MUSEUM LIGHTING - PURE AND SIMPLE

SUCH A POPULAR WHITE PAPER, IT'S ADDED TO THE CATALOG TO SAVE SENDING IT SEPARATELY

by Dr. Jack V. Miller and Ruth Ellen Miller

THE MUSEUM MISSION STATEMENT

The missions of a museum are:

1) Collect and exhibit art and historic artifacts for public education and enjoyment,
2) Protect the collection from damage, and
3) Do this all as efficiently as possible.

That's it, Pure and Simple... preserving and presenting our art and heritage. Anything that detracts from this is artistic or architectural nonsense and a violation of a museum's stewardship.

If the "public" (young or old) cannot see, understand and enjoy the exhibits, the building is not a museum, *it's an archive*. If items are not preserved, whatever it may be, the building is *not a museum*. Without both good presentation and effective preservation, a museum won't be able to continue. Funding is directly proportional to both the quality of art or artifacts, the quality of their presentation and the preservation of the collections.

The Dilemma

The problem is that exhibition always increases the risk of damage. The more visible and more accessible an artifact, the higher the risk. For our purposes, exhibition increases the dangers of light damage, both photochemical damage (fading) and photomechanical damage (structural damage). The safest place for a collection is in a vault, stored away in the dark, but that defeats the museum mission.

The light energy hitting an artifact either reflects off or it is absorbed. Reflected energy hits our eyes where it causes chemical changes. We call that vision. Absorbed energy causes chemical changes in the artifact. We call that photochemical damage. Eyes recover fairly rapidly from light-induced chemical changes. Artifacts do not.

Museums can minimize light damage by minimizing the energy absorbed by artifacts. First, we do this by using good lighting design to lower the overall light levels. Full visible spectrum lighting with all colors represented and none over or under-represented can double visibility without increasing intensity. Eliminating shadows, glare and reflections, lighting artifacts and not areas, and keeping backgrounds subdued also increase visibility while letting us lower overall light intensity. On top of that, it is easy to greatly reduce total absorbed energy without reducing any of the reflected energy that we see. We do this by choosing the proper light sources (following IESNA guidelines), eliminating non-visible radiation (UV and IR), and filtering lighting to match colors.

All this is simpler than you might suspect. We cover the basics here in a few pages.

The War of the Photons

Every museum is engaged in a continuing war against the damaging effects of light. The war begins as light rays (photons) cut through atoms of fragile color molecules and organic materials. The casualties are rare historic documents, sensitive textiles, fragile watercolors, fragile printed materials and organically dyed native arts. Damaged artifacts are given a quiet burial in the archives, never to be displayed again. Even the merchandise in the museum gift shop; clothes, books, posters, videos, can end up light damaged, discounted and sold at a loss.

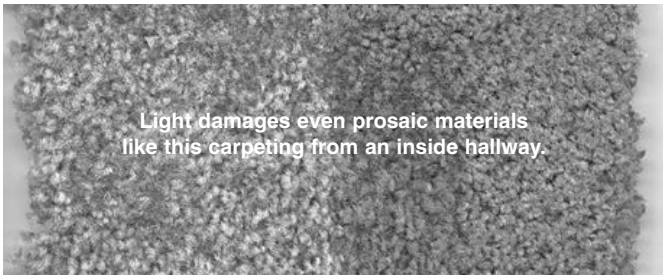
Priceless (or at least, costly) artifacts are set up like targets in a shooting gallery. The attacking weapons are the recessed lights and track fixtures you bought and paid for. The ammunition is the electrical power on every months' electric bill. Those lights magically convert electrical power (electrons) into photon bullets. They are shot at 186,000 miles per second (that's seven times around the world every second) and spin at 10^{14} revolutions per second.

Visible light along with invisible ultraviolet and infrared radiation shoot deep into materials, past and through the open spaces in and between many thousands of atoms. "Reflective" materials need to be 50,000 atoms thick to reflect just half of the photons of a beam of light. Even then, they

Only visible light helps you see.
IR and UV only cause damage.
Light energy is either absorbed or reflected. Only absorbed energy causes damage.
Minimize absorbed energy and you minimize damage!

It is impossible to understand museum lighting without understanding light and its interaction with materials[1]. You need to understand what light is and how it works. It is equally impossible without understanding how people see in a museum[2].

SILK DRESS - EXPOSED JUST 30 DAYS TO FLUORESCENT



HALLWAY - EXPOSED 5 YRS. CLOSET UNEXPOSED

only reflect photons of certain colors of light. The rest of the photons in the light beam bore into the material to seek out and cut the atomic bonds that hold the molecules together. The more light, the more photons. *The more photons, the more damage.* That's quantum physics, pure and simple.

Light Meters Lie

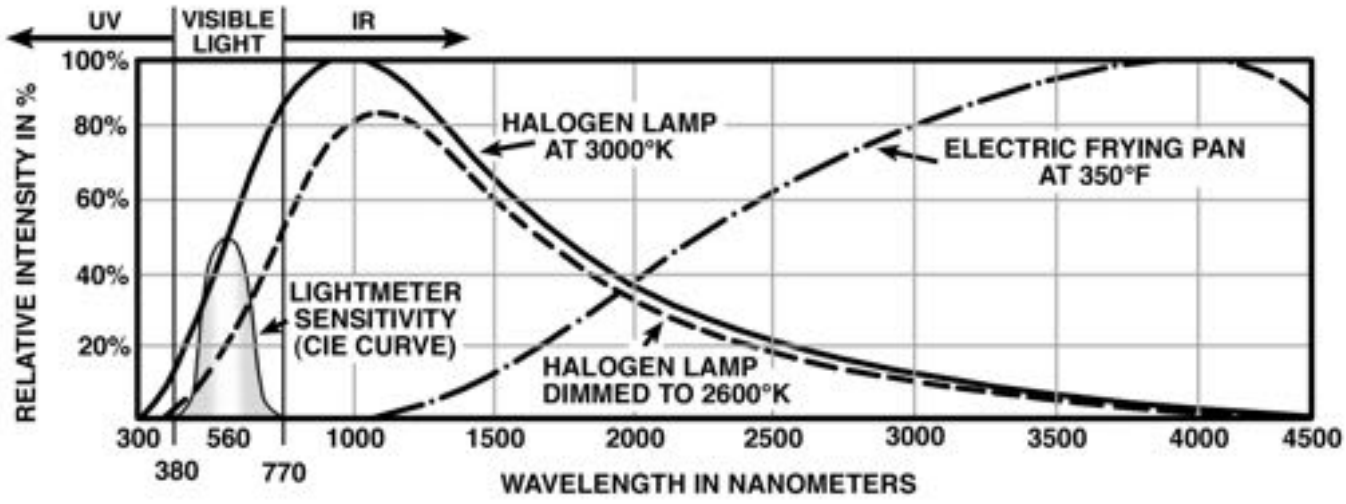
Conservators establish limits for measured levels of illumination to limit damage. Lighting designers over-light exhibits to provide a margin for future changes. Conservators then dim the lights to the specified light level using a "color-corrected" light meter. **Everything is "correct"...but the collections continue to fade.** No one considers the fact that dimming just moves the light energy towards the red and infrared wavelengths, where a light meter is nearly blind. Most of the light is still there. But no one (the viewer or the light meter) can see it...and the damage continues.

