LEDS LIGHTING: TWO CASE STUDIES

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Consumul de energie al sistemului de iluminat al clădirilor poate reprezenta 30% din consumul total. O posibilitate de reducere a consumului de energie electrică şi prin urmare a facturii la energie este înlocuirea lămpilor vechi şi controlul celor noi. În acest scop, sunt studiate şi dezvoltate noi lămpi performante, cum ar fi led-urile LED (recent O-LED). Această lucrare ilustrează, pe baza a două aplicații experimentale, cum folosirea led-urilor face posibilă nu doar reducerea consumului de energie, dar şi redezvoltarea arhitecturală a unor medii specifice şi reproiectarea sistemelor de iluminat arhitectural ce folosesc actual lămpi cu incadescență.

The energy consumption for buildings lighting system can reach 30% of the total consumption. A possible way to reduce the electricity consumption, and thus the energy bill, is related to the substitution of the old lamps and control of the new ones. For this purpose, new performance lamps like LEDs (recently O-LEDs) are studied and developed. The paper illustrates, based on two practice applications, how the LED use makes possible a substantial energy saving. In addition, the use of LEDs makes possible the architectural redevelopment of specific environments and the redesign of historical luminaries, currently characterized by halogen lamps.

Keywords: Domotic system, lamp, LEDs, lighting design, energy efficiency

1. Introduction

In the last years the lighting systems concept has evolved. The lighting system should no longer ensure only operational performances, but also should provide customers visual comfort (pleasant environments, color rendition, color temperature, etc.) and well-being (daylight, dynamic lighting, etc.). Furthermore, in recent years, the lighting design gained a remarkable value for energy saving. In the EU-15 Member States the lighting consumption, as share of the total residential electricity consumption, is between 8% and 23% (if water and heating

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are excluded from residential electricity consumption) [1].

In order to meet such a complex objective, the performances of luminaries and lighting control system must increase. With regard to the luminaries technologies, efficiency of lamps and optical systems has been improved [2]-[4].

In this context, the technology innovation of electronics and lamps will represent the basis of the near future lighting. Studies of new lamps, specifically LEDs and O-LEDs, namely the solid state Light [5], show their important impact. They are recognized to raise entirely different lamps from the past: small-size with high luminance (LEDs), low luminance surfaces (the O-LEDs) [6]-[8]. Nowadays the O-LED technology, used in prototypes with modest performances, is certainly of less interest. On the contrary, the LEDs are becoming an affordable solution to meet the needs of modern lighting product/system.

LEDs have reached interesting features such as [9]:

- high luminous efficiency (90-100 lm/W);
- lower losses in the distribution of the controlled luminous flux compared to traditional lamps (emitting only a beam of 120°, while traditional have about 360°);
- extremely small sizes and consequently extreme flexibility of use;
- good colour rendition (Color Rendering Index, CRI≥80);
- wide range of color temperature;
- light-up instantaneously;
- fully dimmable without colour variation;
- coloured light without filters;
- dynamic color control.

These new lamps, compared to traditional ones, have very high costs. The advantages of this technology are exploited in applications where the particular characteristics of the LEDs (small size, light coloured or dynamic) are used.

Specific application areas of this technology are [9]-[11]:

- the creation of performance luminaries such that to communicate with adequate control systems for the management of lighting contributions.
- the realization of special optical system, ad hoc, with high lighting performance and small sizes.

The purpose of this paper is to illustrate, with reference to two real applications, as the LEDs use makes possible a substantial energy saving, due to its fully dimmable characteristic and their integration into a domotic system. In addition, LEDs use allows the architectural redevelopment of specific environments and the redesign of historical luminaries currently characterized by halogen lamps.

The two cases are very important in the countries with many historical buildings. The obtained results could be applied by other designers.

2. Realization of performance luminaries able to communicate with intelligent lighting management systems

In this section, the lighting system refurbishment of a living room in a historical building in Milan is described. The area of intervention, illustrated in Fig. 1, and Fig. 2 (a) and (b), is defined by a particular architecture. This is characterized by a very long and narrow plan, from a historical glass vault, back-lighting, and with large windows.

