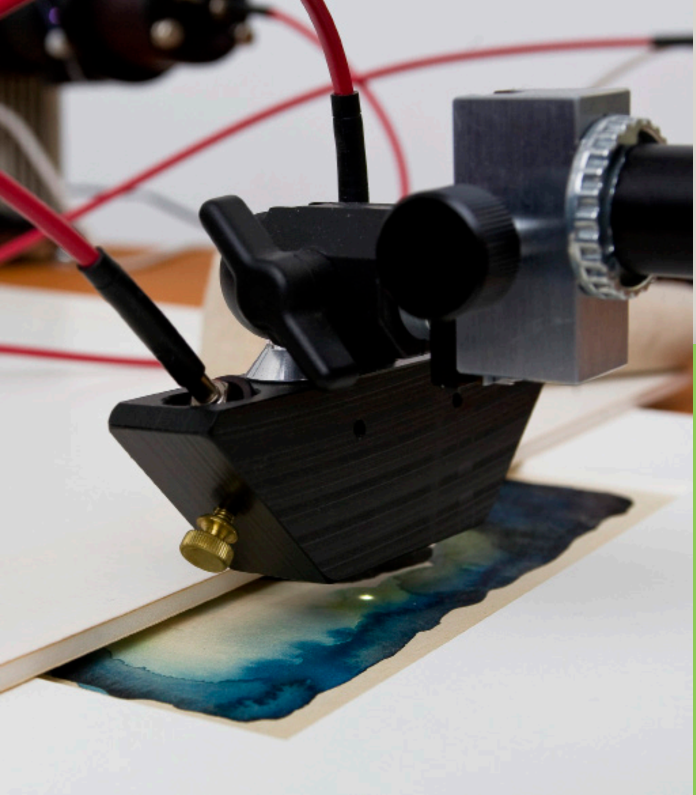


Experts Meeting

Advancing Microfading Tester Practice

A report from an experts meeting organized by the Getty Conservation Institute, March 13-15, 2018

Vincent Laudato Beltran

The Getty Conservation Institute

Advancing Microfading Tester Practice

A report from an experts meeting organized by

the Getty Conservation Institute

March 13-15, 2018

Vincent Laudato Beltran

THE GETTY CONSERVATION INSTITUTE

LOS ANGELES

The Getty Conservation Institute
1200 Getty Center Drive, Suite 700
Los Angeles, CA 90049-1684
United States
Telephone 310 440-7325
Fax 310 440-7711
E-mail gciweb@getty.edu
www.getty.edu/conservation

ISBN: 978-1-937433-72-7

The Getty Conservation Institute (GCI) works internationally to advance conservation practice in the visual arts—broadly interpreted to include objects, collections, architecture, and sites. The Institute serves the conservation community through scientific research, education and training, field projects, and the dissemination of information. In all its endeavors, the GCI creates and delivers knowledge that contributes to the conservation of the world's cultural heritage.

Front cover: Microfading Tester in use on Georgia O'Keeffe, *Untitled* (Abstraction/Portrait of Paul Strand). Photo: Dennis Keeley.

Right: Georgia O'Keeffe. *Untitled* (Abstraction/Portrait of Paul Strand), 1917. Watercolor on paper, 12 x 8-7/8 inches. Georgia O'Keeffe Museum. Gift of the Burnett Foundation. (2007.1.4).

Contents

Acknowledgments

This publication is the result of a collaborative effort, and the author would like to gratefully acknowledge the following contributions: First, my deepest appreciation to the Experts Meeting participants who generously shared their time and knowledge about the microfading tester and provided useful suggestions and comments for refining this manuscript. Within the Getty Conservation Institute (GCI), I would like to express gratitude to Tom Learner, Head, Science, for helping lay the groundwork for such a meeting to occur; and to Reem Baroody, Foekje Boersma, Ashley Freeman, Michal Łukomski, Nicole Onishi, Joel Taylor, and Emma Ziraldo for supporting my organizing efforts. Countless thanks go to the GCI's Publications team, Cynthia Godlewski, Chelsea Bingham, and Megan DiNoia, for skillfully shepherding the manuscript through the publication process; Sheila Berg for copy editing; Gary Mattison for design and administrative support; and Anna Zagorski for dissemination. Finally, I would like to recognize Jim Druzik, former GCI Senior Scientist, for introducing the microfading tester to the GCI and developing our collective expertise in the technique.

Introduction

For a museum to meet its educational and exhibition mandates, it is necessary to expose cultural heritage objects to light, which transmits energy to the artwork and may lead to irreversible change (fig. 1). Guidelines for exhibition lighting have continued to evolve from a prescriptive solution to a risk management approach that seeks to balance access and exposure, all in the context of the transition from incandescent lighting to LED light sources. While a level of light sensitivity may be assumed for an artwork based on expert judgment, colorants that appear similar may have different chemical compositions, and comparable objects may have widely varying light exposure histories, both of which can affect current fugitivity. If the artwork is deemed highly vulnerable to light damage, access to it is reduced and the resulting object rotation increases costs. Thus, assessing the light sensitivity of a specific artwork would ensure that such measures are necessary.

FIGURE 1
Color change of a century-old dress during ten years of museum display. Photo: Stefan Michalski, CCI. ©Government of Canada, Canadian Conservation Institute

The microfading tester (MFT), introduced to the field of heritage conservation in the mid-1990s by Paul Whitmore (Institute for the Preservation of Cultural Heritage at Yale University, previously at Carnegie Mellon University; Whitmore, Xun Pan, and Bailie 1999), is an important tool for understanding the in situ light sensitivity of an artwork's colorant system (i.e., colorant, binder, substrate) without the need for chemical identification. The technique exposes a small area (less than 0.5 mm in diameter) to a bright light source and monitors the resulting color change of this localized area in real time. By assessing the extent of color change during the test, one can ensure that this change remains invisible to the viewer, rendering it virtually nondestructive. The high light intensity of the MFT accelerates this color change and data can be obtained rapidly, allowing for predictions of object fugitivity before the work goes on exhibition. MFT data are commonly compared to the fading rates of Blue Wool (BW) standards, which makes it possible to refine the light sensitivity assessment of an object and propose object-specific light exposure guidelines.