The graph below shows the *complete* spectral output of a quartz halogen track light at 3000°K. Most of the energy (95%) is outside the visible spectrum. About 1% is ultraviolet, below 380 nm. Roughly 94% is infrared, above 770 nm. None of that energy is visible to you or your museum light meter. Lighting manufacturers almost never give you full spectrum data. Now you know why.

A light meter is filtered to the sensitivity of the human eye, the CIE[3] curve. As you can see from this curve, eyes (and light meters) see none of the energy outside the visible spectrum (and then only about half of the energy actually present). Take the filter out of your light meter and you will find that a measured ten footcandles of quartz halogen light is actually somewhere above 200 equivalent footcandles of full spectrum radiation (ultraviolet through infrared). Because NoUVIR is limited to a spectral output matching the CIE curve, ten footcandles of NoUVIR lighting remains ten footcandles.

Dimming Doesn't Help

The dashed line in the graph shows the same lamp dimmed to 50% intensity in the visible spectrum. The actual result is to shift the peak of the curve



1. Jack Miller, Light and Mater: The Dangerous Romance (Seaford, DE: NoUVIR Research, 1993).
2. Jack Miller, Optics and Physiology of Human Vision in a Museum Environment (Seaford, DE: NoUVIR, 1994).
3. CIE stands for Commission International de l'Enclairage, the agency that developed this curve.

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toward the infrared, lowering the total energy hitting the exhibit by just 10%. Your light meter shows half the visible light, but your artifacts still experience 90% of the damage. This is why dimming incandescent tracklighting is not an effective preservation tool.

Who's Looking Anyway?

The orange-yellow color of dimmed lighting also makes things harder to see, especially for older patrons. We need to remember that over one-half of all museum visitors are over 55. They have about half the focal adjustment of someone college age and about one quarter the blue and violet sensitivity. While the color shift of dimmed lighting will effect the appearance of all art and artifacts, this will be particularly apparent and distracting to older adults. In terms of presentation, it is much wiser to operate fewer or lower wattage lamps at full voltage than to consider dimming.

Older people have significantly slower reaction times to lowered light levels. Glare sources (discussed in detail later) can leave an older person "snow blind" for 10 to 15 minutes. A great many older Americans wear glasses. Plan graphics, signs, and exhibits so that they are in the focal range of people wearing bifocal or progressive lenses. Plan lighting for those with the mild vision problems common to older Americans. People over 55 control over 75% of the wealth and discretionary income in this country. Few college students have large collections, leave bequests or are interested in estate planning. Support the people who support you.

Exhibit Lighting Elements

The elements of exhibit lighting match the three goals of any museum:

1. PRESENTATION: Showing the true beauty of art and historic artifacts

2. PRESERVATION: Protecting exhibits from fading and damage, and

3. CONSERVATION: Conserving energy, resources, manpower and funds

These three elements of exhibit lighting (and the three museum goals) are dependent on the things we've discussed above; understanding what light is, how people see it, and what happens when it hits something. Once you understand these fundamentals, you can control the light, protect your collection, and save money in the process.

Presentation

Presentation is an easy term to understand. It is simply the visitors' view of an exhibit...good or bad. Turn off the lights, what do you see? Nothing. You can exhibit the most wonderful masterpieces or historical treasures, but without light, who will know? Who will come?

When you realize that people only see what the lighting reveals, it turns exhibit design upside down. You can have the most beautiful objects in the world, but **only light transmits that beauty to a viewer**. When you walk into a museum, all you really experience is the lighting. Light is the only communication link between the objects and the people. ***If colors are not present in the illumination, or if they are too strong or out of balance, it will distort that communication.*** Poor lighting always creates poor exhibits!

Ignoring good lighting design, glare and reflection can make even wonderful artifacts difficult to see. Bad lighting will make artwork or exhibits dull, lifeless, or distorted. The bottom line is that any exhibit is only as good as what the visitor sees. And the visitor only sees the light you provide.

NoUVIR fiber optic systems produce a full, balanced color spectrum very close to that of sunlight, but with absolutely No UV or IR. Nothing is more dramatic than seeing the change when you switch off ordinary lighting and turn on these remarkable fiber optic systems. The results have been consistent. There is a moment of total silence, followed by a gasp. Then someone says, "I never knew that was so beautiful!" or "I never noticed that he was smiling" or "I didn't know that hat had a feather."

A Side-by-Side Study in Color Balance

The human mind has a unique ability to correct color-distorted light coming through tinted glasses or from off-color lights. The mind corrects the colors to somewhat normal vision in a process called "chromatic adaptation". As you adapt, you will still misidentify colors, lose details and miss variations in hue, but you stop noticing how bad the lighting really is.

Typical museum incandescent and halogen lamps (particularly when dimmed) have poor color

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Such a popular White Paper, It's added to the catalog to save sending it separately

balance. There is too much energy at the yellow/red end of the spectrum and too little energy in the blue/violet hues. This is functionally identical to viewing exhibts through yellow shooting glasses. Your mind adapts to the world turned yellow, but blue hues are suppressed and the violets are missing from your perception. When everything in a gallery has the same distortion, your mind conceals it. You start to think washed out colors with no blues look normal.

The three photographs on the following page were made under identical conditions: the same teacup, exactly the same light level, even the same roll of film. Only the light sources changed. In a gallery, without this side-by-side comparison you might not realize the extreme blue emphasis of fluorescent and LED lighting, the green tint of HID's or the way tin-can parlamps steal the "purple mountains' majesty" from landscapes. Color adaptation interferes. But poor color balance *will* show on your art and artifacts. Colors shift. Skin tones turn lifeless. Subtle hues disappear. People think we exaggerated the color shifts in these photographs. We didn't need to. You can do this same comparison yourself with a colorful artifact or print and a pair of desk lamps using various kinds of lamps.

Since we first did this testing, new sources have become popular. We've added the spectral output for HID and LED sources. The graphs clearly show the color distortion. You can calculate the area of spectral mismatch (the area above and below the sunlight curve) of any source and come up with a number that represents the variation from sunlight. This is called Correlated Color Imbalance. The higher the number, the greater the distortion. You might also call this number the "Coefficient of Ugly".

