*Robert-Gabriel ROIBU*

# LIGHTING BODIES WITH CHANGEABLE GEOMETRY

***Abstract:*** *In this paper, there are presented some general ideas of lighting bodies with changeable geometry, also exposing a few principles of design and modifying some already known geometric shapes. The lightings with changeable geometry provide flexibility, making possible to modify the intensity of light just by a movement (rotation or translation) of the pieces that assemble the mechanism. They are very easy to use and also very useful in certain situations. Also, the best design and the most doable lighting body with changeable geometry will be extended. Therefore, some ideas will be introduced referring to mechanisms that can be used to make this change possible, and in the end the best solution will be chosen. The mechanism isn't too easy to choose because it has to be handy for the user, it has to be easily implemented on the lighting body and not at all complicated. In the paper, there will also be presented some design ideas of the chosen product support. It will have a more simple design, and it has to be appeal to all potential users.*

***Key words:*** *lighting body, changeable geometry, geometrical forms, cylinder, helix, design, mechanism solutions, lighting stand.*

## 1. INTRODUCTION

Nowadays, there are concerns for the introduction of lightings with changeable geometry. In this paper, we are trying to optimize a lighting system for interiors based on modifying the geometry of the reflecting surfaces.

The principle can be extended for an architectural system of the analyzed lighting, in this case predicting that the changeable geometry is going to be required at the level of masks or opaque screens, designed to adapt to a specific light distribution according to a given situation.

It has to be mentioned that this solution is destined for existing interior lighting systems. It's hard to accept, technically and economically, the solution of changing some of the lightings in order to eliminate the troublesome lights of a contemplation area. However, the lightings can be analyzed individually, and afterwards they can be equipped with screens or with additional lenses. This intervention on lightings can generate both esthetic and technical problems. In terms of technical-luminosity, the lighting body can't slow its basic performances required by other standards.

Also, it is extremely important to mention that the size of the technical luminosity presented in the following paper expresses the possibility of saving electric energy in the lighting systems without reducing any visual effect.

In the following lines of this project there will be state a few ideas that will be endorsed in the future chapters of research. In this paper there are some ideas and sketches that will be the starting points of the final product.

## 2. CYLINDER SHAPED BODY GENERATED BY TWO SEMICYLINDERS

We start with a relatively easy concept, with two semi-cylindrical bodies which, placed end to end, they compose a cylindrical body, rotating on a spindle with the help of arms. A LED support is placed inside the cylinder (figure 1). The cylinder shaped lighting has the characteristic design of a lamp post.

The two semi-cylindrical structures have different diameters, so that when we rotate them, the one with the larger diameter enfolds the one with the smaller diameter.

As it can be observed in the figure 1, the lighting body is provided with a few slits, arranged along the height of the cylinder. When the lighting body is fully closed, the light only passes thru them, thus creating a softer light, which can be used, for instance, in creating a romantic moment. Also, when you want a more powerful light, the two semi-cylindrical bodies can rotate, opening up the whole lamp post.

This kind of lighting body can be used in any room of the house, especially in the bedroom.