MFT has become generally accepted as a preventive conservation tool, but there remain obstacles to its more widespread use. While the original Whitmore MFT setup is actively used in the cultural heritage field, subsequent MFT designs have explored the use of different components, potentially causing ambiguity as to which iteration is most appropriate for a specific context. Once an MFT design has been selected, issues can arise in the acquisition and setup of a non-turnkey instrument, as well as with sustaining institutional knowledge for an instrument that may be operated and maintained intermittently. In addition, the MFT is a rare instance in which an analytical technique was developed within the conservation field rather than adopted from a larger external field of study, and as a consequence, has less established means of instrumental support that might be provided by commercial companies. Finally, there can be uncertainty in how to interpret MFT data and apply that information to museum lighting policy.

Following MFT-focused meetings convened by the Rathgen Laboratory and Conservation Science Annual in late 2016, the Getty Conservation Institute facilitated a gathering in March 2018 of selected scientists and conservators experienced with MFT to examine issues related to advancing its practice in the conservation community (fig. 2; appendix 1). The first day (March 13) of the MFT Experts Meeting consisted of a public seminar and instrument demonstration to share information with colleagues from the Getty and similar institutions, as well as conservators in private practice (see appendix 2 for the program). The remaining days (March 14 and 15) were devoted to roundtable discussions on a range of MFT topics, for which this document provides a summary. Session themes included both technical aspects (instrumental variations, BW standards, analytical protocols, and impact on lighting policy) and dissemination (user group and training). A final session recapped the meeting.

FIGURE 2
Experts Meeting participants included scientists and conservators active in MFT development and application (see appendix 1). Photo: Gary Mattison

Instrumental Variations

The general concept of MFT has remained consistent since its introduction to the cultural heritage field. With the continued development of light sources and measurement probes, however, there has been variation in the specific components used to create recent MFTs. Many existing MFTs are based on the original noncontact Whitmore design (fig. 3), which includes a Xenon-arc lamp, 0/45 geometry (light arrives vertically or normal to the sample surface, while the reflected light from the surface is collected at 45° from normal), connecting fiber optic cables, and focusing lenses. The aim of this session was to examine differences in current MFT designs.

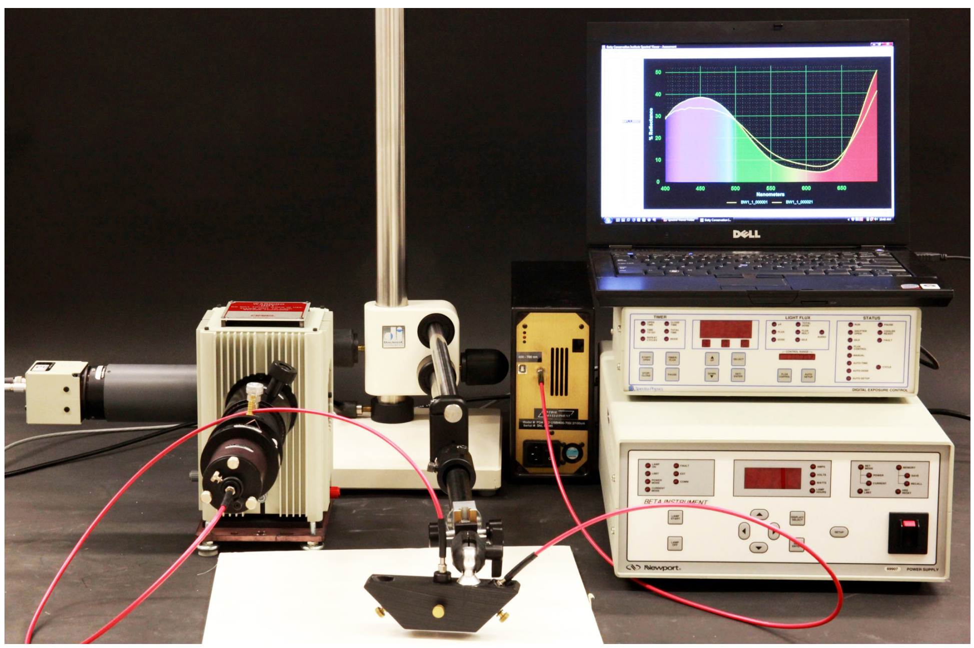


FIGURE 3
Components for the original MFT design by Paul Whitmore. Photo: Jim Druzik

Light Source

The light sources typically employed in MFT are Xenon-arc lamps or light-emitting diodes (LEDs). Xenon-arc lamps generate a white light approximating sunlight and are used in daylight simulation studies; when employed for MFT, filters are used to minimize its ultraviolet component. LEDs are a semiconductor light source that have superseded incandescent lights in many galleries due to its energy efficiency, extended lifetime, and small size. The advantages and disadvantages of these two light sources with respect to MFT are shown in table 1.