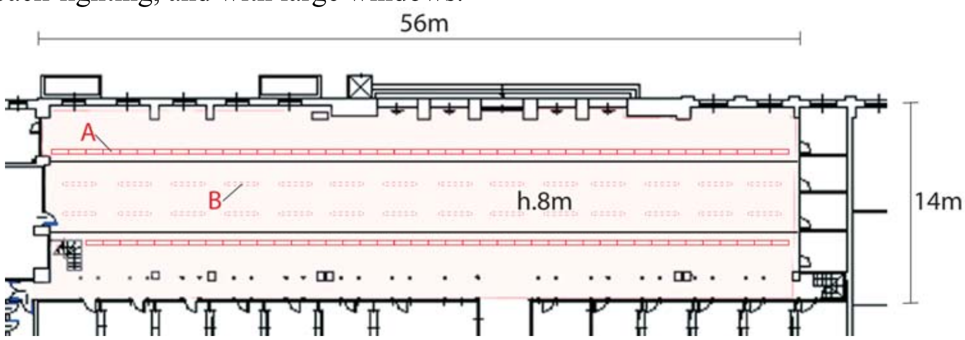

Fig. 1. Building Planimetry. A=main lighting (fluorescent lamps); B= back-lighting vault (fluorescent lamps)

The lighting analysis and the technical query were performed both on the lighting systems and the architectural structure. The results proved:

- the inefficient performance of the system (lighting and energy);
- the hazard conditions of the glazing system covering the vault.

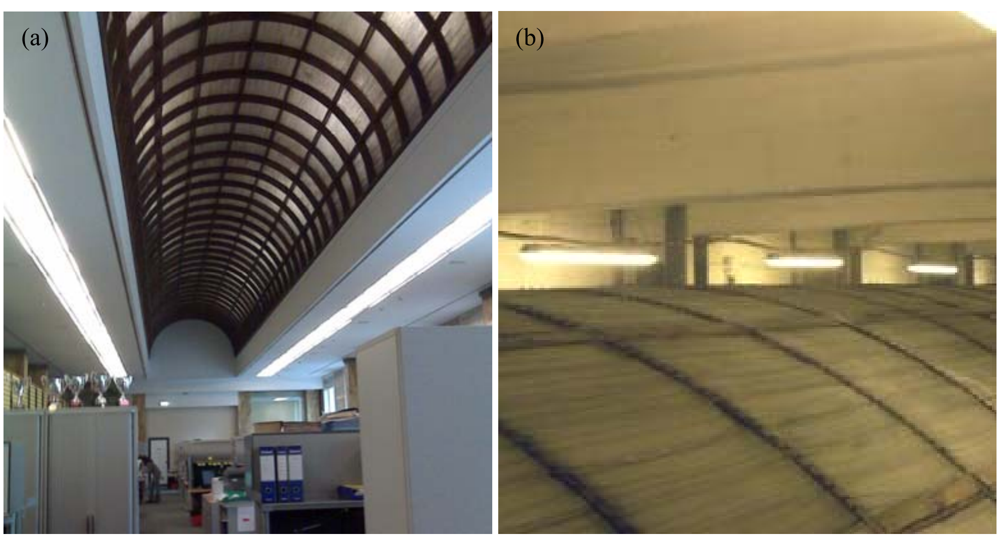

Fig. 2. Location and photos of the room (a) bottom vault, (b) top vault

The settlement of these aspects in the design stage represents a prerogative for future choices.

2.1. Intervention definition

The existing lighting system of the room is composed of fluorescent lamps, both for the back-lighting of the vault and for the area desks, as can be seen in Fig. 2. The comparison regarding the performance and energy consumption between the existing system and the proposed one is reported in Table 1.

This system configuration, as shown by preliminary stage inspection, does not guarantee the minimum lighting levels required by the standard UNI 12464-1 [12]. In fully operative conditions, the system configuration provides a very low average illumination level of 135lx, measured in the present condition.

Regarding to lighting uniformity, the system is deficient because, as it is not equipped with a lighting control system [13], does not allow exploiting the contribution of natural light provided to the closed windows. The luminous flux of the luminaries is provided in an un-differentiated way across the area, leading into clearly distinguishable bands of intense- medium- low- light. Failure to promoting the contribution of natural light determines also, in addition to a lack of comfort for users, a non-negligible energy consumption.