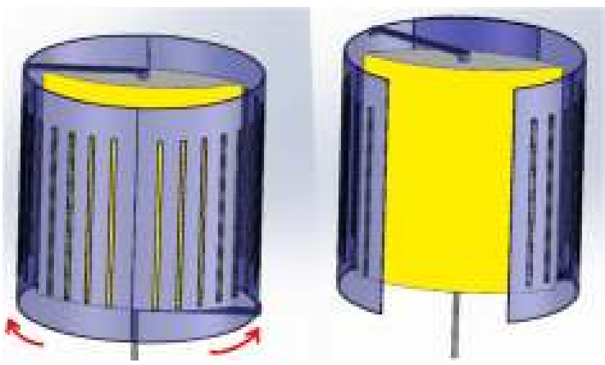

**Fig. 1** Transforming a cylinder into a semi-cylinder

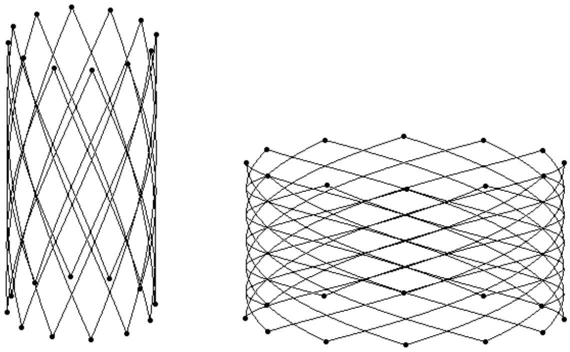

**Fig. 2 .**Lighting body generated by cylindrical helices – isometric view

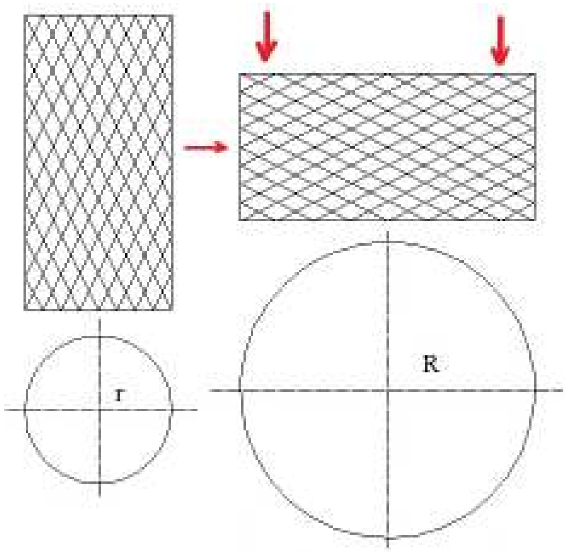


**Fig. 3** Lighting body generated by cylindrical helices – front view and top view

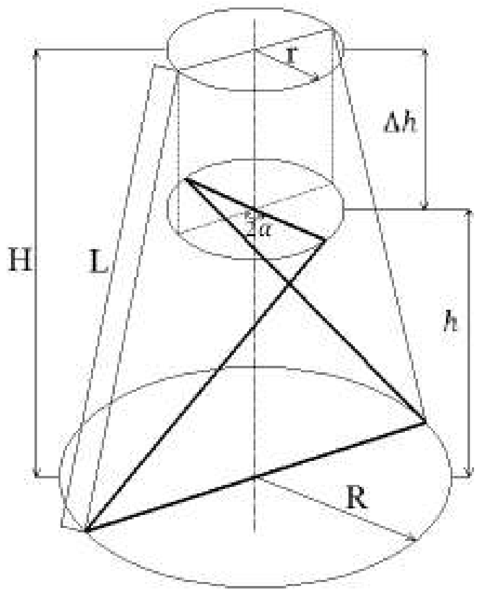


**Fig. 4** Transforming a cone into a hyperboloid

## 3. LIGHTING BODY GENERATED BY CYLINDRICAL HELICES

The lighting body generated by cylindrical helices equally distributed to right and left is the chosen lighting body with changeable geometry of this paper (figure 2 and figure 3). The helices have the same distance between them, and in the moment of height decrease the capacity of light increases, reaching maximum luminosity when the angle between helices is $90^0$, the demonstration being made in the $8^{th}$ chapter of this paper.

This lighting body, unlike other lighting bodies with changeable geometry, provides greater flexibility, covering all the human needs. It also generates a light much more spectacular than other bodies.

The light is necessary to man needs, offering him the opportunity to work during the night, but it's always too weak or too strong, causing headaches or even serious problems to the eyes. The lighting body generated by cylindrical helices gives the possibility of light adjustment, adapting to the human needs.

## 4. CHANGING THE GEOMETRY FROM A TRUNCATED CONE TO A HYPERBOLOID

The change of geometry from a truncated cone to hyperboloid is made with two round plates of different diameters. In order to create the cone shape, these two plates are connected by an indefinite number of bars, making the initial form, represented in the figure 4.