TABLE 1
Comparison of Xenon-arc lamps and LEDs as MFT light sources

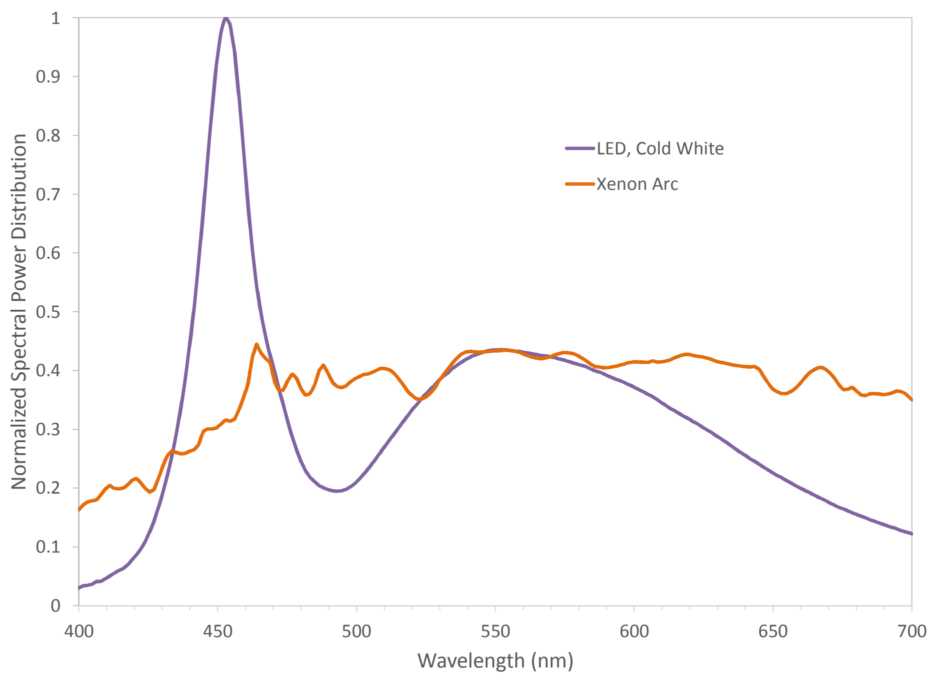
	Xenon arc	**LED**
Advantages	• Broadband spectral power distribution represents the worst-case scenario • Small filament and directional light source that can image much of its output into a fiberoptic cable • Wide wavelength range with the possibility of simulating a UV-containing environment • Long-term stability due to the use of a feedback monitoring loop	• Small size increases the portability of instrument • Small filament and directional light source that can image much of its output into a fiberoptic cable • Can be more representative of LED gallery lighting
Disadvantages	• Larger size is inconvenient for transport • May require alignment of lamp reflectors	• Notched spectral power distribution does not represent the worst-case scenario • Potential issues with long-term stability

The choice between using a Xenon-arc lamp or an LED as the MFT light source can depend on the purpose of testing. If used as a screening tool to flag light-sensitive artwork, either Xenon-arc or LEDs can be a suitable light source. However, the smaller size of LEDs may be more conducive to MFTs that require a smaller footprint or that are expected to travel. If an MFT is utilized for research purposes, the broadband nature of a Xenon-arc lamp may be preferred over the notched spectra of LED sources (fig. 4). To approximate a specific LED profile to match gallery lighting conditions, one could employ an LED light source with a similar spectral power distribution or employ filters to reshape the Xenon-arc spectral power distribution. It should be noted that MFT results using a specific LED profile may not be as relevant should the object be exposed to significantly different lighting conditions in the future. While additional studies are needed, initial MFT experiments conducted by Christel Pesme (M+) examining the exposure of select samples first to Xenon-arc and then to LED light sources suggested that their respective Blue Wool (BW) rankings (*i.e.*, comparison of color difference curves to that of BW1, 2, or 3) were similar (Pesme et al. 2016).

Noncontact or Contact Design

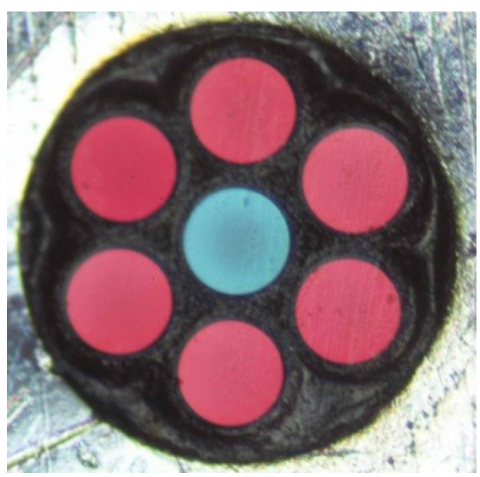
MFT designs typically allow for analysis without touching the sample surface. This characteristic is necessary when testing friable material, such as pastels, and, in the case of the original Whitmore MFT, requires one to align the lamp and spectrometer spots before each test. With a working distance of roughly 1 cm, the Whitmore MFT also allows for the testing of materials through glazing.

FIGURE 4
Representative spectral power distribution of Xenon-arc and LED lamps.
Image: Vincent Beltran



Contact MFT measurements have been employed by Christopher McGlinchey at the Museum of Modern Art (MoMA) (fig. 5), Mark Benson at the Getty Research Institute (GRI, instrument design discussed in Pesme et al. 2016), and others. This MFT setup has the potential to obtain measurements under less than ideal environmental conditions, does not require spot alignment, and may be more reproducible for surfaces with significant micro-roughness; as such, a contact head may be a complementary accessory for noncontact MFTs. At MOMA and the GRI, the primary MFT users are conservators who work with collections that may be more amenable to gentle contact through a Mylar template. Possible drawbacks of contact (other than contact itself) are its inability to test through glazing, the need for a flat surface, and the fact that the test area is not visible during testing.

