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Re: LED Use in the Museum Environment
By: Ken Kane, Lighting Services Inc

You are probably aware of certain claims being made about the use of LED lighting technology in the museum environment. This paper will try to address those claims in a manner consistent with current, high quality, white light LED sources.

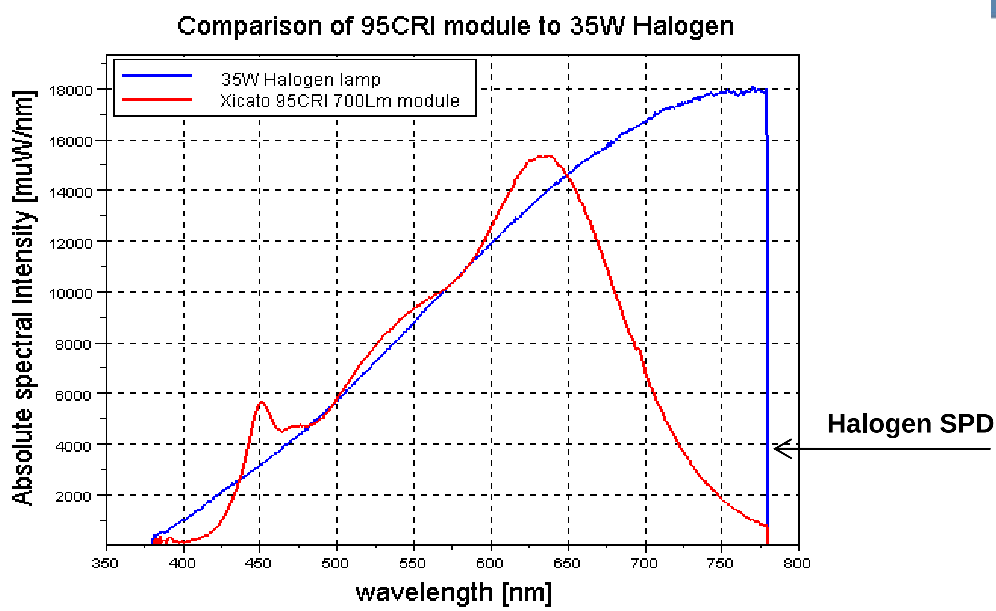
Claims have run the gamut from: LEDs have no UV, and no IR, and therefore any LED is the best source for lighting in museum environments, and lighting sensitive artwork, at any light levels…. to: LEDs are the most dangerous source that can be introduced, because the CRI is lousy, the spectrum has significant spikes, and they will permanently damage your artwork in no time.

As with most statements, the actual facts are somewhere in between, and require an understanding of where those statements are coming from.

Let's start with a qualification of museum lighting. The current "standard" for most museum and gallery lighting is to use a Tungsten Halogen source, of the appropriate output for the desired light levels. Therefore, I will focus my comparison of sources between a high quality, high CRI halogen source, and a high quality, high CRI white light LED.

Halogen sources are the most commonly used source in museum lighting environments for several reasons. Those reasons are:

1. *Spectral Distribution*: Halogen light is full spectrum light. This means that if you analyze a spectral distribution chart (SPD), all colors from the violet end of the spectrum to the red end of the spectrum are present. Artwork that is illuminated by a full spectrum source will be rendered well. In addition, the energy output of the halogen spectrum is well documented, and well understood in terms of exposure to artwork. As a general statement, the most significant alteration of the halogen spectrum for museum lighting has been to filter out the ultra-violet component, and sometimes (although rarely in practice) filter out the IR component. In theory, you then have a source with full spectrum, visible light, insignificant amounts of UV, and insignificant amounts of IR. An SPD of this type of source would look like this:



2. *CRI:* The Color Rendering Index (CRI) of a halogen lamp is near 100, meaning that it will render all artwork well. In theory, a source with an incandescent filament (which is what a halogen lamp is) creates full spectrum light with a CRI close to 100. In practice, the coatings that are typically used in today's halogen lamps introduce small shifts in spectrum that sometimes causes a halogen lamp to exhibit a CRI with a value less than 100, say 97 or 98.

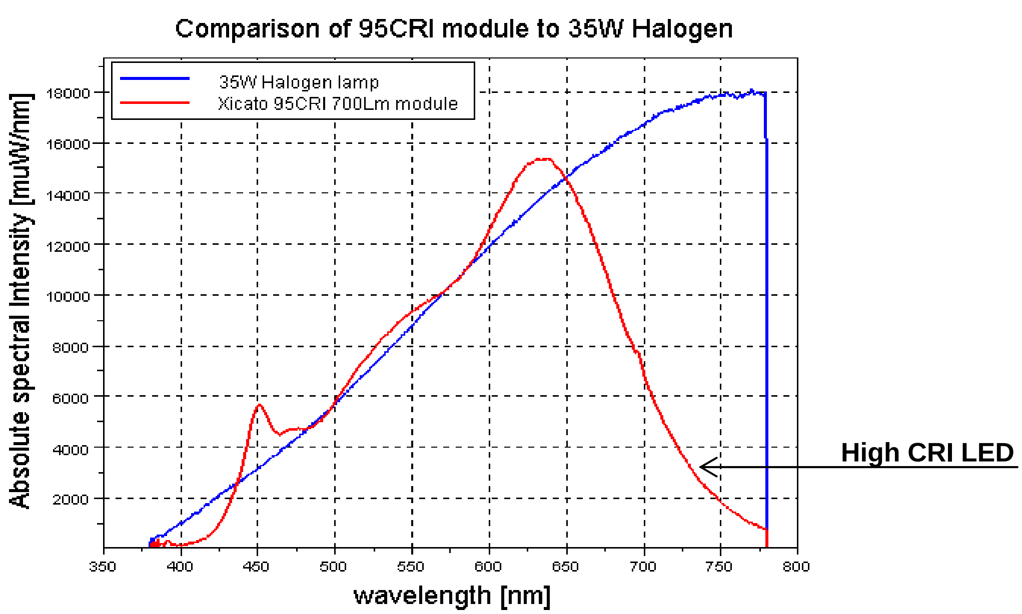
3. *Color Temperature:* Halogen sources have a color temperature that is conducive to illuminating artwork. Depending on the lamp type, halogen sources typically exhibit color temperature readings in the range of 2850K to 3050K. This color temperature range is used in the vast majority of museum environments today.