Another number that helps judge color balance or distortion is Color Rendition Index (CRI).[4] To get this number, test subjects sort colors under specific light sources (picture sorting a box of crayons). CRI is the percentage of correctly identified colors. A CRI of 80 sounds good, but what it really means is that 20% of all of the colors were misidentified. Anything less than 100 CRI shows distortion.

As the spectral outputs show, HID sources have very similar output to tri-stimulus fluorescent. While they have more spikes and valleys, the total area of missing colors (below the sunlight curve) and over-represented colors (above the sunlight curve) is even greater than fluorescent lights. And as with fluorescent lighting, the missing reds make everything look blue-green.

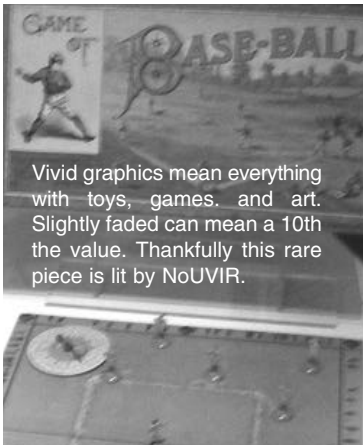
"White" LEDs also have a strong blue tint. In LEDs it is because of the huge blue spike in their output. LEDs are naturally monochromatic (one color). Just as fluorescent lamps generate UV to excite a phosphor coating to emit "white" light, "white" LEDs generate blue light at 450 nm to excite a "white" phosphor. The spectral output makes this distortion obvious.

NoUVIR is a visual duplicate of sunlight (with all the UV and IR removed). Thus, objects reflect their true colors. The coefficient of ugly is almost zero. Color Rendition Index, CRI, is 100. You get perfect color with no distortion.

But visual distortion is only part of the story. The chocolate under pure-white, stone-cold light is unchanged. But halogen light's effect, side-by-side at the same light level for the same time shows the impact of its 94% IR and 1% UV. The cordial cherry becomes a melted puddle. This demonstrates not only halogen's poor presentation (loss of true color and beauty), but its degraded preservation (increased damage). This is also a demonstration of poor conservation as every watt of heat added to a space takes 3 to 4 watts of air conditioning to remove. (But, we're getting ahead of ourselves.)

Watercolors, oil paintings, textiles, ancient glass, minerals, documents, photographs, etc. are all sensitive to bad lighting. The more complex the coloring and the finer the details, the greater poor lighting interferes with true perception. On top of this, for every 10°C rise in temperature, *the rate of chemical reaction doubles*. The question is not, "**Will** bad lighting damage your artifacts?" but, "**When**?" When will your plates or ceramics thermally craze? When will the background fabrics fade and need replacement? When will your textile, watercolor, or other art be damaged by UV, IR or both?

Like "GIGO" in computer programing, "Garbage-in" light creates "garbage-out" vision. Chosing the wrong sources will limit vision, damage collections and degrade the conservation of resources, man-hours and money. The bottom line is presentation, preservation, and conservation are all related and interdependent. Poor lighting will result in severe and inevitable consequences...it's just a matter of time.



Vivid graphics mean everything with toys, games. and art. Slightly faded can mean a 10th the value. Thankfully this rare piece is lit by NoUVIR.

4. Today published CRI is often optimistic. It started with using fewer color test samples to improve scores. Now the trend is to pick whichever computer program calculates the best CRI.

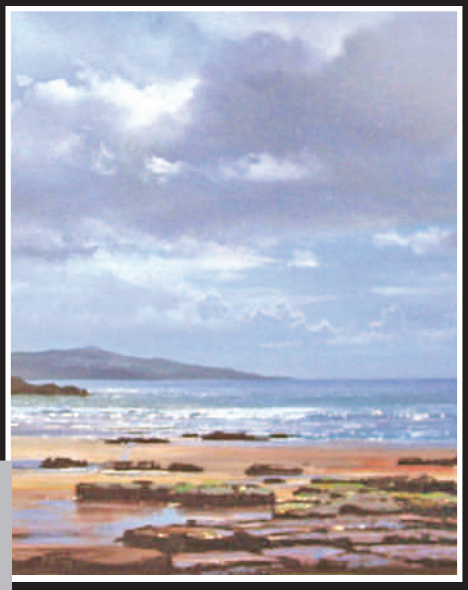
SIDE-BY-SIDE COMPARISONS OF LIGHT SOURCES

KNOW YOUR LIGHT SOURCES. SHOW THE REAL COLORS.

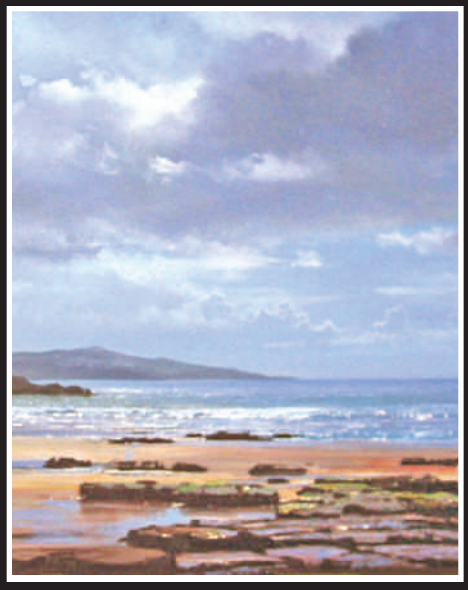
The cup to the left is lit with NoUVIR. It shows all the color and all the data against a brilliant china white background. No colors are missing. No colors are overstated. No colors are dulled. The cup to its right is lit with halogen. This is good retail lighting unless you notice there is too much red. The blues turn dark. The white china turns a warm off-white. The sage background turns yellow. Now compare it to good-quality fluorescent lighting as seen on the left. Women have long felt this energy solution forced them to live with ugly...and they are right. The colors turn cool. Some colors are completey missing which is why the sage background behind the cup looks gray. The white china is tinted blue.

Spectral output is important. If colors are missing in the lighting, those colors on the object look gray. If specific colors are over-represented, the opposite colors appear dark and damage increases. Our minds do color correct, so we may not notice. But deep down, we realize that things are duller, less spectacular and less beautiful than they should be.

Quality art looks good under most lighting. But it is surprising how much some sources cause us to miss. Over the years in pursuit of energy efficiency, fluorescent and LED lamps have made our world grayer. Beware of claims of "good" color and "white" light. Look at spectral outputs.



INDIRECT SUNLIGHT - PERFECT
We are designed to see in sunlight.
It has all the colors.
It gives us all the visual data.



NoUVIR - PERFECT
All the colors. All the data.
Matches sunlight to within 96%.
We see slightly more brilliance in color and detail, because our eyes are not responding to UV or IR.