FIGURE 5
A 6/1 bifurcated fiber optic tip (blue circle: light introduced to sample, red circles: light directed to spectrometer) employed as a contact MFT head at the Museum of Modern Art. Photo: Christopher McGlinchey, MoMA

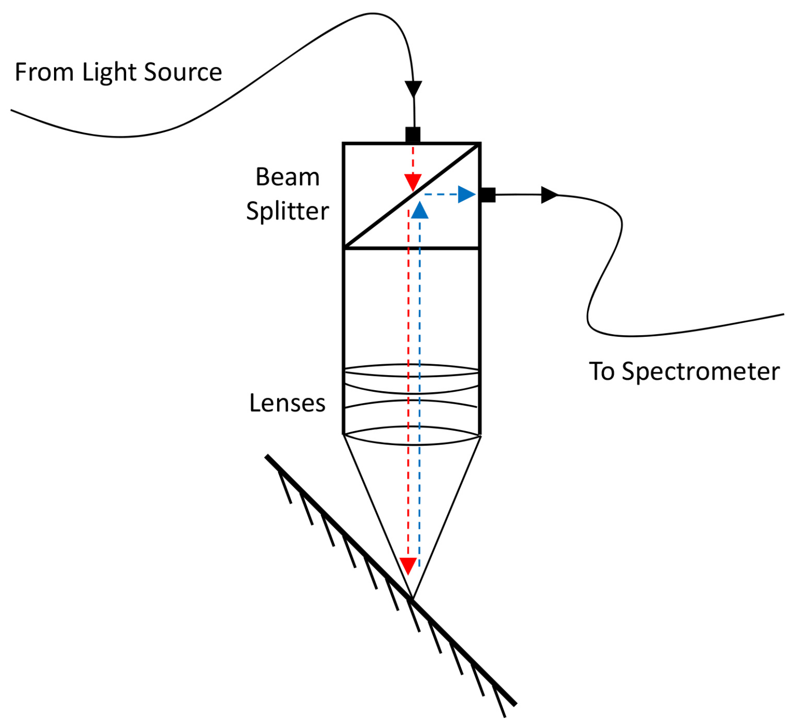


Measurement Geometry

The majority of MFTs employ a 0/45 geometry to assess diffuse reflected light. As a consequence, this setup has a narrow depth of focus, requiring careful alignment of the illumination and collection spots (though this is mitigated by the use of a larger-diameter fiber optic cable for collection).

Recent MFT iterations have employed a measurement probe that operates in retroreflection mode. In this setup, the reflected light returns along the same path as the illumination beam, providing a wider depth of focus and eliminating the need to align separate illumination and collection spots (fig. 6). The retroreflective probe also allows for adjustment of the measurement angle away from 45°, though this can affect the resulting light intensity and dosage and require angle-specific calibration. Experts Meeting participants employing this geometry include Haida Liang (Nottingham Trent University; Liang et al. 2011) and Jacob Thomas (University of Gothenberg).

FIGURE 6
A schematic for a retroreflective MFT probe. Image: Haida Liang, Nottingham Trent University



Fiber Optic Cables and Lenses

The transmission of light from the source to the sample and from the sample to the spectrometer is conducted through a series of fiber optic cables and lenses. The original Whitmore design used a fiber optic cable for collection that had a wider diameter (600 μm) than that of the illumination fiber optic cable (200 μm), providing some tolerance when aligning the illumination and collection spots.

Chromatic and spatial aberrations present in standard lenses have led some to employ achromat lenses to minimize these irregularities and produce a more uniform fading spot. However, given the high cost of achromats, the performance of standard lenses likely remains satisfactory for MFT.

Typical MFT spot sizes are less than 0.5 mm in diameter, and the size of the spot is a function of the diameter of the illumination fiber optic cable and the conjugate ratio of the lens. Use of a smaller spot size may decrease testing time (note that this is also dependent on the light dosage), but can be less representative and have the potential for increased surface heating; this latter point is particularly important to verify to ensure safety when testing artwork. Larger spot sizes may be more appropriate for materials with higher surface roughness, but can extend testing duration (which again depends on dosage).

Automated MFT

Tomasz Lojewski (AGH University of Science and Technology) and Jacob Thomas recently undertook development of an automated MFT (Łojewski and Łydżba-Kopczyńska 2019). This MFT has advanced through several generations and includes the following:

- 0/45 geometry
- White LED light source connected to a feedback loop
- Automatic alignment of lamp and spectrometer spots
- Potential operation as a black box

This automated MFT represents a step toward a more commonly used tool, but effective training on the use of the instrument and interpretation of the data remains key to the successful application of the technique.

Round-Robin Testing

Following the MFT Experts Meeting, a round-robin test of various MFT designs was organized and carried out by Betty Sacher, a PhD student at University College London/Tate, and results are forthcoming. The experiment requests MFT users examine the light sensitivity of a preselected sample set of colored papers representing new commercial products, handmade samples, and historic samples, as well as BW standards. A similar round-robin format was previously organized by Bruce Ford (National Museum of Australia, independent consultant), with select results discussed by Pesme et al. (2016).

Potential Action Items

- Determine stability of various LEDs over a range of time periods
- Explore MFT standardization, particularly with respect to spot size and dosage
- Compare results between 0/45 and retroreflective geometries

Blue Wool Standards

Used to characterize material lightfastness, Blue Wool (BW) standards consist of eight dyed wools of increasing sensitivity. The first three—BW1, BW2, and BW3—are thought to encompass the fugitivity range of light-sensitive colorants (Michalski 2018), and MFT data are commonly calibrated to their color difference curves.

Though BW standards are used widely as a means of communicating MFT data, various issues have been identified, including the following:

- Use of BWs outside the definition of the standard, which is designed to bleach to whiteness under daylight. In contrast, MFT focuses on a relatively narrow color difference range.
- The presence of multiple versions of BW standards from the United States, the United Kingdom, and Japan, with varying presentations (i.e., a loose weave or stretched on a card) and the potential use of different dyes
- Textural issues when choosing an appropriate test spot for MFT, as well as the differing response of loose or stretched dyed fabric
- Potential variations among BW suppliers, leading to inconsistent response between batches and the need to identify cards exhibiting the appropriate behavior
- Occasional identification of BW2 as problematic, with BW1 and BW3 generally showing more consistency
- The cultural heritage field's position as a minor user of BW standards, making it difficult to advocate for change (e.g., use of a flat rather than textured surface)

Blue Wool Alternatives

Han Neevel (Cultural Heritage Agency of the Netherlands) and Tomasz Lojewski have explored the use of photochromic dyes as an alternative to BW standards. These commercially available dyes are composed of a polymer-solvent system that hinders conformational change of the dye molecule and may be reversible on exposure to UV light. The goal is to calibrate these dyes against BW standards.