Evaluating the current configuration of the system and the problems that characterize the environment under retrofit, the objectives in the design stage are closely related to the standard UNI 12464-1 [12], the energy-saving policies and the safety conditions of the vault. The objectives that must be achieved are:

- ensure an average illumination level of 300-350 lx[5] (implemented to achieve 500 lx as established by the standard, through desktop lights);
- maintain a level of lighting uniformity over the entire area occupied by the desks > 0.5;
- ensure total color rendering index CRI ≥ 80;
- avoid glare;
- optimize energy utilization;
- ensure comfort and well-being;
- improve safety of windows in the vault.

2.2. Lighting design proposal

A major problem related to the environment under refurbishment is the danger of obsolete system windows of vault. It is a potential danger to the safety

[5] This value is considered enough by the customer in relation of his experience and of the compliances of the employers.

of the people below, as well as being a less efficient lighting system. In order to solve this situation, the replacement of existing windows with polycarbonate (PC) lights panels is proposed. This polymer layer is characterized by a texture able to extract and restore the environment, providing the lumen output with drowned coast LEDs, with an excellent performance.

Appropriate studies, performed in collaboration with the producer, have led to products that can satisfy the lighting parameters required. In order to properly illuminate even the remote areas of the room and improve the overall color rendering values[6], the system has been integrated with luminaries with last generation fluorescent lamps and wall washer optical. The configuration of the new lighting is described in Table 1. To optimize the management costs and the user's comfort, the lighting system has been fitted with an intelligent management tool.

2.3. Simulations

The results of the proposed lighting retrofitting may be evaluated quantitatively calculated by using the DiaLux software [14]. As highlighted in the obtained false color images shown in Fig. 3, the proposed design provides illumination levels around 360 lx, fitting with the proposed design objectives. The excellent lighting uniformity, about 0.7, on the whole area of interest is obtained. This is obtained considering a maintenance factor of 0.8.

Table 1

Performance and energy consumption comparison of current system vs the new proposed one

	Typology of installed lighting	N° of luminaries	N° of lamps for luminaries	Power lamps (W)	Power supplier (W)	Power (kW)	Em (lx)
Current lighting	Back-lighting vaulted (fluorescent lamps)	28	1	58	15	19.3	135
	Main lighting (fluorescent lamps)	66	4	58	2x15		
New lighting	Lighting vault (Lumisheet panel)	552	-	21	5	16.0	360
	Main lighting (fluorescent lamps)	30	1	49	6		

[6] Used LEDs have a CRI a little bit less than 80, as required by the standard for working room.

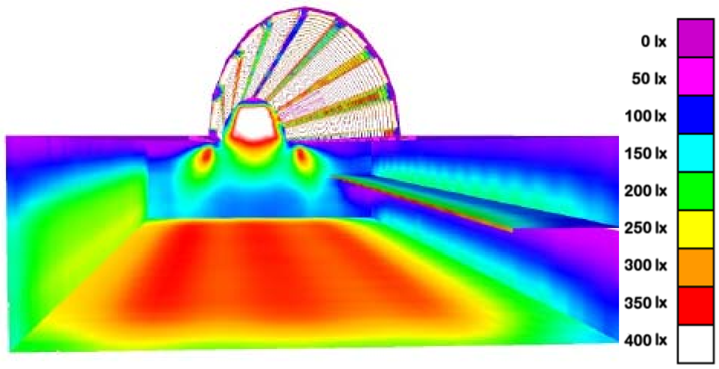

Fig. 3. False colour rendering of the new lighting system; the different colours represent the diverse value of illuminance in lx obtained in the room under analysis

The data for the new lighting systems are reported in Table 1. The illumination levels increased significantly from average value of 135 lx, below the value established by standard UNI 12464-1 [12], to the value of 360 lx. The installed power decreases by 25%. This is mainly due to the very low efficiency of the existing lighting system under and over the vault. As a matter of fact the luminaries over the top are suitable to illuminate the vault, but cannot give contribution to the illumination level of the room. The lighting system in the room is characterized by outdate lighting with low efficiency.

At last, regarding the energy consumption, it is useful to consider the absence of any lighting management system. In the application presented this condition is detrimental. If a small portion of the hall, with intensive daily and yearly traffic, has to be illuminated, the lighting management system must be operational 24 hours, 365 days, with enormous waste of energy and high costs.

The retrofitting solution, however, with its ability to be integrated with intelligent systems (devices for lighting flow management, varying according to the contribution of natural light in each individual areas, turn on/off) introduces considerable savings as reported in Table 2.