The larger diameter plate is considered fixed and the smaller diameter plate is mobile. Therefore, by rotating the mobile plate counter-clockwise, it modifies the geometry, thus creating a hyperboloid shape. The mobility of the smaller plate also has a translation movement, approaching the larger diameter plate. This approximation is achieved by the rotation movement due to the rigid metal bars. If at first, when the lighting body had a truncated cone shape, it had a height noted *H*, but rotating the mobile plate by the angle 2α, the height of the body drops at *h*. The height difference between the initial phase and the final phase is noted with *Δh* (fig. 4).

Knowing the following:

- *R* – radius of the fixed plate;
- *r* – radius of the mobile plate;
- *L* – length of the generators (rigid bars);
- *H* – maximum height of the lighting body;
- *h* – minimum height of the lighting body;
- *2α* – rotation angle of the mobile plate.

We intend to calculate:

- $\Delta h$=height variation of the mechanism

Giving the next relations, we intend to simplify the formula for $\Delta h$=height variation of the mechanism, also using the particular case when the radiuses of the plates are equal:

$$h = \sqrt{L^2 - (R^2 + r^2 - 2rRcos2\alpha)} \quad (1)$$

and:

$$H = \sqrt{L^2 - (R - r)^2} \quad (2)$$

Knowing:

$$\Delta h = H - h \tag{3}$$

The previous formulas are being replaced resulting:

$$\Delta h = \sqrt{L^2 - (R - r)^2} - \sqrt{L^2 - (R^2 + r^2 - 2rRcos2\alpha)}$$

Also using the special case when $R = r$ the relation simplifies to:

$$\Delta h = L - \sqrt{L^2 - (2R^2 - 2R^2cos2\alpha)}$$

$$\Delta h = L - \sqrt{L^2 - 2R^2(1 - cos2\alpha)} \tag{4}$$

Or it can be found out:

$$\Delta h = L - \sqrt{L^2 - 2R^2(1 - cos^2\alpha + sin^2\alpha)} \tag{5}$$

In the end we get to the following formula:

$$\Delta h = L - \sqrt{L^2 - 4R^2sin^2\alpha} \tag{6}$$

In the figure 5 the same model is represented, but in the particular case of the superior plate's radius equal to the inferior one.

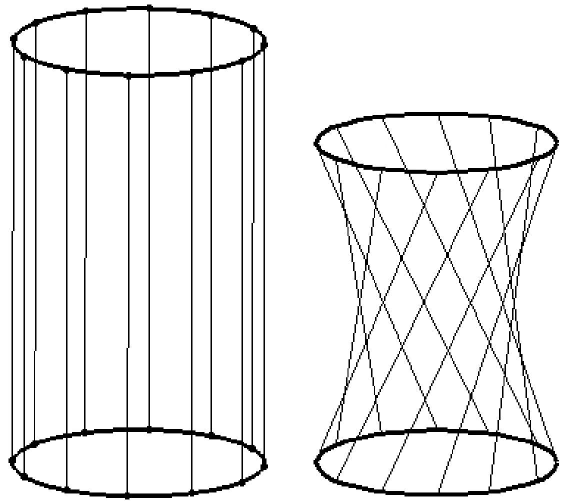

**Fig. 5** Cylindrical-hyperboloid lighting body

## 5. REDUCING THE HEIGHT OF A CONIC BODY

This case is similar with the previous one, but insted of the rotation movement of the superior plate, the mechanism performs a translation motion of the same plate. The rigid metal bars are made of two parts, working with a similar principle to the telescopic cane.

Reducing the lighting body to a 2-D image, right view or front view, the used dimensions can be easily calculated. You can see these calculus operations bellow based on figure 6 from the next column.

Knowing the following:

- *D* – longer diameter;
- *d* – smaller diameter;
- *H* – height of the lighting body.