Though promising, the commercial use of photochromic dyes remains a work in progress. Quality control can be a major obstacle when developing a new standard, with factors such as batch to batch inconsistencies, potential change in behavior due to impurities, and coating difficulties hindering the process.

Just Noticeable Difference

A just noticeable difference (JND) represents the amount of change that is perceptible to the viewer. While various estimates of the light dose needed to induce a JND for BW standards have been suggested by Stefan Michalski (1997) and Jonathan Ashley-Smith (2002), it is thought that these may overestimate the JND dose, particularly with respect to BW1 and BW2. The definition of JND, which assumes ideal viewing conditions and applications of color over a large area, is also at odds with MFT's small-scale assessment of imperfect objects. It is generally agreed that a JND determined by MFT for a work of art should be larger than 1 ΔE^*_{ab} (this unit refers to a color difference calculation introduced in 1976 and is discussed further on page 16). In practice, a color difference of roughly 5 ΔE^*_{ab} indicates the threshold for ceasing MFT, eliminating the possibility of visible alteration on the artwork.

Blue Wool Standard Repository

Despite the stated issues, BW cards remain the best standard available to MFT users. However, given the variation observed in some BW cards and the fact that future availability is not assured, establishing a repository of vetted BW cards may provide a supply of consistent standards for MFT users and act as a short- to medium-term response until BW alternatives are developed or adopted by the textile dye industry. Since BW cards can be used over an extended period if tested judiciously and stored in the dark between use, the quantity required need not be overwhelming. The creation of a BW card repository would necessitate additional discussion on the development of testing procedures (e.g., similar dosages, verification of color change behavior) performed by multiple analysts, with selected institutions acting as storehouses of vetted BW cards.

Potential Action Items

- Conduct aging tests of BW to estimate JND
- Explore viability of BW standards repository

Analytical Protocols

Regardless of the different components used to build the various designs, MFT users are confronted with similar issues in the collection and interpretation of MFT data.

Site Selection

Testing strategies can focus on the analysis of a small area or attempt a more superficial survey of a larger area, with the former striving for a smaller error bar and the latter allowing for examination of more materials. If one is conducting replicate analysis, all colors might be tested once before returning to the first color, allowing for a time difference. Midtones are preferred, as more of the spectra will exhibit moderate reflectance and contribute to the resulting color difference.

The assumption that similar colors on an object have the same chemical composition is based on the belief that the artist had access to a limited color palette, with hues representing mixtures. Though the spectra may not be distinct enough to determine if two colors are chemically different, supplementary data from techniques such as UV-induced fluorescence can provide additional evidence.

The rationale for replicate analysis is to provide corroboration of initial tests, particularly for the most light-sensitive areas, and to check for potential user error. This confirmatory role of replicates allows for shorter durations than the initial test. While variability in the Blue Wool (BW) equivalence may be observed for multiple tests of the same color, an argument against excessive replicates suggests that variations in color difference behavior across a single color is rare. In the end, the decision on the number of replicate tests will be dependent on the number of test spots desired and the available time allotted to MFT.

Light Intensity

The intensity of the light source (commonly between 2 and 6 million lux) will play a role in defining the duration of an MFT run. A common aim of MFT is to obtain a reasonable response for BW3, which is roughly half as sensitive as BW2 (which is again roughly half as sensitive as BW1); for example, a light intensity of 600 millilumens can provide a sufficient dynamic range across BW1 (ΔE^*_{ab} of ~5 in 3–4 minutes) to BW3 (ΔE^*_{ab} of 0.5-0.7 in 5 minutes). The use of higher intensities may result in a BW response that is too rapid. For objects with high or unknown light sensitivity, one should proceed with caution, initially testing with reduced light intensity (using a neutral density filter) followed by incremental increases to full power.

It was suggested that radiometers, rather than the more common lux meters (considered unreliable by some), be used to record the absolute power of the light source. Lux meters report photometric values that are weighted according to the sensitivity of the human eye, while radiometers provide unweighted absolute values. Key parallel quantities include radiant flux (radiometric, units of watts) or luminous flux (photometric, units of lumens), which indicate the total emitted light from a light source, and irradiance (radiometric, units of watts/m^2) or illuminance (photometric, units of lumens/m^2 or lux), which indicates the total light on a surface. One can convert between photometric and radiometric units given the spectral power distribution of the lamp, though conservators and curators may prefer to continue reporting in the photometric unit of lux given its relevance to BW ranking and lighting policy.

Color Difference

Color difference (ΔE) in CIE L*a*b* color space (fig. 7) was defined in 1976 by the Commision internationale de l'éclairage as the Euclidean distance and termed ΔE^*_{ab}. Revised color difference calculations were introduced in 1994 and 2000 that added weights and corrections to address perceptual nonuniformities of the L*a*b* color space. While it is suggested that the most recent, 2000 color difference calculation be used, its more complicated formulas and the fact that spectrometers commonly report ΔE^*_{ab} have sustained use of the more straightforward 1976 calculation. It should also be noted that there is the potential for slight differences in BW equivalence when applying the various color difference formulas. Spectral Viewer, a program developed at the GCI to examine MFT data from Control Development spectrometers, is currently limited to reporting color difference using the 1976 and 1994 formulas (though results for the latter are close to those of 2000). Experiments using the 1976 formula suggest that a ΔE^*_{ab} of roughly 15 coincides with initial visibility of the test spot. Thus, using an MFT termination threshold of ~5 ΔE^*_{ab} ensures that the test location on an artwork remains imperceptible to the viewer.