Table 2

Energy and ordinary maintenance of the vault costs

	Em (lx)	Installed power (kW)	Total hour (kh)	Energy consumption (MWh/y)	Total amount (k€/y)	Maintenance costs (k€/y)	Total Costs (k€)
Current lighting	135	19.3	8.76	169	25.4[a]	1.2+11·0.5	32.1

New lighting	360	16.0	4.38[b]	70	10.5[b]	-	10.5

[a] In the estimation of costs an energy cost of 0.15€/kWh and the operation, as it is now, of 24 hours a day, 365 days a year have been considered.
[b] In the estimation of costs an energy cost of 0.15€/kWh and the home management system presence has been considered. According to assessments made, the smart turn on/off of the system can be compared to a switch at full speed for 12 hours, 365 days a year.

According to assessments made, the integration of an intelligent system corresponds to a situation of full demand for only 12 hours/day on an annual base.

The new system allows 66% energy savings and a 70% reduction of total costs, for operation and management (the current operations of maintenance with the use of panels in PC to replace outdated windows, are avoided). In this analysis, the maintenance costs related only to the security of the vault are considered. They consist in one big operation in august and monthly controls in the rest of the year.

2.4. Final Evaluations

The proposed lighting system, due to the efficiency of the luminaries and to the integration of a home automation system, can meet the requirements of the standard UNI 12464-1 [12]. In addition, can lead to significant energy and cost savings. The increased lighting parameters associated with the integration of daylight also enhance comfort and environmental well-being for users who work every day in the room.

Finally, the specificities of the light panels solution, only achievable for obvious dimensional features with LEDs sources, allows the securing and upgrading of the vault through the strict respect for the historical identity of the place.

3. Realization of special optical systems, unique pieces, with high lighting performances and small size dimension

For the treatment of the particular field of LEDs application associated to optical systems with high-performance lighting, the case study on the retrofitting design of some historical luminaries characterized by halogen lamps is reported.

Currently, the lighting system of the entire area under investigation, shown in Fig. 4, is ineffective and very expensive from an energy point of view. In fact, downstream of the use of 3.99 kW of power, the lighting profiles at floor level are extremely low, ranging around 40-50 lx. This low lighting behaviour is due to both the use of inefficient lamps, like the halogen, and the absence of optical system within luminaries. This is because they have been manufactured in a historical period in which the studies of the optics and the sensibility for energy savings were not particularly developed. In our case the absence of optical systems produces the dispersion of the luminous flux emitted by the lamps, about 50% toward the ceiling, the vault and walls of the environment. The detailed description of the current lighting system can be derived from Table 3.

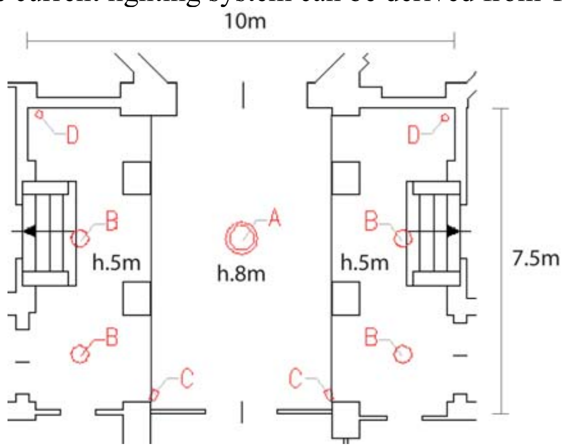

Fig. 4. The area under analysis and the current lighting system: A=historical central chandelier; B=historical lateral luminaire; C=projectors; D=spots

Table 3

Performance and energy consumption comparison of current system vs. the new proposed one

	Typology of installed lighting	N° of luminaries	N° of lamps for luminaries	Power lamps (W)	N° of supplier	Power supplier (W)	Power (W)	Em (lx)	Total Costs (€)*
Current light	central lamp	1	5	300	-	-	4018	40/50	2200
	lateral light	4	1	300					
	spots	2	7	35					
	projectors	2	1	400					
New light	central lamp	1	200	1	17	10	884	135	485
	lateral light	4	41	1	4	10			
	spots	10	10	1	1	9			

* In the estimation of costs an energy cost of 0.15€/kWh and 3650 hours a year of operation have been considered.