We intend to calculate:

- $\Delta h$=height variation that reduces the mechanism:

$$a = \frac{D-d}{2} \tag{7}$$

If we want to reduce the angle α until it is equivalent with the value of the angle *β*:

$$\beta = {}^{\pi}/_{6} \tag{8}$$

As so, applying c$tg\beta = {}^{h}/_{a}$, we will know that:

$$h = \frac{a\sqrt{3}}{3} \tag{9}$$

Knowing: $\Delta h = H - h$

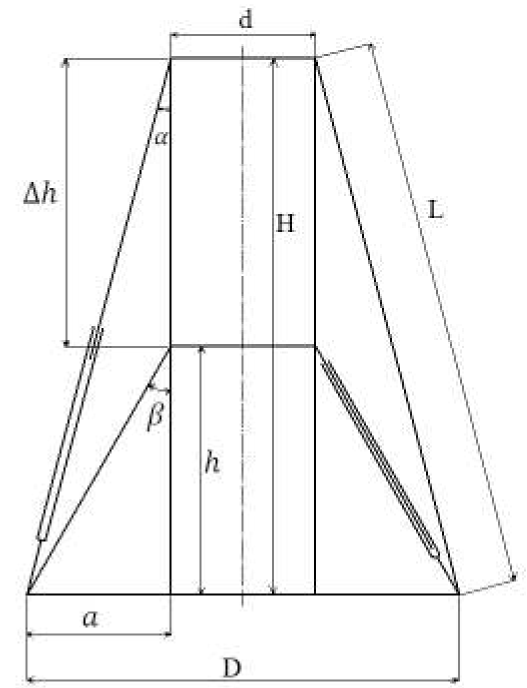


**Fig. 6** Reducing the height of a truncated body

Replacing the value of *h* with the previous calculated value, it results the final value of the height variation, if the angle *β* is known:

$$\Delta h = H - \frac{(D-d)\sqrt{3}}{6} \tag{10}$$

*Numerical application:*

Knowing the following: $\begin{cases} D = 300 \\ d = 200 \\ H = 300 \end{cases}$

We intend to calculate the height variation, also knowing the angle *β=π/6*:

$$\Delta h = 300 - \frac{(300 - 200)\sqrt{3}}{6} \rightarrow \Delta h = 271{,}13\ [mm]$$

*Observation:* These last two chapters (transforming the cone shaped body into a hyperboloid, and reducing the height of a cone) can be used together, in one structure, thus making a more complex lighting body, being provided with both rotation movement of the superior spindle and the telescopic cane principle.

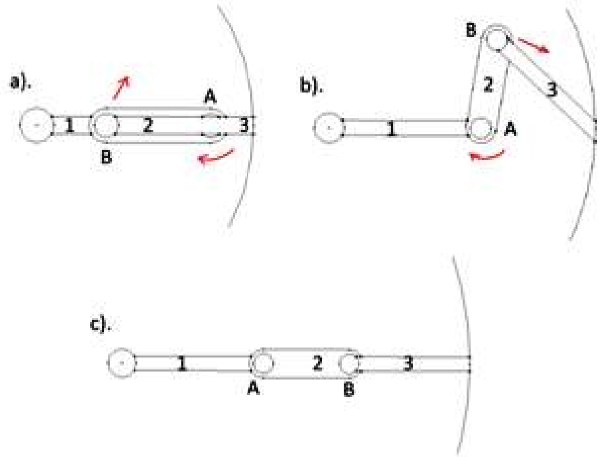


**Fig. 7** Interior action mechanism:
a). Minimum brightness
b). Medium brightness
c). Maximum brightness

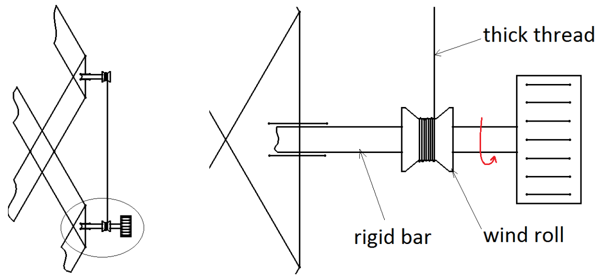


**Fig. 8** The mechanism of the body generated by helices

**Fig. 9** Lighting body generated by cylindrical helices

## 6. THE LIGHT CONTROL MECHANISM OF THE LIGHTING BODY GENERATED BY CYLINDRICAL HELICES

In the following lines will be exposed some ideas of mechanisms that can be applied to the lighting body generated by cylindrical helices.