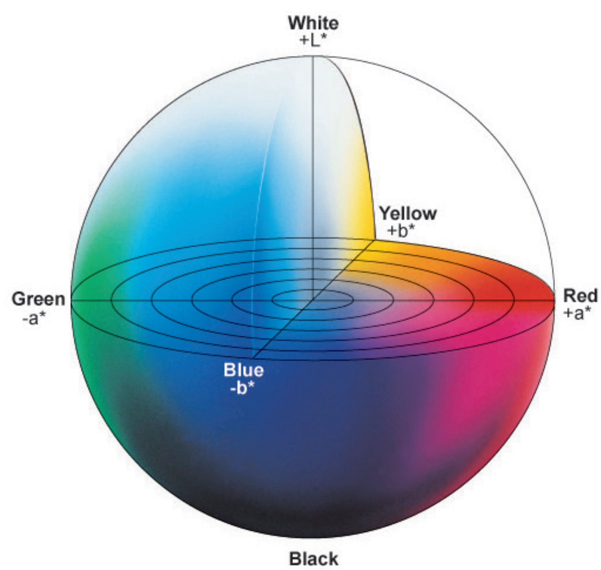
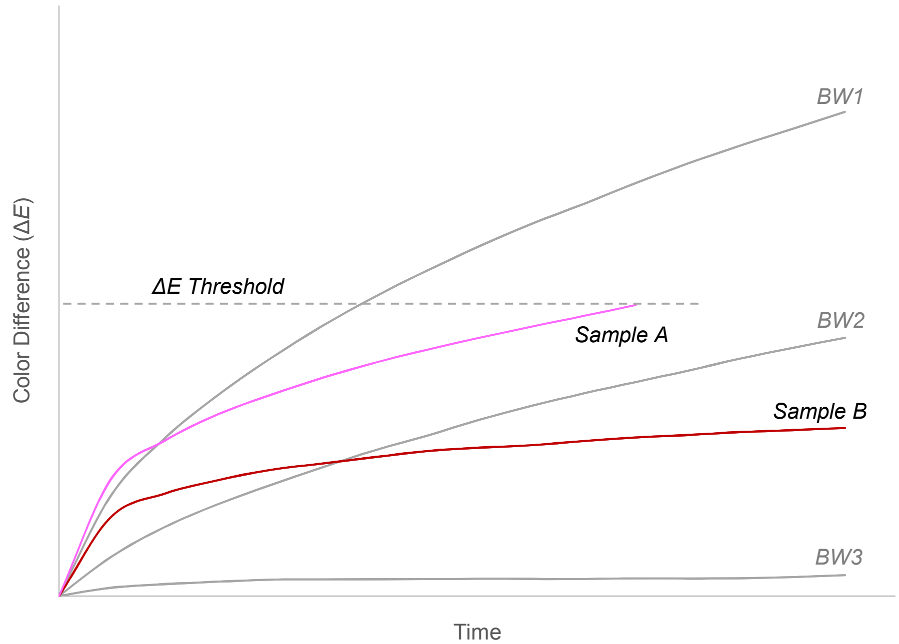


FIGURE 7
Spherical representation of CIE L*a*b* color space. Image: Courtesy of Konica Minolta Sensing.

Blue Wool Equivalence

The assignment of a BW equivalence to a sample color on an artwork typically focuses on the end of the test duration or when the termination threshold has been reached, with assignment based on its proximity to the color difference values for BW1, BW2, and BW3 or intermediate estimations (e.g., BW1.5 or BW2.5) (fig. 8). Assignment of BW equivalence at the end of the test emphasizes the response of the colorant system following extended light exposure. In some cases, a sample may initially track the steeper color change of a more sensitive BW (e.g., BW1 or BW2) but progressively exhibit color change closer to that of a less sensitive BW (e.g., BW2 or BW3) as the curve plateaus. An alternative means of assigning BW equivalence highlights the point at which a color difference curve reaches 1 JND, as this presumably connects the ranking more directly to lighting policy. In any case, the possibility always exists that extended tests might result in further shifts in the color difference curve of the sample relative to those of the BW standards.

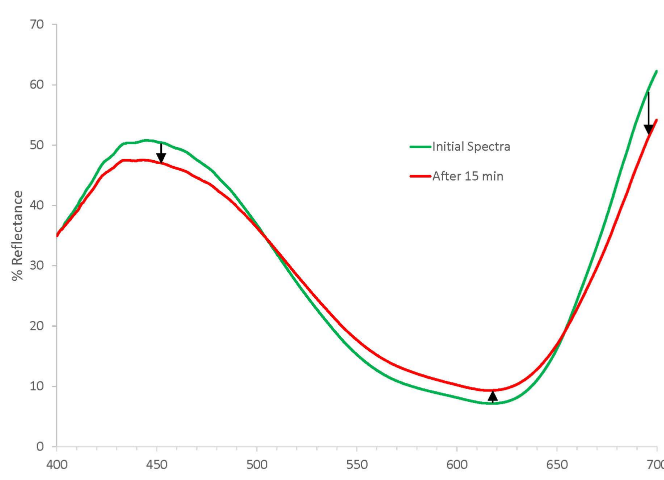
FIGURE 8
Comparison of sample color difference curves to those of BW standards to assess BW equivalence. Image: Vincent Beltran



Spectral Analysis

Many MFT analytical protocols focus on examination of colorimetric values (L*a*b*) or color difference, but the raw spectral data remain the fundamental source of information. Assessment of the reflectance spectra over time can highlight which wavelength regions show the maximum change (fig. 9) and describe how this change is taking place. Spectral behavior during MFT can also indicate the occurrence of testing errors, such as a slipped probe head, resulting in a constant shift in the spectra across the wavelength range. Haida Liang has been a strong advocate for this added layer of data analysis.

Figure 9
Comparison of MFT reflectance spectra for BW1 over the duration of the test. Image: Vincent Beltran



Color accuracy in the data may be dependent on the state of the spectrometer and can complicate sharing of data. Color measurements can be verified through the testing of color reference tiles and/or regular instrument calibration. However, the role of MFT as a screening tool for light-sensitive material places more emphasis on relative differences in the MFT data than absolute color measurement.