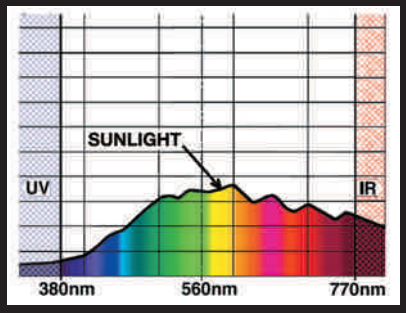
HALOGEN - TOO ORANGE
The colors are all there, but with four times the red and orange.
High IR contracts pupils. We see less detail and are not as comfortable.

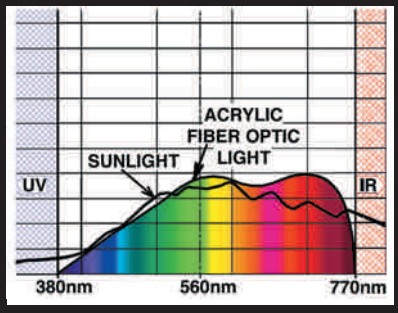
Close to sunlight for every color.

Lots of blue. Lots of red.

But no UV. And no IR.

Painting looks awesome.

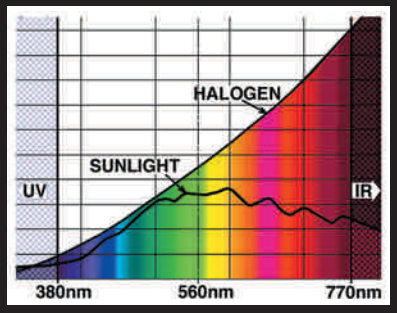




4x the red compared to sunlight.

Too little blue.

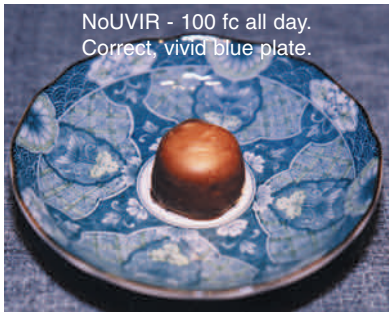
The light blue sea and bright sky turn violet. The tidepools become dark and muddy.

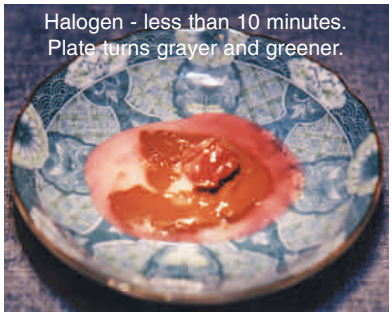


SIDE-BY-SIDE COMPARISONS OF LIGHT SOURCES

KNOW YOUR LIGHT SOURCES. SHOW THE REAL COLORS.

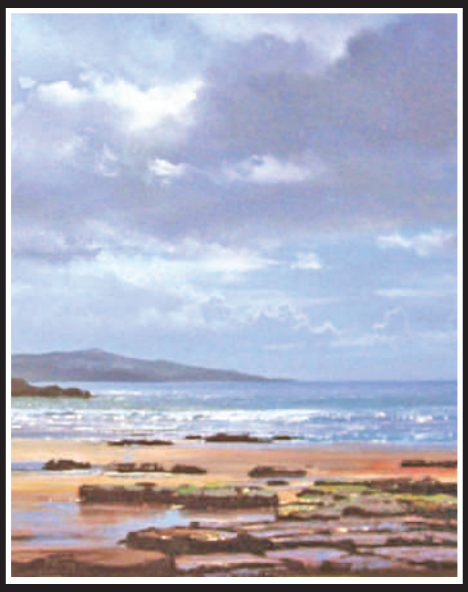
These cordials were each lit at 100 footcandles. On the left three NoUVIR luminaires (12-watts) spotlight the chocolate. On the right a halogen PAR 20 (40 watts), filtered through glass as if in a museum light attic, lights what started as an identical chocolate. In less than 10-minutes we had a beautiful chocolate cherry cordial and a melted puddle. NoUVIR has no IR (0 watts of heat). A 40-watt halogen, even filtered through glass, is still a 37.6 watt heater.



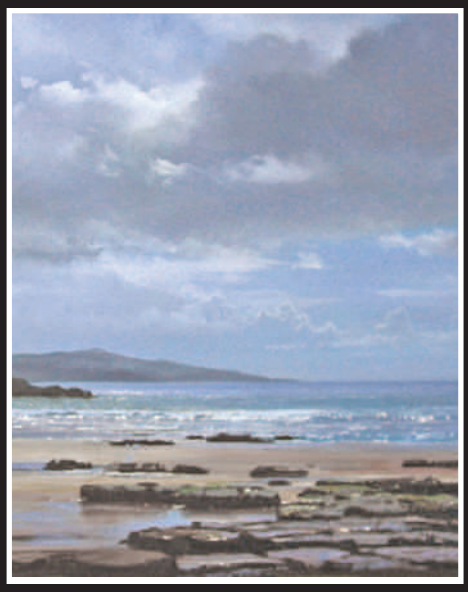


The Second Law of Thermodynamics basically says things tend to break. Add energy and they break faster. Remove energy and the process slows. Remove all of the energy (Reflected Energy Matching or cold storage in the dark) and it stops. Raise temperatures 10°C and the rate of chemical reactions double; think cross-linking, photo-oxidization, and chemical reactions with pollutants. Melting (changing a solid to a liquid) is a simple chemical reaction. It's all about energy. Reflected energy never damages. Absorbed light does.

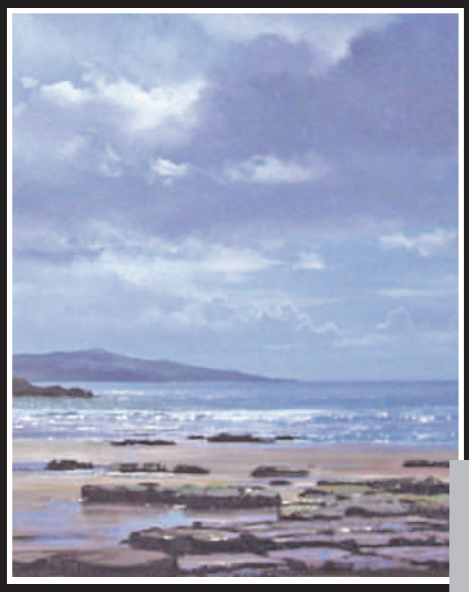
This demonstration clearly shows the destructive IR energy in a filtered low-watt lamp. The photos also show a clear lack of presentation. The blue plate looks gray. The chocolate appears overly red. This is all because of the overly-represented red light in halogen sources. Don't settle for less than perfect!



NoUVIR - PERFECT
We see every color and every detail.
We enjoy all the beauty.
With no UV and no IR, we see better with less fatique.



FLUORESCENT - TOO DULL
Colors are missing. They turn gray.
That is beauty you can't see.
The work is not as vivid as painted.
Your eyes work harder.