The first idea is exposed in figure 7.a, b, c. It's a mechanism composed of three branches (numbered in the figure) and two hinge points (denoted by A and B). Arm 1 is fixed, attached to the axis of the lighting body, and the articulation A is also fixed.

Starting from the minimum diameter of the lighting body (figure 7.a) and rotating branch number 2 from the articulation A, it reaches the form in figure 7.b, where it can be observed a slight increase of the diameter of the body. The movement continues until it reaches maximum luminosity (figure 7.c).

Another mechanism of the lighting body generated by helices is introduced in figure 8. Here is shown a detail of the intersection of four helices to highlight the presence of two rigid bars that stretch along the diameter of the lighting body. They are linked by a thick thread (for example, gout) wrapped around a roll, similar to fishing rods.

On the bottom bar it can be noticed a reinforcement that makes the rotation possible, so that it will reduce the distance between bars, increasing brightness.

Between these two mechanisms, the second one will be chosen, being simpler to handle. The wheel that helps with the change of geometry is visible, in the exterior of the body, unlike the previous mechanism, where the handling is beneath the body, being more uncomfortable for the user.

## 7. THE SUPPORT OF THE LIGHTING BODY GENERATED BY HELICES

A simple support was applied for the lighting body with changeable geometry, being easy to made with minimum costs and pleasant for the majority of users.

As can be seen in figure 7, this body stand helps with the increase of flexibility, allowing the user to focus the light in a desired angle and spot. This also stands another degree of freedom for rotating the light spot around the stand.

Therefore, this support is doable, maximizing the flexibility of using the lighting body generated by cylindrical helices.

## 8. CALCULUS

This chapter refers to mathematical demonstrations of the lighting body generated by helices.

The first goal that can be achieved mathematically is calculating the maximum angle of brightness that can be obtained with the lighting body generated by cylindrical helices. This demonstration is possible using the surface of the rhombus ABCD, shown in fig. 10:

$$A_{romb} = L \cdot L sin\alpha = L^2 sin\alpha \qquad (11)$$

To obtain the maximum brightness, the sinus of the angle α must be equal to 1:

$$sin\alpha = 1 \rightarrow \alpha = \frac{\pi}{2} \qquad (12)$$

Therefore, the surface of the rhombus is now identical with a square:

$$A_{romb} = L^2 \qquad (13)$$

This means that the brightness reaches maximum when the cylindrical helices intersect themselves under the angle of $90^0$ ($\pi/2$) and, in other words, when the development of the lateral surface is a square.

The same demonstration can be done using the development of one helix, representing the diagonal of a square when it reaches maximum luminosity. Thus, applying the formula of the square area and adapting the sides with the known data (square diagonal), it can be determined that the maximum brightness of this lighting body is reached when $\pi/2$.

Therefore, in the figure 11 the same helix is presented with the length $L$ with the general angle α.

The surface of the rectangle OACB is:

$$A = Lcos\alpha \cdot Lsin\alpha \qquad (14)$$

With the help of a little mathematical artifice, multiplying and dividing by 2, it results:

$$A = \frac{2L^2 sin\alpha cos\alpha}{2} = \frac{L^2 sin2\alpha}{2} \qquad (15)$$

The maximum surface of the rectangle can be obtained by deriving the previous formula:

$$A' = \frac{L^2}{2} 2cos2\alpha = L^2 cos2\alpha \qquad (16)$$

If $A' = 0 \rightarrow 2\alpha = \pi/2 \rightarrow \alpha = \pi/4$

This means that the maximum luminosity is obtain when the cylindrical helices intersect under an angle of 90 degrees (π/2) or when the unfolded lateral surface is a square.

