Characterizing Different UVA Lamps

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Introduction

Ultraviolet-induced visible fluorescence is a valuable technique for the examination and documentation of cultural heritage artifacts. The consistency and repeatability of the images captured is crucial for conservators recording changes to the artifact before, during, and after treatment. A previous study observed that low pressure mercury UVA lamps exhibited spikes in output intensity (Sexton and Messier 2015). Our study further characterizes eight different UVA lamps, comparing their basic specifications; output intensities; warm-up times; output profiles over one hour; emission spectra; visible light leakage; and different emission peaks that can influence the resulting fluorescence.

Test 1: UV Output & Output Profile Over Time

The UVA output was measured with a UVP UV Radiometer. The meter was positioned 3 feet away from each lamp measured, adjusted to 6 feet for No. 1 and 2 lamps due to their powerful output. The measured intensity is listed in the 2nd column in Table 2. To compare their output profiles, the meter was positioned at different distances that gave approximately the same intensity (45 W/cm^2), seen in column 4. The distance was calculated based on the inverse square law, seen in column 3. The distances for No. 1 and No. 2 lamps were arbitrarily determined at 108 inches due to the space limitation of the testing location.

The UV output of each lamp was characterized in three categories: first, how fast the lamp warms up initially; second, how stable the output is over a one-hour time period; third, how the lamp performs if it is turned off and turned back on right away.

The test was done in a darkened room. The meter's sensor was positioned at the distance highlighted in green in Table 2. The meter readout was captured with two cameras set to time lapse function. The first camera captured at a one-second interval for about 5 minutes. The second camera captured at a ten-second interval for one hour. Each lamp was turned off, turned back on, and captured for ten additional minutes. The readouts are plotted in columns 2 and 3 in the table below.

The temperature of the lamps were also measured with a Raytek MiniTemp IR thermometer one foot away from the lamps and at 5 minutes and 1 hour after they were turned on. These readings are listed in the last two columns in Table 2.

Table 2: UV Intensity vs. Distance

	Meter distance	Measured intensity	Calculated meter distance	Targeted intensity	Adjusted meter distance	predicted intensity	Lamp temp. (°F)	
							In 5 mins	In 1 hour
1	72	190	148	45	108	84	104	295
2	72	682	280	45	108	304	74	85
3	36	33	31	45	---	---	73	81
4	36	20	24	45	---	---	73	92
5	36	45	36	45	---	---	81	109
6	36	53	39	45	---	---	71	108
7	36	8.5	15.5	45	---	---	74	88
8	36	36	32	45	---	---	72	73

Table 2: All distances are in inches and intensity in W/cm^2. The calculated distances (highlighted in red) for No. 1 and No. 2 were outside the range of the darkened room. The adjusted distance, 108 inches, was determined based on the space availability. The room temperature before any measurement is at 70°F.

Test 2: UV Output Spectra and Visible Light Leakage

The output spectra of each lamp was recorded with an Ocean Optics SD2000 spectrophotometer to read from 200nm to 900nm, shown in column 4 in table below. The near 400nm region and the IR region are emphasized to show visible and IR emission by each lamp. The visible light emitted from the lamp can affect the visible fluorescence from the object when irradiated. The last column in the table below shows the visible light from the lamp captured with a Nikon D800E and a 60mm lens fitted with two filters, Peca 918 and Kodak 2E (Kushel 2011). This filter set blocks wavelengths below 420nm and above 700nm.

UVA lamps	Output profile, initial warm-up	Output profile over 1 hour	Output spectra	Visible light leak
Dimension (inches) stated with each lamp	X axis: Time, second; Y axis: UVA Intensity, W/cm^2	X axis: Time, minute; Y axis: UVA Intensity, W/cm^2		Exposure setting: ISO=200, f/8, 1 sec

