sc., and Ph.D. degrees in electrical and electronics engineering from the University of Gaziantep. He is currently with Middle East Technical University-Northern Cyprus Campus. His research interests include the microwave and electromagnetic investigation of unconventional materials and structures, wave propagation, scattering, complex media, metamaterials and their applications; and solar systems

Murat Fahrioglu
obtained the BS degree in Electrical Engineering from Michigan State University, in 1993, the MS degree (1994) and the Ph.D. degree (1999) from the University of Wisconsin – Madison. He is currently an Assist. Professor at Middle East Technical University – Northern Cyprus Campus in the Department of Electrical and Electronics Engineering. His main interests are in Game Theory applications in electric power systems and more specifically in the design of demand management contracts between electric utilities and their customers to avoid forced outages. He is also working on renewable energy integration into power systems and assessment of solar and wind energy resources

Ali Muhtaroglu
received his B.S. from University of Rochester in 1994, M.S. from Cornell University in 1996, and Ph.D. from Oregon State University in 2007, all degrees in Electrical Engineering. He is currently an associated professor of Electrical-Electronics Engineering at Middle East Technical University (METU) Northern Cyprus Campus (NCC). His experience and research interests include Integrated Circuit (IC) design, renewable energy systems, and low power system architectures. He is a Senior IEEE Member

CONTENTS

VOLUME 23 **NUMBER 3** **2015**

LIGHT & ENGINEERING
(SVETOTEKHNIKA)

PARTNES OF LIGHT & ENGINEERING JOURNAL

Editorial Board with big gratitude would like to inform international lighting community about the Journal Partners Institute establishment. The list with our partners and their Logo see below. The description of partner's collaboration you can found at journal site
www.sveto-tekhnika.ru

GENERAL PARTNER

BL Group

BL GROUP HOLDING

PLATINUM PARTNERS

LIGHTING SOLUTIONS

enercom
СОЗДАЕМ ВОЗМОЖНОСТИ

PHAROS-ALEF

ГЛОБАЛ ЛАЙТИНГ

GOLD PARTNERS

МОССВЕТ

ZUMTOBEL

ГСТЗ
г. Гагарин

Instrument Systems
light measurement

GE Lighting

SILVER PARTNERS

alanod

RAINBOW
ELECTRONICS

ВНИСИ

Светотехнический завод
ВЛАДАСВЕТ

НИИ

BRONZE PARTNERS

НИИИС

ВИ
СХ