3.1. Design proposals

The project to refurbish the historical luminaries (one central and four lateral ceiling lights) and to enhance the architectural environment has been articulated through the study of new optical systems for each type of luminary and through the redesign of the global lighting. Specifically, a commercial linear LEDs system was used in order to eliminate the existing lighting vault composed by the projectors.

The single central chandelier was designed by replacing the 5 halogen lamps of 300W, with an optical system consisting of 200 LEDs lights with reflector, lens and integrated heat sink of 1W, as shown in Fig. 5.

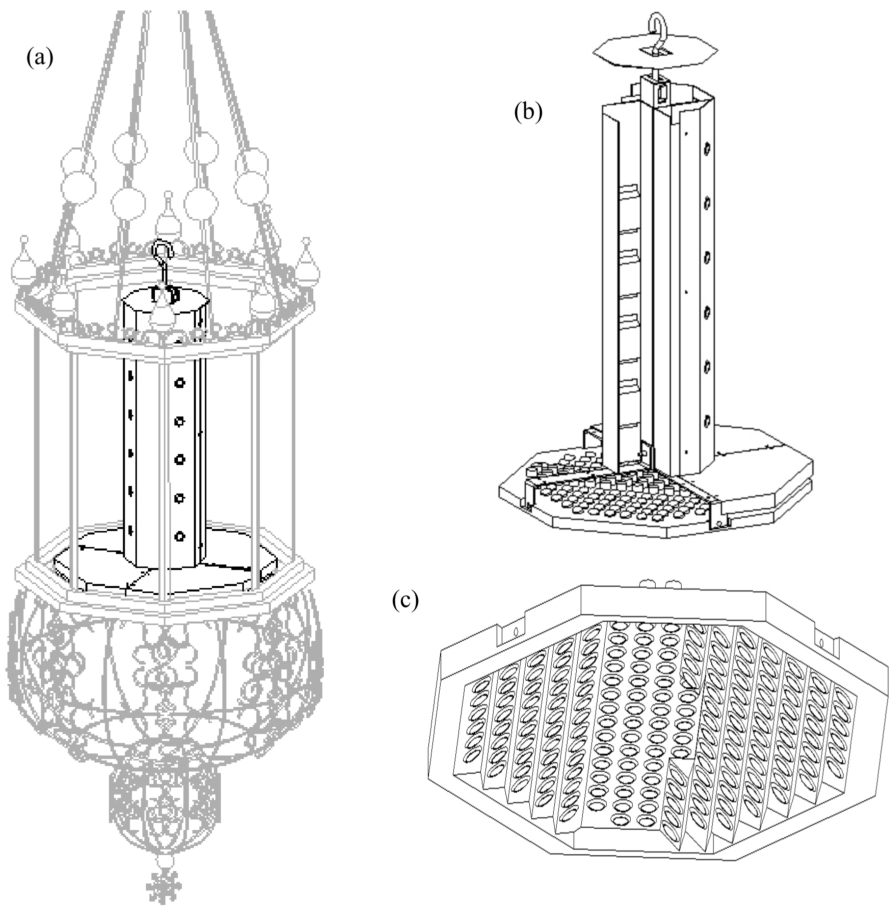

Fig. 5. (a) Historical central chandelier with the new LED optical system inside; (b) and (c) the new LED optical system

Also the four lateral ceiling lights, illustrated in Fig. 6, have been redesigned by replacing the present halogen lamp of 300 W with an optical system characterized by 41 LEDs lights with reflector, lens and integrated heat sink of 1W.

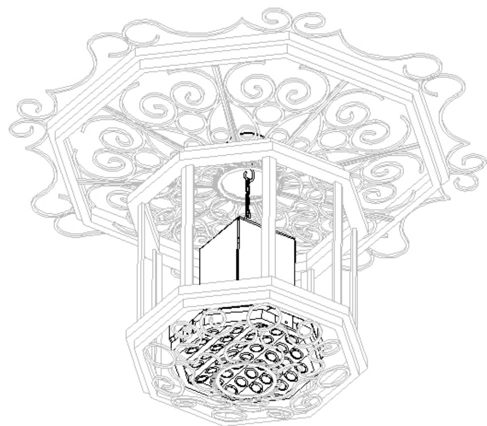

Fig. 6. Historical lateral ceiling light with new optical LED system inside

3.2 Simulations

From the simulations illustrated in Fig. 7 conducted with the DiaLux software [14], the luminance level of the site (obtained considering a maintenance factor of 0.8) has been shifted from a situation of very low illuminance (40-50 lx) to a new significantly higher (150 lx). Furthermore an energy and cost savings of about 75% is obtained, as reported in Table 3. (Maintenance costs are not considered because they aren't known by developer.) Taking into account both the difficulty to operate in such architectural context and the very limited lifecycle of the halogen lamps - about 2000 h - compared to that of LEDs sources/power supplies - estimated at about 35000 h -, the benefits would be even higher.