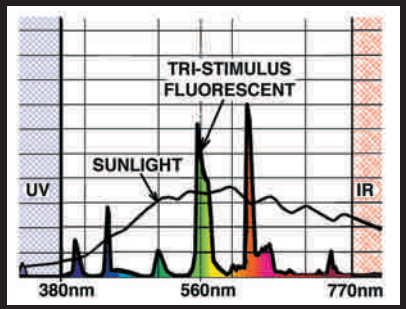
LEDs - TOO BLUE
Colors get washed in blue and green.
The depth disappears.
One designer says LEDs "have no soul."
Until you see them side-by-side, you won't realize how much you are missing.

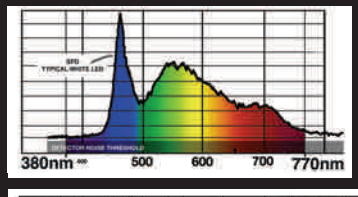
MUSEUM LIGHTING

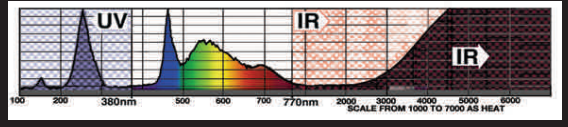
Fluorscent lamps and LEDs have jagged outputs with spikes of colors that tend to sway any color near it into the same hue. Things look flatter and more monochromatic.

The white gaps are missing colors, object color appearance shifts towards the spike color.

The tall spikes are colors that dominate. Even the best quality "warm" LEDs have dominant blues and greens that cause distortion.







See all the data. The UV and IR in LEDs are often not on a manufactuerer's graph, yet can be very harmful to eyes and objects.

"White" LED lights all have a dominant blue color regardless of their "warm" or "cool" mix of phosphors. A good-quality LED light will look "white." But they will always have a hidden bias towards the blue.

If lighting color dramatically mismatches the color of an object, like this POW flight suit, *it will look ugly.* More visible lght is absorbed. Damage rates accelerate. Since light is absorbed and not reflected as data, the object presents a strange color. It does not look "right" as the light is not producing enough of the correct color to accurately reflect data.

The huge blue component of the LED lighting here changed the color of the flight suit and the background. But the LEDs caused another problem for this museum. LEDs are designed around an unfocused emitter. Optics narrow the beam, but fail to capture stray light. The uncontrolled LEDs hugely overlit the suit shoulders and also overlit the case's walls and floor. *The case's background overwhelmed the artifact.*

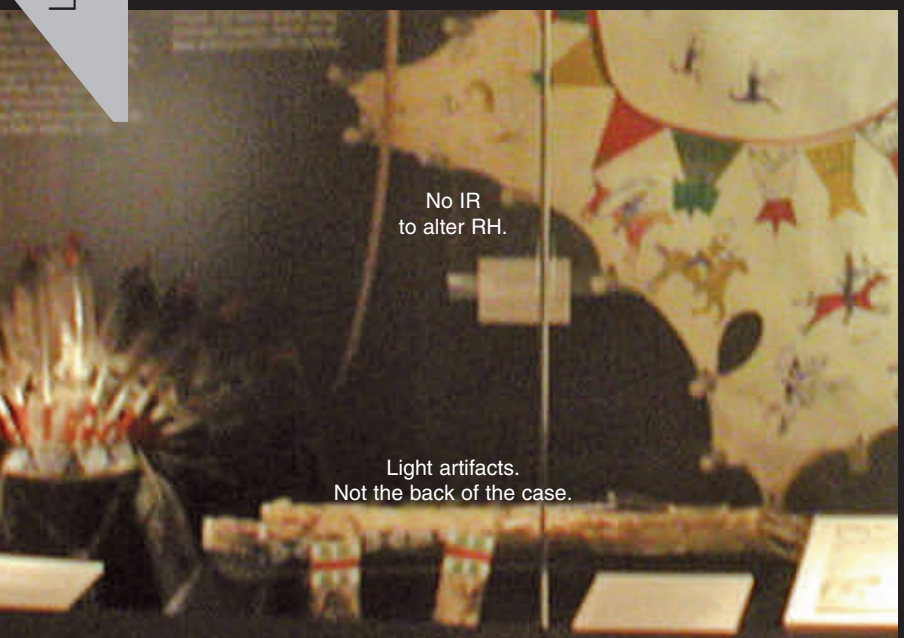
The case was so objectionable, that the museum re-lit it on the spur-of-the-moment during another fiber optic lighting project. A few fibers from an adjacent room made a radical change. With the artifact now a focal point and the correct color, plus the glare removed from the graphic panel, the museum's story was better told. Side-by-side, the differences are obvious.

HALOGEN - 94% TO 96% IR **FLUORESCENT - 72% IR** **LED - 75% IR** **NoUVIR - 0% IR**

HEADS UP! IR causes damage in more ways than speeding up the chemistry to shorten life. Aim a light with IR at an artifact and the object surface warms (often without showing a temperature change in the case air). The surface expands. Slowly, over time, the underlying materials warm and expand to match. With the increase in surface temperature, **surface humidity drops.** In organic materials, the surface shrinks. Then the object absorbs moisture from the surrounding case air expanding slightly.

At the end of the day, the lights go off and the process reverses. The object cools and shrinks, changes humidity and expands, and slowly comes to equilibrium with the case, shrinking again. This differential expansion and contraction is how God makes sand out of rocks. It is how museums spall mineral samples, split wooden objects and turn ivory and laquer boxes to splinters.

These IR driven RH cycles cause more than physical damage. As moisture moves in and out of artifacts, it carries everything contained in the air. Data shows that leather objects, boots, books, footballs, Native American artifacts, etc., can absorb 1/2% of their wieght **each year** in sulfuric acid from sulfur dioxides in urban air. IR creates these RH cycles in all organic materials. One sports museum described it's halogen lit cases as "pizza ovens".



A rare book library found shielded fluorescent lights in library cases raised case temperatures 10°F. That results in a 15% drop in RH. Hot. Cold. Dry. Moist. Every day. Over and over. NoUVIR dropped case fluctuations to less than +/-1.5°F, half of the gallery HVAC fluctuation. RH remained stable.

A natural history customer discovered that extinct eggs were being etched by chemicals from visitor's breath drawn in by IR driven case breathing. NoUVIR stopped it. Another was amazed to discover that the rings of dust around mineral specimens were spalling from IR cycles. NouVIR has no IR.

IR is dangerous. Put your hand on a light. Is it warm? Then, whatever the box says, it isn't no UV and no IR.

