SORAA®

LED LIGHTING IN MUSEUMS: MANAGING DAMAGE TO ART

By Soraa Chief Scientist Aurelien David

Introduction

With the advent of LED technology allowing even more control over light sources, a renewed scrutiny of museum lighting best practices has surfaced. How do we best use LEDs to light art beautifully while respecting its fragile nature?

The unfortunate reality is that any radiation damages art. Therefore, proper museum lighting hinges on the tradeoff between highlighting art while keeping its conservation in mind. More specifically, at any position on an art piece, damage is caused by the local flux of photons, weighed by their relative damage (with short-wavelength photons being, on average, more damaging). In consequence, there are three factors that determine the amount of damage:

- The amount of light (total lumens)
- The distribution of light (local illuminance on the object)
- The spectrum of the light

These concerns are listed from most to least important in practical situations. This may come as a surprise, as spectral considerations are a frequent talking point in the field of art curation. To clarify this, let us examine these factors in detail.

Factors for Art Conservation

1 . Amount of Light

Damage scales linearly with the amount of light. Fortunately, the human vision system is excellent at adapting to a wide range of light levels —— an ability evolved from light variations found in nature. Therefore, while direct sunlight can reach upwards of 100,000 lux, a well-designed interior at a few tens of lux can be comfortable.

SORAA

Selecting moderate-to-low light conditions is a very efficient way to preserve art. By cutting the illuminance from 300 lux to 30 lux, a piece's lifespan with regards to light is increased tenfold i.e., 1,000%. Optimizing illuminance is the factor with the largest impact on conservation.

Of course, maintaining comfortable viewing conditions precludes too low an illuminance. This can be solved by playing with the influence of light contrast on acuity. In particular, an art piece illuminated with a moderate illuminance is more visible when placed in a dim or dark room rather than a brightly-lit room.

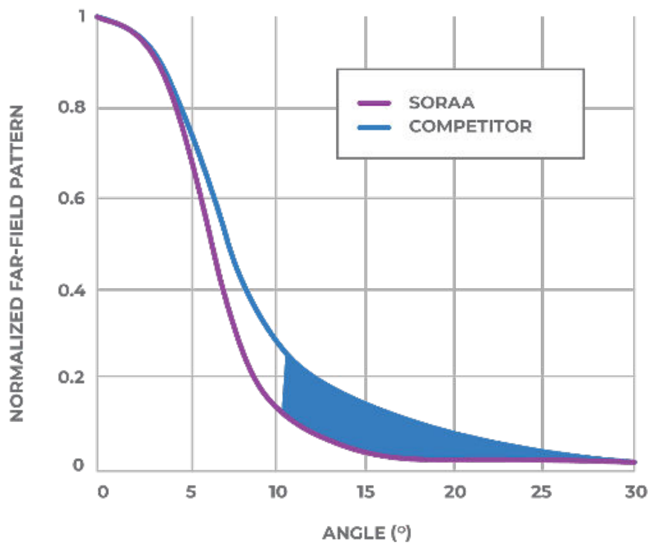
When using LED sources, the need for low illuminance and strong light level control increases the importance of products with excellent dimming capabilities.In particular, stroboscopic flicker, which can become severe when dimming a lamp with a low-quality driver, is unacceptable in museums.

2. Distribution of Light

Ideally, illuminance is uniform across an art piece. Realistically, however, the distribution of any light sources varies with angle — usually with maximal illuminance at the center of the spot. If the illuminance varies by 30% across the width of an art piece, the center of the piece is 'over-exposed' and suffers 30% more degradation. Thus, the quality and uniformity of a beam is crucial.

In addition, large-angle light can deliver lumens in unwanted directions. A directional optic directed towards one piece may emit a substantial amount of spill light towards another piece, increasing its illuminance. The best way to assess this effect is a detailed inspection of the beam profile, since usual specifications such as beam angle do not convey information about the actual beam shape.

For illustration, Figure 1 compares the beams of two spot lamps having substantially different large-angle behavior. Here again, an unwanted excess illuminance (and hence damage) of 15-20% can occur in the case of bad beam quality.



Far Field Pattern:

Figure 1 . Beam patterns of a 10 o Soraa lamp and a 15+ Competitor spot lamp. The competitor lamp has a slightly wider waist, as expected from its beam angle. However, it also shows a very substantial excess light at half-angles in the range 15-25 o (as much as 15% of the CBCP, shown as a shaded red region) which can be accidentally delivered to adjacent art pieces.