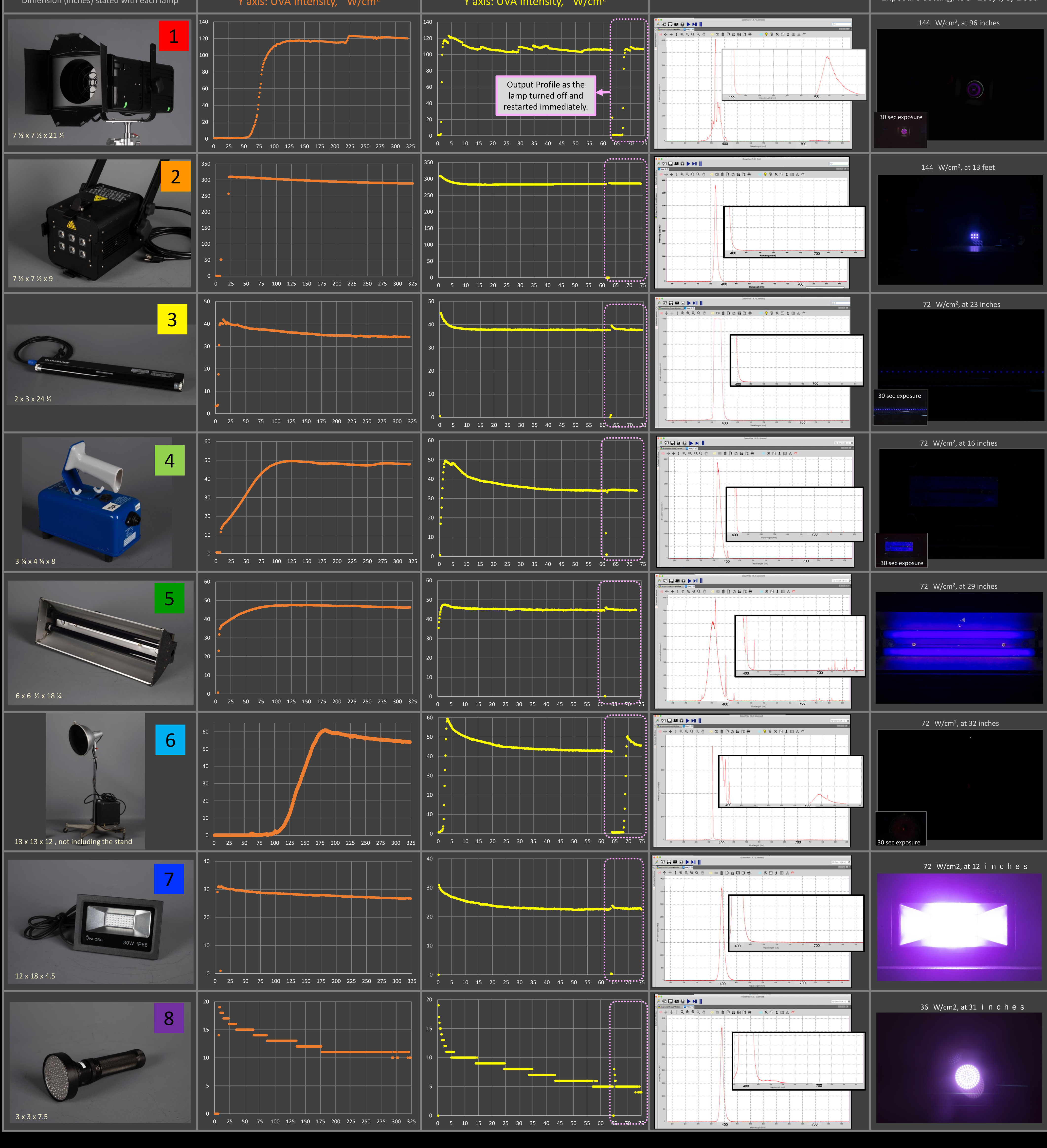


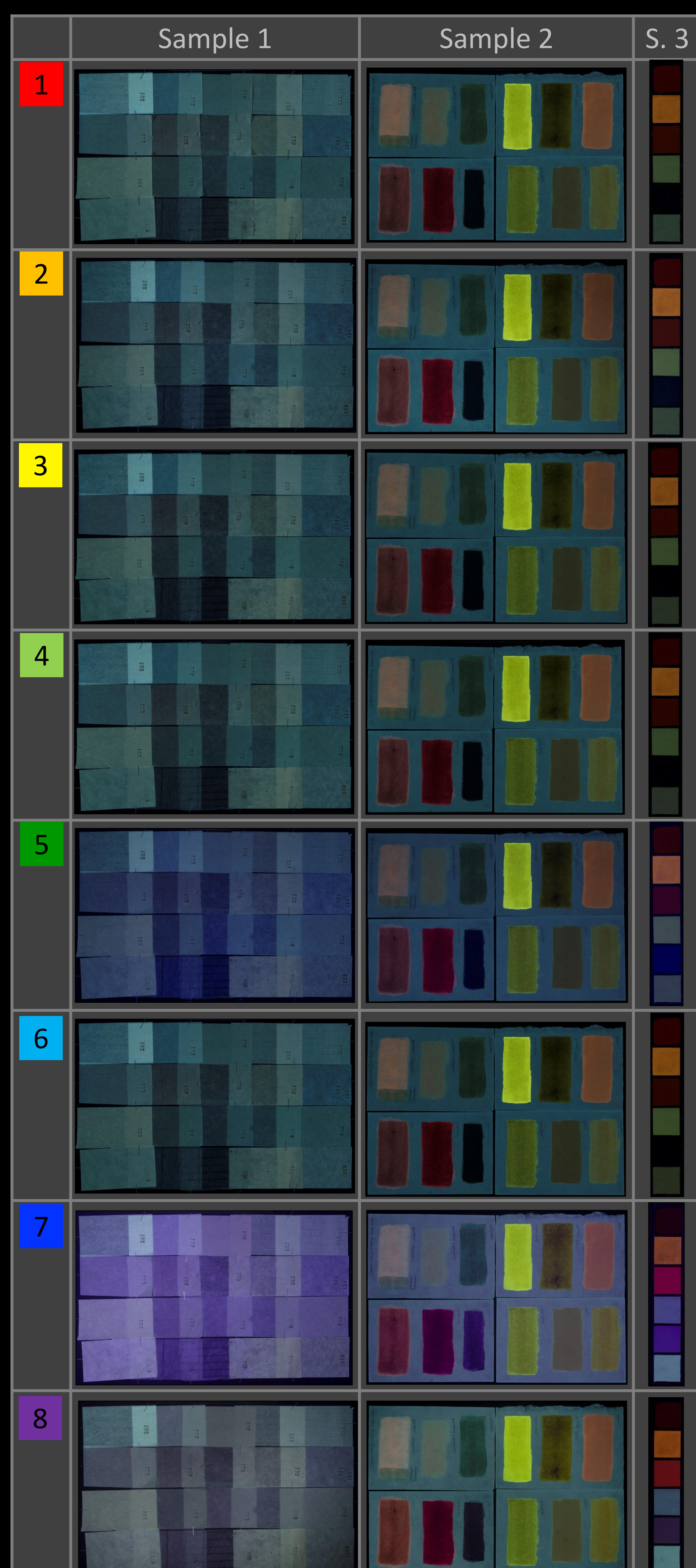
Table 1: Useful Specifications from Manufacturers

	Lamp	Type	filtration	Emission Peak	Cost ($)	wattage	Light spread
1	Longthrow by Wildfire Lighting	Hg vapor, high Pressure metal halide bulb	external UV passing, visible blocking filter	365 nm	1095 (discontinued)	250	90 degree
2	Viostorm by Wildfire Lighting	LED (6 arrays)	no	365 nm	2850	60	40 degree
3	Ultrablade by Wildfire Lighting	LED (12 arrays, 24 inches)	dark glass envelop	365 nm	249	9	120 degree
4	SuperBright by UV Systems Inc.	Hg vapor, low pressure fluorescent bulb	external UV passing, visible blocking filter	368 nm	459	15	Not listed
5	GE black light (F15T8 BLB)	Hg vapor, low pressure fluorescent bulb	dark glass envelop	not specified	15 per bulb (bulb only)	15	Not listed
6	legacy UVA lamp (Philips Mercury Vapor, H37KB-250)	Hg vapor, high Pressure HID bulb	Pyrex UV passing, visible blocking filter (discounted)	365 nm	Not available	250	Not listed
7	Onforu	LED (50 arrays)	no	385-400nm	21.25	30	120 degree
8	McDoer UVA flashlight	LED (100 arrays)	no	385-395 nm	19.90	18 (batteries)	Not listed

Sample 1 (left): different Japanese papers from Hiromi Paper Inc.
Sample 2 (middle): different natural dyes from Japan
Sample 3 (right): from top to bottom, genuine rose madder in watercolor, light shellac, vat orange in acrylic, zinc white in acrylic, titanium white in acrylic, and lead white in linseed oil.