I.S.O. BLUE WOOL FADING SAMPLE TESTS

250,000 Footcandle Hours @ 10,000 Fc

TEST LIGHT SOURCE:	I.S.O. #1	I.S.O. #2	I.S.O. #3	I.S.O. #4	% SOLAR FADING	REM FACTOR
A. SUNLIGHT					100%	1.0
B. COOL-WHITE FLUORESCENT					89%	1.1
C. DIMMED INCANDESCENT					79%	1.3
CC. WHITE L.E.D.					67%	1.5
D. UV FILTERED FLUORESCENT					55%	1.8
E. MR-16 HALOGEN					53%	1.9
F. IR FILTERED HALOGEN					47%	2.1
G. NoUVIR® FIBER OPTIC LIGHTING					16%	6.3
H. RED FILTERED ACRYLIC FIBER					14%	7.1
I. REM FILTERED ACRYLIC FIBER					1%	100.0
J. UNEXPOSED (CONTROL)					0%	∞

WATERCOLOR FADING SAMPLE TESTS

LIGHT SOURCE	I.S.O. #2 BLUE WOOL	VIRIDIAN GREEN	CHROME YELLOW	ROSE CARTHAME	LAKE CRIMSON	AVERAGE COLOR FADING	% OF SOLAR FADING	REM FACTOR
DIRECT SUNLIGHT	100	100	50	50	50	70%	100%	1.0
COOL-WHITE FLUORESCENT	90	80	30	60	80	68%	97%	1.0
2900°K INCANDESCENT	100	90	20	50	60	64%	91%	1.1
LIGHT EMITTING DIODES						43%	61%	2.2
UNFILTERED ACRYLIC FIBER OPTIC LIGHTING	25	20	0	20	40	21%	30%	3.3
LIGHT TINT ACRYLIC FIBER OPTIC LIGHTING	0	10	0	0	20	6%	8.6%	11.8
REM FILTERED ACRYLIC FIBER OPTIC LIGHTING	0	0	0	0	5	1%	1.4%	71.4

% FADING (COLOR LOSS)

What does the data say?

Photons are particles. They have mass and energy. When those particles hit an object, they either reflect as data or are absorbed. Absorbed, they transfer their energy to the atomic structure of the object they hit. That energy breaaks chemical bonds and creates chemical change. The more particles absorbed, the more damage occurs.

Since each light source has a different mix of photons (spectral distributon), different sources will have different damage rates. Coefficeint of damage is determined by the color of the light when compared to the color of the object lit. Objects that partially reflect UV are susceptable to IR. Objects that reflect IR are usually susceptable to UV. Red light damages blue objects and vice versa. Color distortion from mismattched light sources is a good visual indication that light energy is being absorbed rather than reflected. Bad color rendition causes damage.

Removing the UV (all of the UVA, UVB and UVC) along with all of the IR eliminates the 70 to 95% of light energy that does not aid vision and can only cause damage. Achieving the same visibility with a fraction of the energy greatly extends object life. This is a huge benefit to museums, archives, private collectors and even store managers with valuable inventory.

I.S.O. blue wool fading tests (the standard most photochemical work has centered on) show cool-white fluorescents as the worst offender, followed by incandescents and then white LEDs. Note, however, that a soft wash with a good color balance, UV-filtered fluorescent may be less dangerous than higher intensity “white” LED spots. For conventional lighting, IR filtered halogen was the least damaging.

Repeating fade testing with samples in a range of colors gives similar results. All samples were exposed to a total of 250,000 fc hours illumination. This is equivalent to 10-years of museum display at an intensity of 10 footcandles.

NoUVIR fiber optic lighting in both tests showed 1/3 of the fading of halogen or incandescent sources and 1/5 of the fading of the same quantity of sunlight. Put in practice that means NoUVIR will extend exhibit life by 3 to 5 times. Ten years becmes 30 to 50 years!

Use of REM filters to maximize reflected energy and minimize absorbed energy increased NoUVIR’s protection to 53 to 64 times that of halogen and 100 times that of sunlight. LEDs, fluorescents and HID sources will fall somewhere between halogen and sunlight. A fragile 1-year exhibit is now safe for 100!

General wash by floods with spots on uniforms.

All spots with no wash on background.

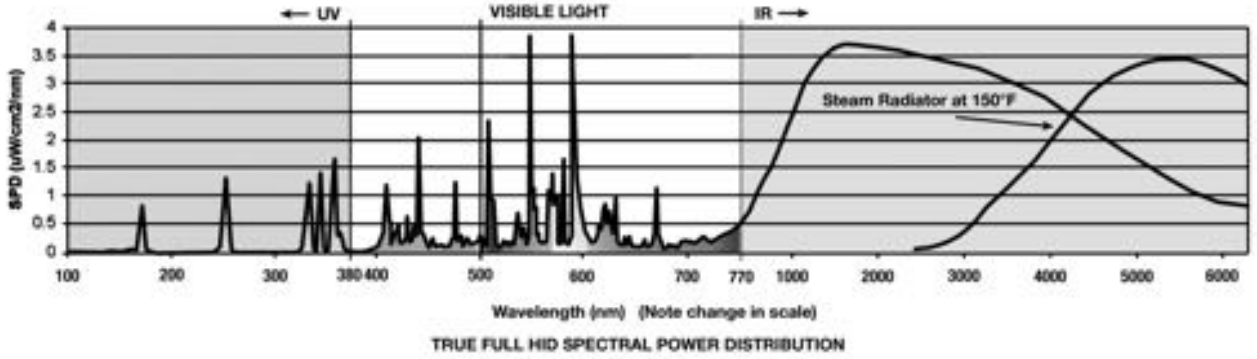
MUSEUM LIGHTING - PURE AND SIMPLE

SUCH A POPULAR WHITE PAPER, IT'S ADDED TO THE CATALOG TO SAVE SENDING IT SEPARATELY

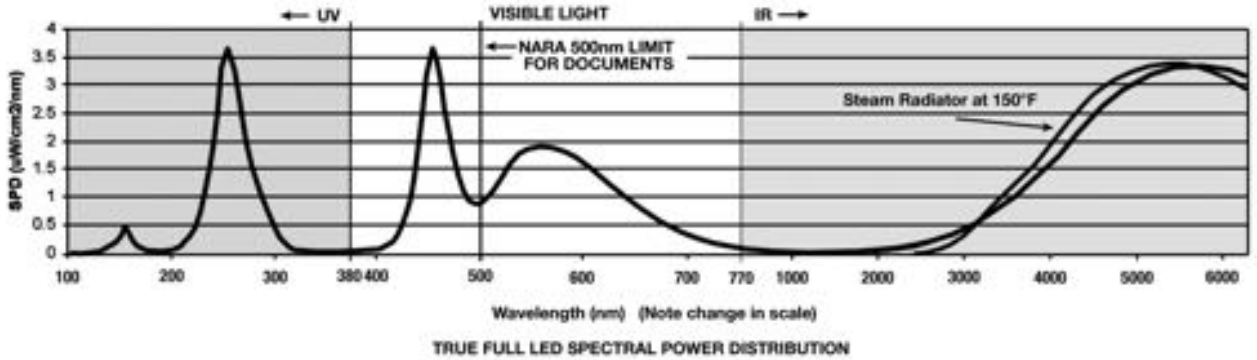
Preservation

Preservation is also an easy term to understand. It is simply the protection of the collection from the damage (remember the chocolate?) By the way, protection can extend to case linings, carpets, graphics and even the merchandise in the museum's store. As we've seen above, light is either reflected by an object, helping you see, or it is absorbed by the object, causing photochemical and/or photomechanical damage. Ultraviolet and infrared don't help you see. They can only cause damage, so the first task is to remove all light energy that doesn't help you see.