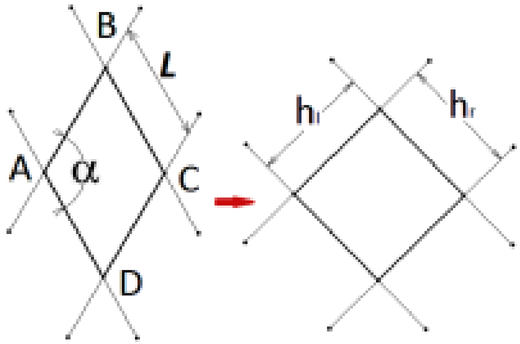


**Fig. 10** The intersection of two pairs of helices (rhombus)
$h_l$ = helices orientated to left;
$h_r$ = helices orientated to right.

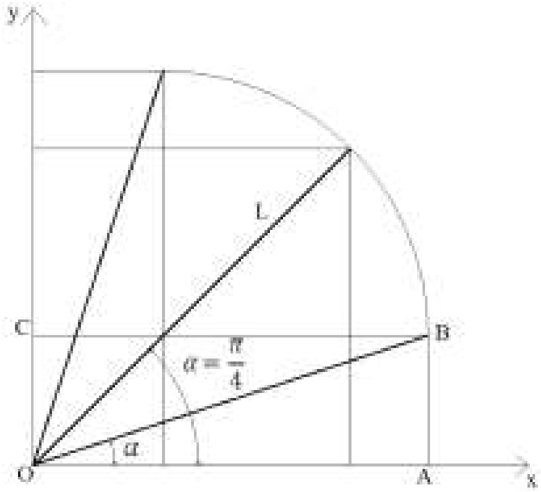


**Fig. 11** Unfolding a cylindrical helix

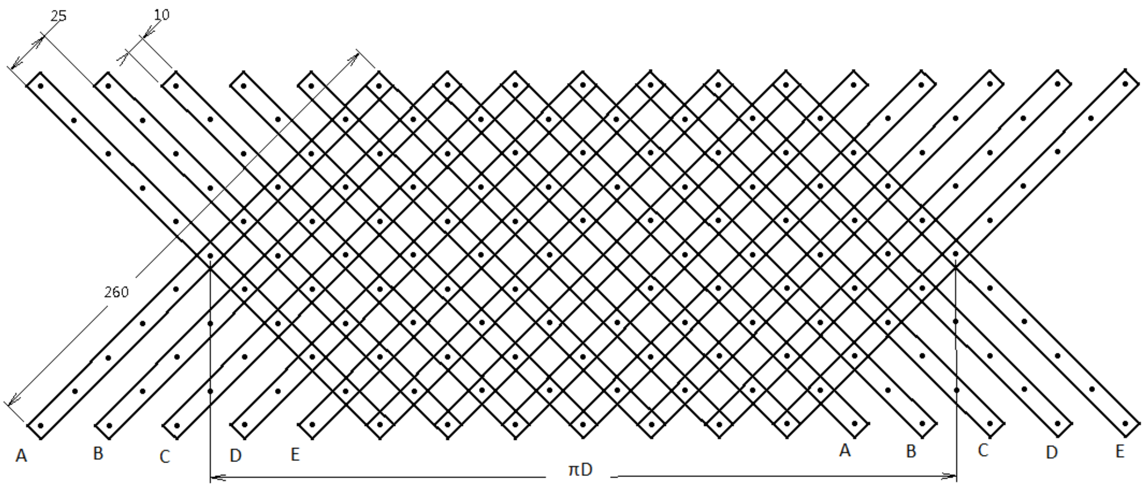


**Fig. 12** Development of the helices

In the next rows, it will be determined the diameter of the lighting body, in the moment of maximum luminosity. This will be the maximum diameter of the lighting body because if it would open more it would have the same light as so far.

So we start with the following inputs:

- The length of the helices: $L$=260 mm;
- The width of the helices: $l$=10 mm;
- The step between helices: $p$=25 mm;
- Number of helices: $n$=12x2=24;
- Maximum height: $H_{max}$ =240 mm;