Large-angle light can also play another detrimental role: 'second-hand' glare to the viewer. Most museums know to how avoid direct glare, by hiding line-of-sight to light sources. However, large-angle light can create second-hand glare (for instance, due to specular reflection off of paintings). In turn, this glare reduces visual acuity and leads to the need for higher illuminance and thus, more damage.

The best way to address these issues is by using of directional sources with high-quality beam profiles, smooth distribution, no hot spots, proper beam angles, and low spill and glare. While the additional use of glare-reducing shades and louvers can help mitigate stray light, they can also create too sharp of a cut-off in the beam profile, which degrades its aesthetics. In short, accessories cannot always substitute initial beam quality.

3. Spectrum of Light

The spectrum of light also plays a role in degradation. In general, it is argued that photons of short wavelength can cause higher damage. This is illustrated on Figure 2 (Note that this is only an approximate trend. The specific wavelength sensitivity depends on the pigments of each paint or material —an important point discussed further below).

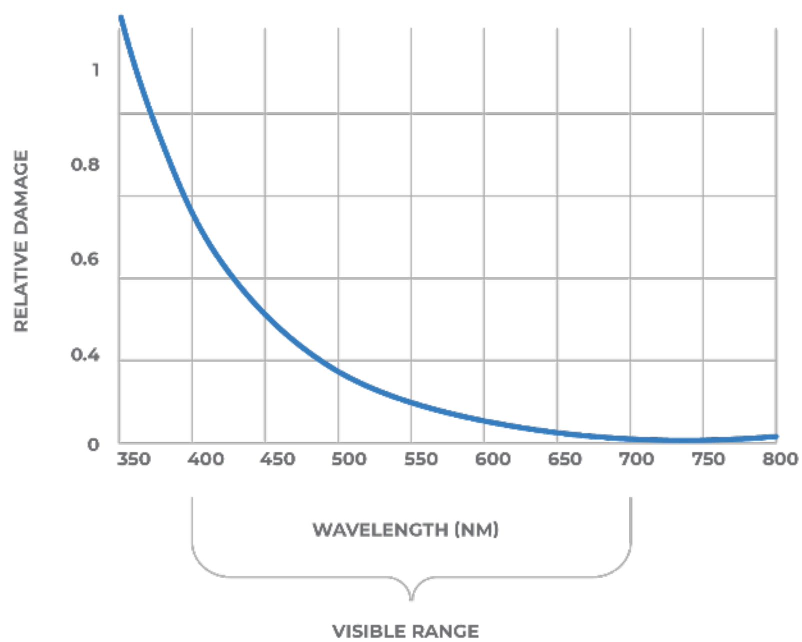


Figure 2 . Average relative damage of radiation versus its wavelength. Shorter wavelength causes more damage to art.

This leads to a few obvious rules. First, non-visible radiation (especially ultra-violet radiation) should always be avoided because it causes damage without any benefit to the viewer. This concern is moot with modern LEDs however, since they emit virtually no UV radiation (below 400 nm) and very little infrared. For example, Soraa's LEDs emit about 100 times less UV radiation than halogen lamps (therefore, the use of UV filters is superfluous). Second, sources with a lower CCT are usually preferable because they contain relatively less short-wavelength radiation. As an extreme example, the use of sunlight (with high CCT and large UV content) causes a large risk of damage.

Beyond these simple rules, however, the trade-off between damage and the quality of the spectrum can be more complex. Good color rendition usually requires wide wavelength coverage in the visible spectrum. Violet light helps render whites, for example, and deep-red light helps render various warm colors and flesh tones.

A full-spectrum, high-CRI LED will render colors appropriately, but for a given illuminance, the extra radiation implies a slightly higher nominal damage — typically on the order of 20-30% versus a low-rendition LED. Consequently, the choice between color rendition and damage should be considered with care. If higher color rendition is preferred, one option is to reduce the illuminance by 20-30% to maintain the damage level — essentially trading off lumens for color quality.

Human perception studies show that our vision system is very sensitive to changes in color rendering but quite insensitive to light levels, so improved color at a lower illuminance is often a viable choice.

The damage function shown in Figure 2 only indicates an *approximate* trend (with short-wavelength radiation being more damaging). However, more recent and careful research indicates that this curve is not accurate for all real-world objects. For instance, a recent article [Luo18] has compared the damage caused by a full-spectrum Soraa LED lamp and a conventional blue-based LED lamp on a variety of colored artifacts, and concluded the Soraa source is in fact less damaging on average, contrary to conventional wisdom. This is because specific pigments can have a complex wavelength sensitivity, ignored by simplified approaches such as that of Figure 2.