4. *Damage Potential or Relative Damage Factor.* This is a way of characterizing any light source in terms of its radiant power, with the understanding that shorter wavelengths of light (UV- blue region) are more damaging than longer wavelengths (Red – IR Region) since longer wave lengths of light have less energy. By using the widely accepted works of Harrison, Krochmann, and later Saunders and Kirby, it is generally accepted that halogen sources have a damage potential of 1.4. Since incandescent and halogen sources are inherently full spectrum, but with a higher proportion of longer wavelengths (red), their damage potential is less than a source which has a higher color temperature. Keep in mind, however, that this also assumes that all UV is removed from the source by way of high quality filtering (below 400 nm).

Why a current generation high quality LED source should be considered for use in a museum environment.

To compare the above points with a high quality white light LED, there are a few things to consider:

1. *Spectral Distribution:* Not all LEDs are created equal. This is an extremely important point, since it is easy to lump all halogen lamps into a relatively close category in terms of characteristics. For LEDs, it's impossible to lump them all together, since they can be designed to exhibit such a wide range of characteristics. White Light LEDs can have very poor CRI's (in the 60's), or very high CRI's (98). White light LEDs can have very blue color (CCT>6500K), or very warm color (CCT<2700K). For the purposes of this paper, all references to white light LEDs going forward will reference a high quality, white light LED with a high CRI and a warm color temperature of 2700K – 3000K. An SPD of this form of LED source is below.



2. *CRI:* The color rendering index of this source is as high as 98CRI, using the current metric. This has been verified by several independent testing laboratories, using the same metrics that would typically be used to measure a halogen, or any other source. This CRI, when compared to a halogen source is virtually identical, and in fact measures higher in some areas such as R9 (deep red).

Ra = 97 typical, 95 min • Data for 3000K • 2700K and 4000K are similar

	Ra	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Standard XSM	81	80	85	89	81	78	80	86	66	16	64	79	58	81	93	75
Artist Series XSM	98	98	99	98	98	98	97	98	98	96	99	98	88	98	98	98
Typical IR coated Halogen Dichroic	98	98	99	99	99	98	98	99	97	92	97	98	97	98	99	97
Typical Compact Metal Halide	82	90	94	69	82	81	81	87	71	27	59	62	55	93	78	88
Typical Compact Fluorescent	87	91	93	86	91	89	90	88	70	17	76	91	81	93	92	81

3. *Color Temperature:* High quality white light LEDs are a phosphor based lighting system. This means that a blue LED is used to excite a yellow phosphor to create white light. The color temperature is "tuneable" based on the wavelength of the blue LED, and the wavelength of light emanating from the phosphor mixture. 2700K, similar to incandescent, and 3000K, similar to halogen are two typical CCT's available with a high quality white light LED.

4. *Damage Potential:* Because of it's relatively continuous spectrum with the additional benefit of an extremely low UV component, as well as extremely low IR component, the damage factor of a high quality white light LED source can actually be less than that of a halogen, or even an incandescent source. Using the same calculation method as compared to other sources, the white light LED represented in the previous SPD has a relative damage potential of .84 at 3000K.

The lack of actual test data on the current generation of white light LEDs relative to conservation requirements is an issue. While there may be scientific data to support all claims made in this paper, there is a distinct lack of completed testing on LED lighting specific to conservation concerns. Tests such as the ISO Blue Wool test are currently underway in several locations, but as of yet those results are not published.

While LED light sources are relatively new in terms of high quality white light illumination, there are many ways to measure and evaluate their characteristics for use in museum lighting environments. The concept of evaluating a new source for its appropriate use is not new; it simply has to be evaluated in a thoughtful, scientific way. The most important aspect for the selection of any source when considering illuminating light sensitive objects is to understand what the criteria is for the illumination, and then evaluate sources for how they measure up to the selected criteria. The current generation of high quality, high CRI LEDs should be considered and evaluated by the same set of criteria as any other source when considering their use in the museum environment. If this is done, there is no doubt that high quality, high CRI white light LEDs are ready for use in the museum environment.

Sources:
Letter by Jim Druzik, Getty Conservation Institute, Carl Dirk, University of Texas El Paso, Ku'uipo Curry, KCLD, July 2010

Steven Weintraub, Letter to The Green Task Force, American Institute for Conservation, April 28, 2010

LED sources: Xicato labs

CIE 157; 2004