Potential Action Items

- Determine visibility threshold in ΔE-2000 units

Impact on Lighting Policy

The interpretation of MFT data plays an important role in facilitating communication about lighting policy with conservators, curators, facilities staff, and other interested parties and can prompt discussion on how light exposure affects an artwork's appearance or plans for future exhibitions and loans. Through the use of MFT, lighting decisions can be informed by quantitative evidence of an artwork's light sensitivity and discussed in common terms of Blue Wool (BW) equivalence, lux-hours, light levels, preservation targets, and time. MFT results can reinforce existing lighting policies, and often the data may result in an increased number of objects on display and/or extended exhibition durations. Conservators may also have a lighting strategy in mind and are looking to MFT for confirmation. In the end, MFT provides information that will be considered by conservators and curators among a range of often competing factors to aid their decisions about exhibition and display.

Complementary Tools

The Light Damage Calculator (LDC) from the Canadian Conservation Institute can serve as a complementary tool to MFT for visualizing predicted change. The LDC provides a means of examining the fading of a single colorant, a single colorant under different scenarios, and a collection of colored objects. Similarly, the maintenance of visual examples of color change (physical or photographic) may help initiate conversation about cumulative light damage.

MFT Case Studies and Databases

As previously discussed, widespread use of MFT has been hindered by various issues, including uncertainty by some as to the reliability of MFT data. Though MFT was introduced in the mid-1990s, publications describing MFT data sets remain infrequent, in part due to its primary role as a screening tool for selected objects before exhibition, limiting the scope of study. Equally scarce are published comparisons between pre-exhibition MFT assessments of an artwork's light sensitivity and follow-up color monitoring of the same object during and after exhibition. Examples of such comparative studies have been presented by Sarah Freeman (J. Paul Getty Museum; Freeman et al. 2014) and Bruce Ford (Ford and Smith 2017). The collection and sharing of a wide range of MFT case studies will further demonstrate the application of and need for MFT.

Databases of MFT results have been organized by some private practitioners (e.g., Bruce Ford) and colleagues at cultural heritage institutions (e.g., Season Tse at the Canadian Conservation Institute; Vincent Beltran and Ashley Freeman at the Getty Conservation Institute), and dialogue at the Experts Meeting focused on the merits of merging databases. By examining a database of numerous MFT analyses, one can identify classes of light-sensitive artwork that can be targeted for MFT. Such a resource also allows for the reassessment of lighting guidelines for object types, which would be particularly helpful for institutions without access to MFT. For individual objects, it is important that information regarding light exposure history and MFT sensitivity assessments remain accessible to future collection stewards.

A major concern about reliance on an open access MFT database to make light-sensitivity judgments is the potential of sacrificing individual artworks that are more unstable than the mean fugitivity for that object type. This runs counter to the ethos of MFT, which seeks to assess the individual needs of each artwork. Further, access to a MFT database should not be a means of avoiding MFT. The wide availability of MFT data may also have an impact on artwork sales and institutional reputations as heritage caretakers.

Reciprocity

The concept of reciprocity refers to a material response as a function of exposure (or dosage), which can be defined as the product of intensity and time. For light exposure, intensity and time are often reported in lux and hours, respectively. If reciprocity holds, a similar response should be observed for the same exposure, whether the intensity is low and duration is extended or the intensity is high and the duration is brief.

Extreme exposure conditions in accelerated aging techniques such as MFT push the boundaries of reciprocity. Discussions about potential reciprocity breakdown with respect to MFT data can be initially unclear and lead to questioning of MFT results. Note that reciprocity is not an intrinsic material property but rather a response of a material to a test condition, including ambient environmental conditions. While it is difficult to systematically address reciprocity due to the wide range of materials and test conditions, it may be of more concern for rapidly changing materials.

What is promising is the fact that the relative rankings of BW1, BW2, and BW3 are generally retained during MFT. Thus, one can use the consistency of BW rankings as an internal standard to bridge MFT results and lighting policy. The main concern with reciprocity breakdown is when the dose response might be so distorted as to mistake stability for instability; that is, an artwork is estimated as stable with MFT but proves unstable in typical light conditions. Though thought to be unlikely for the vast majority of materials, such behavior has been observed in select grasses and leaves (Beltran et al. 2014) and arsenic sulfide-based realgar and orpiment, and MFT results for these samples should be treated with caution. The community of MFT users should continue to publicly flag similar outlier behavior.

While a similar disconnect between MFT data and long-term observations of paper yellowing has been noted, this highlights not reciprocity breakdown but the fact that MFT is focused on photochemical degradation. Since paper yellowing is understood to be a thermally driven chemical process, this behavior will not be induced solely by exposure to high light intensity.

Reciprocity testing may be particularly important for extremely sensitive colorants but requires experiments with a range of light intensities and extended durations. If reciprocity is maintained, one could be confident in assuming an artwork would respond in a comparable manner when displayed in gallery lighting conditions. It is recommended to also investigate the spectral MFT data, as differences in the spectra may not be clearly reflected in color difference curves. Reciprocity testing of BW1, LightCheck Ultra, and dyed silks has been conducted by Julio del Hoyo-Meléndez (National Museum of Krakow) and Marion Mecklenberg (retired, Museum Conservation Institute) (del Hoyo-Meléndez and Mecklenberg 2011).