Knowing this information and knowing from the previous demonstration (12) that maximum luminosity is represented by the fact that:

$$\alpha = \frac{\pi}{2}$$

It's noticed from the development in figure 9 that we can use one of the squares that gets created between the helices to calculate the distance between two extreme points of intersection (diagonal of the square):

$$d = \sqrt{2p^2} \quad (17)$$

Therefore, we can calculate the circumference of the cylindrical body:

$$c = (\frac{n}{2} - 1)\sqrt{2p^2} \quad (18)$$

Finally, applying the formula of the circle circumference, we can calculate the circle diameter:

$$\emptyset = \frac{(n/2-1)\sqrt{2p^2}}{\pi} \quad (19)$$

Applying all known data, we can determine the maximum diameter that can be reached by the lighting body generated by cylindrical helices: $\emptyset_{max} = 124\,mm$

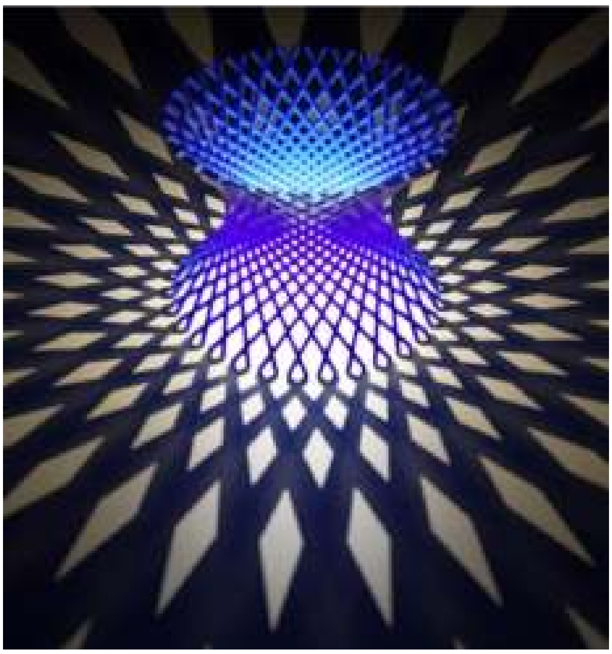

**Fig.13.** The visual effect of a hyperboloid shaped lighting

It is also possible to determine the minimum diameter of the lighting body. Since the brightness will be minimal, the slots must be almost closed. Therefore, the helices will be almost glued to each other. Multiplying the number of helices on a single direction with their width, we add a tolerance of 3 mm each (the slot through light penetrates), and finally we apply these data into the circumference formula (18):

$$\emptyset_{min} = \frac{p\frac{n}{2}+3\frac{n}{2}}{\pi} \quad (20)$$

Applying the values, we calculate the diameter:

$$\emptyset_{min} = 50\,mm$$

This information represents all the data needed to build a prototype of the lighting body generated by cylindrical helices.

## 9. CONCLUSIONS

First of all, the lighting systems provide us the safety we all need. Besides the safety, the lighting bodies with changeable geometry offer flexibility. When the light from our room is too powerful for our needs, by changing the geometry of the lamp, it generates a lower light similar with the one we see in the figure 13. Also, by changing the geometry we can concentrate the light into a special spot where we mostly need it.

The lighting body generated by cylindrical helices offers a spectacular light, by the help of the mechanism from chapter 6.

Besides the nice aspect, the lighting bodies with changeable geometry can reduce electrical costs. In this paper it is shown that the used formulas are very simple and easy to apply, making the calculus practical.

In the future will be assembled a functional prototype of the lighting body generated by cylindrical helices with the chosen mechanism and support.

## REFERENCES


[1] Marin, D. (2013). *Course notes, Industrial Shape Design (Note curs, Designul formelor industriale)*, PUB, Bucharest

[2] Moroldo, D. (1995). *Contributions of achieving flexible interior lighting systems by lightings with changeable geometry (Contribuții la realizarea sistemelor de iluminat interior flexibile prin corpuri de iluminat cu geometrie variabilă),* UTC, Bucharest

[3] Băilescu, Al., Savopol, D. (1969), Electrical Illumination (*Iluminatul electric)*, Technical Edition (Editura tehnică), Bucharest


**Author:**


**Eng. Robert-Gabriel ROIBU**, Student, Faculty of Aerospace Engineering, Department of Engineering Graphics and Industrial Design, Polytechnic University of Bucharest; robert.gabriel.roibu@gmail.com