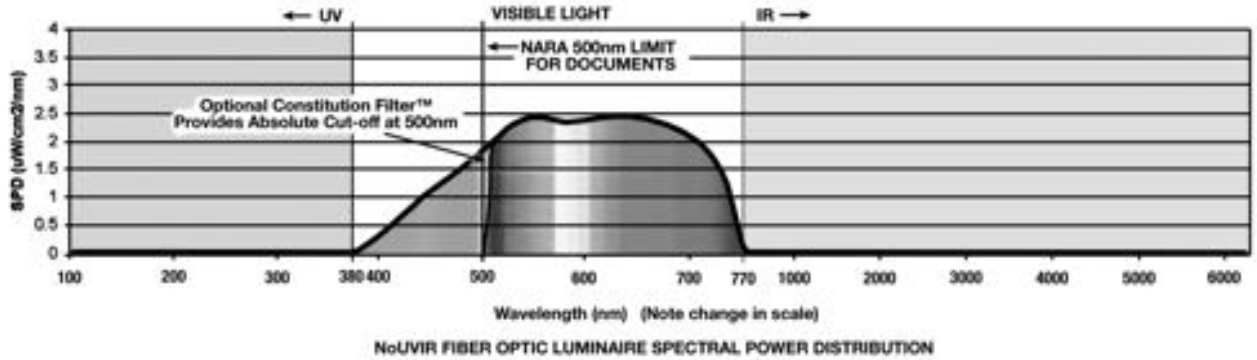
Getting information on energy outside the visible spectrum is sometimes difficult. It's even harder when you understand that most UV meters only read UV above 300 nm. But UV emissions 150 to 250 nm are found in many modern sources. Few manufacturers bother to filter sources in ranges where almost no one has measuring tools. Fewer still bother to give you accurate data. It's a matter of



TRUE FULL HID SPECTRAL POWER DISTRIBUTION



TRUE FULL LED SPECTRAL POWER DISTRIBUTION



NoUVIR FIBER OPTIC LUMINAIRE SPECTRAL POWER DISTRIBUTION

EORLs describe this WWII base in miniature.

Knowing spectral output helps you match sources to artifacts. UVB is used to fast cure plastics. Over time UV will break up the materials used to create exhibits like these highly-detailed models. The museum used NoUVIR. But if it had to choose something else, the light with the least UV would be safest.

Leather is harmed by UV, but more quickly destroyed by IR. Infrared drives RH cycles. Over time these leather artifacts would not only dry and crack; but will pick up and retain acids from the air. A light with the least heat to minimize RH changes would be the better choice. Of course, these exhibitors picked the very best choice...NoUVIR.

MUSEUM LIGHTING - PURE AND SIMPLE

Such a popular White Paper, It's added to the catalog to save sending it separately

We are in a battle involving photons. The museum mission is a balance between protecting and exhibiting their collections. History's tresures cannot be hidden away in archives in the dark or we will fail to learn from them and build on them. We may even be forced to repeat certain parts of history we would rather not experience again.

UV and IR are usually a hidden enemy in this battle, undeclared combatants. Artifacts themselves can also be a mixed bag of challenges. So, why submit them to UV or IR which cannot in any way help someone to see them?

This historic model battleship is made of paper, wood, metal, white thread, wire, plastic, wax, paint, printing ink and fabric. And it is exhibited beside a miniature histoirc battle flag (see the tight spot in the left foreground), a piece of wood salvaged from a battle, a historic pair of binoculars and a leather case that has literally been through the war along with a handwritten journal. How do you set conservaton standards for a particular material? Safe lighting, controlled lighting, with no UV and no IR, protects this wonderful hodge-podge of materials and objects, so the story of WWII can be told.

"what you don't know won't hurt me". Here are the full spectrum outputs (UV through IR) that most people won't show you.

Removing all UV and IR dramatically retards fading and damage[5]. Both laboratory and museum testing have proven that lighting systems with no UV or IR **extend the exhibit life a minimum of 3 to 5 times**, when compared to typical museum lighting[6]. Tests of various lights with both widely-used ISO blue wool and fugitive dye samples in assorted colors showed some surprising results:

1) Fluorescent lamps faded the ISO samples only 10% less than sunlight.
2) Dimmed incandescent and halogen lamps caused fading within 4% of fluorescent lamps.
3) UV filters on fluorescent lamps only reduced fading by 30%.
4) Adding glass IR filters to halogen lamps only reduced fading by 10%.
5) Fiber optics with no UV and IR reduced fading by 80% (five times the exhibit life) compared to fluorescent, incandescent or halogen lamps.
6) Lightly tinting fiber optics to match artifact color reduced fading by 91% (twelve times the exhibit life) compared to fluorescent, incandescent or halogen lamps.
7) Color filtering fiber optic lighting to exactly match the color of an artifact reduced fading by 99% (increased exhibit life by 100 times). Color-matched lighting stops fading.

This testing led to the science of Reflected Energy Matching. Remember, you only see reflected light and it's only the absorbed light that causes damage. Matching light color to artifact color *does not change appearance.* Again, you only see what is reflected. Hundreds of fading tests show that NoUVIR lighting greatly retards damage and increases exhibit life. Then added color matching filters can virtually stop all of the photochemical damage**!**

NOT RECOMMENDED

The light bulb in this toy oven can bake a cake in just 3 minutes. How long will it take to bake an artifact? Fluorescent lamps are used in tanning beds and to cure plastics. LEDs are used to singe hair, kill microbes in water and blind mice. Your artifacts deserve NoUVIR.

Conservation

Conservation is simply stewardship of a museum's materials, personnel, and financial resources. The whole idea is in the old saying, "Waste not, want not." And in an era of tight budgets, it can be a matter of museum and staff survival.

Bad lighting results in more than poor presentation and destructive preservation. It also means that the lighting is inefficient. It wastes power. It generates heat. And every watt of power put into lighting takes 3 to 4 watts of air-conditioning to pump out.

5. We started teaching the need to eliminate UV and IR in the early 1990's. By 2000 the Illuminating Engineering Society of North America (IES) established guidelines recommending filtering all UV and IR in museum (and commercial) environments. You'll find these guidelines in the *IESNA Lighting Handbook*.