Test 3: Photography Results

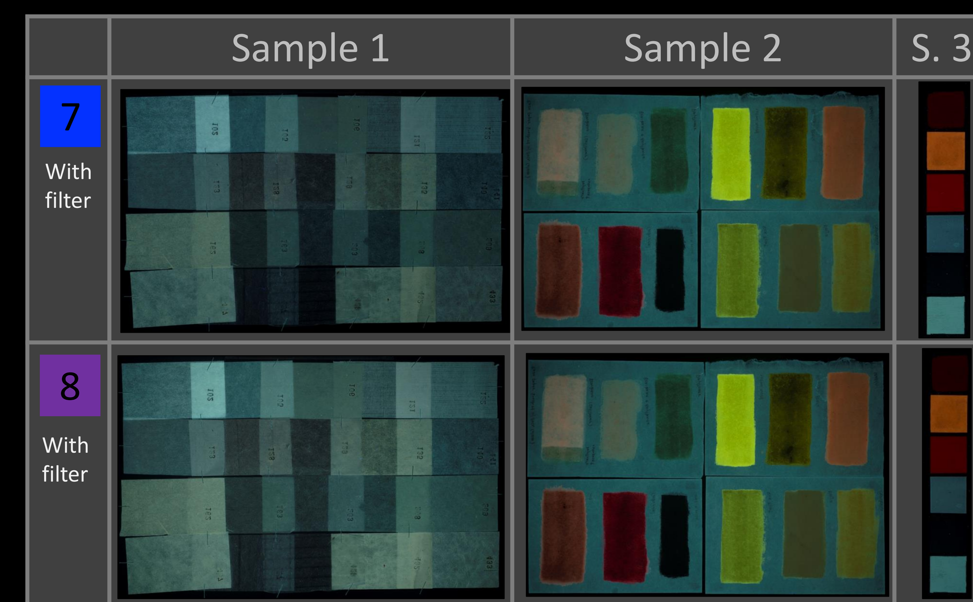
Three samples were used as test targets to compare the fluorescent color (see above). The fluorescence was recorded with the same camera/lens/filter package described in Test 2. The results are shown below. All images are processed with the color temperature set at 10,000 and tint at +35 with the parametric curve adjusted to + 40 for the darks and +20 for the shadows.



	Lamp	Resources
1	Longthrow	Discountinued, available from used equipment store
2	Viostorm	https://wildfirelighting.com/product/viostorm-uv-led-lighting-series/
3	Ultrablade	https://wildfirelighting.com/product/ultrablade-led-series/
4	SuperBright	http://Store.uvsystems.com
5	BLB black light by GE	Most light bulbs supply stores, such as https://www.lightbulbs.com
6	legacy UVA lamp	Fixture and lamp filter not available bulb: https://www.bulbs.com/product/H37KB-250
7	Onforu	http://www.amazon.com
8	McDoer	http://www.amazon.com

Test 4: Effect of Wavelengths

Lamps No. 7 and 8 have different UV peaks from the known 365nm peak for mercury vapor UVA lamps. The lamp filter from No. 1 was used to eliminate the significant visible light leakage from No. 7 and 8 observed in previous tests. The three samples were photographed with these two lamps again after the filter was applied. The results are shown below.



Discussion of the Test Results

Test 1: Most of the lamps required a short warm-up time (within 5 minutes). Lamps No. 2, 3, 5, and 7 have the most consistent output profile over a one-hour time. No. 1 and No. 8 exhibit obvious fluctuations in intensity. The intensity of Lamp No. 8 falls off quickly and does not seem to stop. Lamps No. 4 and 6 also exhibit fall-off but at a much slower rate. As expected, mercury vapor lamps generate more heat than LED lamps. Lamp No. 1 in particular became extremely hot after one hour.

Test 2: Based on the output spectra, all lamps emit UV and some visible light. Lamps No. 1, 4, 5, and 6 emit varying amounts of IR. The filter set used in this study blocks IR and visible light under 420nm. The visible light leakage images show that lamps No. 2, 5, 7, and 8 have visible light output that cannot be blocked by the filter set.

Test 3: The captured fluorescent colors were consistent with lamps No. 1, 2, 3, 4, and 6. Though No. 2 has visible light leakage that cannot be blocked by the filter set, in comparison to its high UV output, the visible light leak appears to be insignificant. The visible light leakage from lamps 5, 7, and 8 resulted in differences in fluorescent colors.

Test 4: The fluorescent colors of the samples recorded using No. 7 and 8 with visible light eliminated are noticeably different from those with lamps 1, 2, 3, 4, and 6, seen particularly with zinc white, the 3rd swatch from the bottom of Sample No. 3. This is due to the different UV emission peaks from these two lamps.

Conclusion

Consistent capture of UVA-induced visible fluorescence is dependent upon output profile, filtration, visible light leakage, and wavelength. The fluctuation and fall-off in intensity over time influences the exposure time. This should be considered when one needs to replicate the shot. Proper filtration of the lamps and the lens is crucial to accurately record fluorescent colors. Lamps with visible light leaks beyond 420nm are not recommended for photography due to the inaccuracy of the colors recorded. Some materials may have a specific UVA excitation range. Different UVA peaks emitted from the lamps may cause these materials to emit different fluorescent colors. This may influence the identification of materials or interpretation of the fluorescent results.

Acknowledgements

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References

[1] Sexton, Jennifer M., and Paul Messier. 2015. Permanence of the Target-UV™ and UV-Grey™. http://www.uvinnovations.com/resources: UV Innovations.
[2] Kushel, D. 2011. "Chapter 6: Photographic Techniques." In *the AIC Guide to Digital Photography and Conservation Documentation*. Washington, DC: AIC.