Although warm-white sources (2700 – 3000 K) are often advised due to their lower content in short-wavelength radiation, an argument can be made that in some cases, a high-CCT source is preferable. If a landscape was originally painted under sunlight, its colors may be more faithfully rendered under a higher CCT (4000 – 5000 K), and the slightly higher degradation may be acceptable if it offers the viewer a truly superior experience. For perspective, a Soraa Vivid lamp at 4000 K induces 35% more damage than the 2700 K version.

SORAA®

Summary

In summary, the total amount of light can strongly influence the lifespan of art — by one or several orders of magnitude — and should be carefully optimized. The other two effects, light distribution and spectrum, have a more modest influence (on the order of a few tens of percent) and can somewhat extend a work of art's lifespan. Even though the effect of spectrum is a frequent point of discussion, it is not in fact the dominant effect. Simple calculations of damage based on spectrum can make inaccurate predictions.

Damage Mitigation Strategies

Selecting a conservation strategy is a complex task which ultimately rests in the hands of the museum's curator and lighting designer. Below, we share a few art damage mitigation strategies to consider.

1. General Conservation

In the case of all-purpose conservation (i.e., when conserving articles that are not known to be exceptionally sensitive to light), general good practice is adequate. The key step is the use of moderate light levels supported by adequate light contrast. Overall low light levels in museum rooms, combined with directional lighting to selectively light art pieces, give the best opportunity to conserve visual acuity at low illuminance. This trend in museology is obvious when comparing old-style galleries with uniform lighting to modern museums, where theatrical-like light contrast is commonplace.

In addition, selecting sources with a high-quality beam distribution and directing them appropriately avoids light spillage and glare that cause unnecessary degradation. Careful consideration of the most adapted spectrum can also optimize the trade-off between color rendition and conservation.

2. Conservation of Highly Critical Objects

Some artifacts require a much higher amount of care, such as centuries-old fabrics and papers that are especially sensitive to light, or particular paintings whose rare pigments are overly fragile. These artifacts are usually —– and unfortunately— easy to identify as they have already faded significantly over time as a result of extensive exposure to standard light.

In such cases, any advanced measures can and should be considered to minimize further degradation. This includes the use of timed illumination, with the item only being illuminated when visitors are present in the room, or for specific short lapses of time. Curators may also consider specially crafted light spectra, using multi-LED systems, to maximize the tradeoff between color rendition and damage for the specific piece of interest. Note that such targeted efforts are complex and time-consuming, and most museums will find that they can only afford them for the most fragile of artifacts.

Using Soraa Lamps to Illuminate Art in Museums

Here are a few reasons why Soraa products are an excellent choice for lighting museums, providing the highest quality while being respectful of the art:

World-class beam quality:
Soraa's optics are carefully crafted to offer the best beams. They provide narrow beam angles (down to 4 o) with a clean beam shape and low glare and spill, for excellent control of light direction.

Full spectrum:
Soraa's full-spectrum sources offer the best color rendition of art and convey a superior visual experience. For the same damage level, using these sources at slightly lower illuminance is a sound alternative to slightly-brighter sources with poor color rendition. It is worth highlighting that Soraa sources are no more damaging than traditional filament lamps. For instance, compared to a bare halogen lamp, the relative damage of a Soraa VIVID lamp (with the same CCT and illuminance) is 85%. This is the same value that would be obtained by adding a UV filter to the halogen lamp, but with the added benefit that Soraa lamps render whiteness— a capability halogen lamps lose with UV filters.

Excellent dimming:
At low light level, a high-end driver that dims with low flicker is important. Soraa's drivers, including its new best-in-class MR16 two-stage driver, stand up to that demanding task.

SORAA®

Beam pattern flexibility:

As an added benefit, Soraa's versatile Snap System™ offers a unique opportunity to finely tailor directional beams. From beam spreaders to more complex beam shapes, CCT shifters to produce a particular ambience and even color-enhancing filters to restore the vividness of faded objects, Soraa offers many possibilities beyond a simple directional lamp.

Reference: [Luo18] Museum lighting with LEDs: Evaluation of lighting damage to contemporary photographic materials, H-W Luo, C-J Chou, H-S Chen, MR Luo, Lighting Research and Technology 2018.