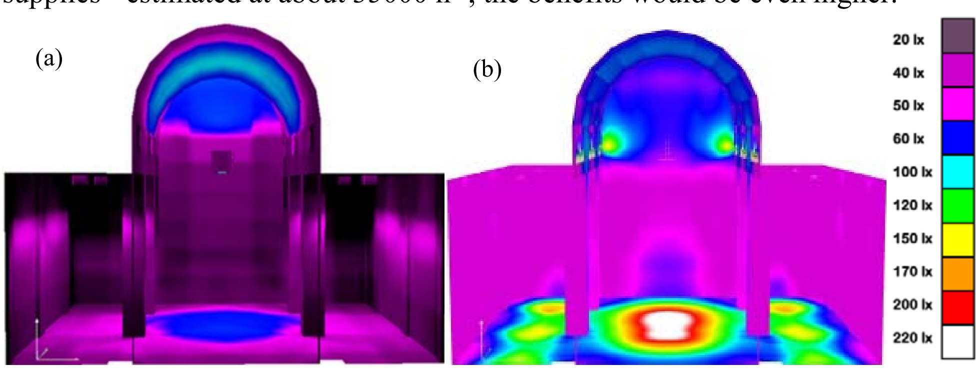

Fig. 7. Rendering comparison through false colours (a) old and (b) new lighting system; the different colors represent the diverse value of illumination level in lx in the room under analysis

Moreover, also from the aesthetic evaluation of the environments, the use of small lamps easily to orientate and with differentiated optical systems facilitates the creation of areas of emphasis. In this situation, for example, the enhancement of the central aisle and of the vault results extremely easy and immediate.

3.3. Final Evaluation

The proposed case study demonstrates the effectiveness of the LEDs based solutions performed in the frame work of the lighting system refurbishment in historical locations, where conservative and not-invasive interventions are required. This has been possible because of the small sizes, which provide a huge flexibility for use, and discrete lighting characteristics. Moreover, considering that the solutions are beyond the state-of-the-art for what concerns the chromatic color index and the low lighting efficiency, the LEDs luminaries allow to obtain a suitable environmental pleasantness.

On the other hand, the proposed solutions may represent a new approach of the conservative refurbishment theme linked to the eco-environmental sustainability all lover the National territory.

At the end, regarding the energy and costs savings, the LEDs-based solutions (with light efficiency η of 90-100 lm/W) are more convenient with respect to the old generation lamps, incandescent (η = 12l m/W) and halogen (η = 20 lm/W), nowadays installed quite in the overall Italian historical building stock. Also the integrations with fluorescent lamp (η = 100 lm/W) can be an interesting way to make the ambient more dynamic.

4. Conclusion

Scenarios that characterize the lighting design are nowadays becoming increasingly complex. In addition to the technical/functional needs, the comfort condition, the user's well-being and saving energy have now priority. In line with these developments, even the traditional conception of the luminaries is changing.

The need to find new technological solutions for lighting systems is proved by numerous research projects aimed to study new sources of illumination. For example, the special in studying and developing power LEDs and O-LEDs [9]-[10] is significant. The advent of O-LEDs technology will lead to a conceptual revolution of the light source. The use of innovative lighting sources, such as power LEDs (small, efficient and dynamic), is already introducing benefits in some specific areas (such as implementation of lighting performance able to communicate with the management daylight systems and implementation of optical systems with high lighting performances and small size).

Furthermore, the proposed solutions, considering the high relevance and the huge number of historical buildings in Europe, in view of a more conscious policy of retrofitting and valorization of the artistic-cultural building stock, is a thematic of specific interest since can be replicate all lover the world territory.

Finally, considering the growth perspectives of these lighting sources in the nexy years, and their positive results provided over a relatively short time since they came into the light design, in the short- medium- term, their use may be extended to the more traditional areas of illumination.

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