6. Ruth Ellen and Jack V. Miller, Reflected Energy Matching as a Conservation Tool (Seaford, DE: NoUVIR Lighting, 2003). Available from NoUVIR, this book presents the science and test data for Reflected Energy Matching. See Catalog page 7-7 and 7-10.

MUSEUM LIGHTING - PURE AND SIMPLE

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Each NoUVIR projector powers up to 32 individual fiber optic luminaires. It is not unusual for a single projector (i.e., one light bulb) to illuminate two or more cases. NoUVIR installations require less energy and far fewer light bulbs. With the added savings in HVAC load, NoUVIR installations can provide 50% to 70% overall gallery energy savings.[7]

Energy savings are only one way NoUVIR reduces operating costs. Case linings, signs and graphics last longer. IR driven case breathing and associated dust problems are eliminated. Exhibit rotations and cleaning cycles are extended. Maintenance and labor costs drop, all the result of good lighting.

A – LIGHT ARTIFACTS, NOT AREAS

People come to a museum to see the art and artifacts. Except for historic sites, people don't visit museums to see walls and ceilings. Good lighting design will **make each artifact a center of interest.**

One of the most important features of the NoUVIR system is ***control***, the ability to put an exact amount of light precisely where you want it. In lighting a painting, don't splash light all over the wall around it. Instead, illuminate the painting evenly and uniformly from top to bottom, to show exactly what the artist painted. Conventional lighting can't do that because the light on the top of the painting will always be several times brighter than the light on the bottom. That's the $1/r^2$ law at work. NoUVIR's adjustable beams let you control intensity on each part of the painting top to bottom. You'll see all the color and details you never knew were there.

Lighting a small artifact, such as an Egyptian faience or ancient jade sculpture, doesn't require flooding an entire case with light. Just zoom the fiber optic luminaire's beam to the size of the artifact, and let light scattered from the object add a little soft glow to the interior. Now the case lining is not visually competing with the object. Similar objects can be grouped and lit with a single beam, showing the viewer the items are related, something impossible if you are lighting areas.

Lighting artifacts instead of areas lets you place artifacts made of different materials in the same case or on the same wall. Now each object can have a lighting intensity and effect that specifically fits the individual size, color, and importance of each item. Fragile papers can be displayed next to engraved metal. Gemstones may be displayed on fugitive costumes. Watercolors and oils may be exhibited on the same wall. Your imagination chooses the placement and emphasis for each artifact and for each light pattern. The moon behind the hawk on the right is simply a beam of light from a NoUVIR spotlight.

Lighting artifacts not only gives you more effective presentation, it is more efficient as well. One NoUVIR gem and geology exhibit used 40 NoUVIR projectors (40 light bulbs) to replace 700 halogen light fixtures (and their 700 light bulbs). This took 60,000 watts off line; quadrupled the light levels on the individual minerals; and improved the color,

7. Los Angeles Department of Water and Power documented 70% gallery energy savings after they funded a museum's NoUVIR installation as a power conservation program.

Having the zoom control to make beams bigger or smaller to light artifacts, instead of washing light across areas makes a big difference in presentation. The objects can be more brightly lit . The backgrounds stay subdued.

In a black and white photo, you can really see the even tone of most lighting. Lit without the tight control of fiber optics, the crystals have the same shade as the background. Relit with NoUVIR, the crystal specimens capture more light. They capture more interest and look more valuable. Same case. Same objects. The only differnce is the high-tech NoUVIR lighting.

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appearance, and depth of the specimens. The exhibit looked better, and the museum dramatically cut its operating costs. Over the last decade the energy savings have exceeded a million dollars.

B – BACKGROUNDS MUST BE SUBDUED

Exhibits should always be brighter than the background and graphics around them. Exhibits should be on stage, the center of attention. Two-to-one is a good rule. Artifacts should be twice the intensity of the background.

Added to that, nothing in view should be more than twice as bright as the dimmest lit exhibit in a gallery. This includes windows, banners, large lightly colored graphics and video presentations. More museum vision problems are caused by glare from over-lit areas than by too low of light levels.

Your eye sees the entire scene, almost 180°; artifact, background and any visible light sources. Then your eyes set your iris diameter like the f-stop of a camera, adjusting to average the total light present. A window, a bright background or an over lit graphic will cause your iris to contract. The result is a mild case of "snow blindness". Direct glare from overhead lights does the same thing, only to a greater degree. You can read quite well at 2 to 3 footcandles given a few minutes to adjust and no glare sources or bright visual distractions.

This dark background absorbed so much light, a pinspot created the moon.

If a gallery or lighting design draws visitor attention and they gaze up into or past a light source, the visitor is effectively blinded to the exhibit for five to fifteen minutes. Fiber optic lighting is unique in that the light sources can be kept completely from view; often hidden entirely inside a display case behind door reveals and mullions. With no scatter or spill, fiber optic sources can even aim past a vistor without causing glare. Visitors adjust to the balanced lighting and enjoy uniform vision throughout the gallery[8].

C – CONTROL GLARE and CONTROL CASE REFLECTIONS

A museum must protect exhibits from things like dust, contamination, visitors' hands, breath, sneezes, etc. Usually that means a case or "window" between the artifact and the visitor. But windows can create distracting reflections.

Case "windows" act like the "one-way" mirror in a police line-up. Witnesses (museum visitors) are in a darkened room and suspects (museum artifacts) are in a well lighted room (case). With low lighting in the witness' room, the viewers see the suspects (artifacts) very clearly. But if the lights are bright in the viewers' gallery, viewers see reflections of the lights, the walls, their own images, and every illuminated item in the room in the window.

TV off, no internal light from inside "case". Everything reflects.

TV on, light source from inside "case". Reflections disappear.

Internally lighting cases minimizes glare and reflection. NoUVIR is perfect for internally lighting cases. You can demonstrate how this works with your television. In the upper portion of the photo the "case" is dark. Room lights create reflection and glare. The bottom portion shows the same scene, in the same room with the same lighting. But now the "case" is lit. The reflections are still there, they have just faded to insignificance. **Your ability to see into a display case is directly proportional to the ratio of the interior and exterior light levels.**

Museum galleries should have low ambient light levels. Low ambient lighting increases the visibility of exhibits and minimizes damage to both artifacts and furnishings. Conceal lighting to avoid glare. Use draperies over "historic" windows. (Draperies were common and important insulation in winter.) Use reversed graphics to avoid large white areas. Light artifacts to conservation levels and then set ambient light to half that level. You'll be amazed at the result.

Please feel free to call us with any questions at 302-628-9933. NoUVIR's mission is saving our art and heritage from light damage.

8. Jack Miller, Optics and Physiology of Human Vision in a Museum Environment (Seaford, DE: NoUVIR, 1994)