Potential Action Items

- Collect MFT case studies, including those comparing pre-exhibition MFT data and long-term color monitoring
- Maintain list of samples for which reciprocity failure may contradict MFT results

User Group

The development of a community of MFT users requires the sharing of and accessibility to information related to the technique and can serve both experienced users and those seeking to acquire an MFT. An early attempt at coalescing an MFT user group was initiated at the Getty Conservation Institute by Jim Druzik (retired) and Christel Pesme (now at M+) in the mid- to late 2000s and focused on new users of the Whitmore MFT. Information was to be accessed through a closed website, but its impact was minimized as email was the preferred distribution route, circumventing the need to upload and comment on the site. Further, the MFT community at that time may have lacked the critical mass for this effort to gain traction. More recently, an MFT user group was set up on Researchgate by Stefan Rohrs (Rathgen Laboratory) as a forum to continue discussions initiated at the 2016 MFT meeting organized by the Rathgen. However, subsequent participation has been intermittent, and the use of Researchgate may not be widespread in the cultural heritage field.

Potential Models

The website established for the Mass Spectrometry and Chromatography group (MaSC, mascgroup.org) may serve as a model for improved communication with MFT users. Organized by a five-person steering committee that included Christopher Maines (National Gallery of Art), the independent MaSC website acts as an information dissemination point rather than an information creation point and, lacking a chat function, is not intended as a discussion forum. While the user group may be dormant for extended periods, ready access to curated information maintains the site's usefulness. The MaSC user group convenes every two years for a meeting and workshop.

Active discussions of MFT issues may be better suited to a more accessible platform such as the Conservation DistList (ConsDistList), which is supported by the Foundation of the American Institute for Conservation of Historic & Artistic Works. Received as an email twice weekly, this collection of conservation-related information reaches a wide audience in the cultural heritage field. MFT questions and answers may be posted on ConsDistList, and the responsibility to respond can be shared. There is also the potential to utilize free web communication tools that will invite people to have a more in-depth discussion, as was done by Chris Stavroudis (private conservator) as a follow-up for participants on the GCI's series of Cleaning Acrylic Painted Surfaces (CAPS) workshops, a key component of its Modern and Contemporary Art Research Initiative.

MFT Website

Assuming a similar development path as the MaSC group, a proposed MFT website might act as a repository of didactic information related to MFT, allowing it to remain relevant for an extended period. Such a website could include annotated bibliographies; descriptive case studies; data analysis software; relevant links; and component lists, schematics, and protocols for various MFT instrumentation. An updated list of MFT users around the world might be shared as a means of facilitating the development of regional networks of MFT expertise. Should a Blue Wool (BW) card repository be established, the MFT website could act as an access point to vetted BW cards. Similar to the MaSC website, active discussion would not be a feature of the MFT website; this activity would be shifted to ConsDistList. New additions to the MFT website can also be announced on ConsDistList. Maintenance of a website may be initially driven by the GCI, with the hope of shared responsibility moving forward.

An existing website dedicated to MFT (microfading.com) has previously been established by Bruce Ford, in part to present his services establishing MFT instrumentation and training users. Though the commercial aspect of the website has been deemphasized, a separate noncommercial MFT website might be needed. Ford's website remains an invaluable resource and accomplishes some of the items previously described. It would be prudent to solicit feedback from Ford on the potential development of a new website and either link to microfading.com or present some of its contents with the permission of and attribution to Ford.

Potential Action Items

- Create and organize an MFT User Group website and various didactic materials related to MFT
- Create a list of MFT users worldwide to facilitate the development of regional networks of MFT expertise
- Explore a web communication tool to complement ConsDistList discussion
- Collaborate with Bruce Ford to build on resources at microfading.com

Training

Providing MFT training opportunities is an important component of advancing MFT practice in the cultural heritage field. Training can encourage the shift from a small group of MFT users composed mostly of conservation scientists to the larger community of conservators. Feedback from conservators may be sought to identify their needs with respect to MFT. Possible venues to reach conservators include AIC, FAIC, IIC, and ICOM-CC.

Scope

An MFT training curriculum should address the entire scope of the technique, including fundamental color science and spectroscopy, object safety, principles of operation, data interpretation, impact on lighting policy, and hands-on operation. Despite the technical complexities previously described, the concept of MFT is straightforward, and minimal experience with the technique will increase one's comfort level. Exposure to the various iterations of MFT (and the support available, potentially via a user group) is particularly valuable for prospective users in deciding on the version that is optimal for their context.
An audience subset that may be targeted for selected workshops are those who are already familiar with the technique. Workshops for the MaSC group originally skewed toward introductions to specific analytical techniques. However, it was noted that the people who most benefited were experienced users, as it provided an opportunity to learn tips and tricks that had an immediate impact on the usability of the technique. Once presented, workshops should actively seek participant feedback that can benefit future iterations.

Research into Practice

The GCI's Research into Practice Initiative provides a potential path for developing a recurring training course. This series seeks to integrate emerging scientific knowledge into practice, drawing on the perspectives of scientists and conservators and identifying areas of further work and collaboration. Previous Research into Practice training workshops have included Cleaning of Acrylic Painted Surfaces (CAPS), Conservation of Plastics in Museum Collections, and the X-ray Fluorescence (XRF) Boot Camp for Conservators. Organized with the Institute for the Preservation of Cultural Heritage at Yale University, the XRF Boot Camp is a relevant model for an MFT training course, as it focuses on the fundamentals of XRF and data interpretation to improve the use of handheld XRF for the study of cultural heritage.

Influencing Decision Makers

While MFT training largely focuses on conservation staff, there is also the potential to inform decision makers about the importance of MFT as a preventive conservation tool. While resources are needed to create capacity, decision makers need to be convinced that these resources are indeed necessary. This includes encouraging heads of conservation and curatorial departments to allow time for a conservator or curator to be trained on and conduct MFT. Lectures at the College Art Association (CAA) or American Alliance of Museums (AAM) meetings may be possible means of reaching this audience.

Increasing Demand

Concomitant with advancing MFT practice in the field will likely be increased demand for the service. There are a growing number of MFTs, but they largely reside at cultural heritage institutions and are used to examine accessioned objects, rendering MFT inaccessible to private collections or institutions without MFT. However, a greater demand for MFT can create an opportunity for private practice conservators to become experts and offer this service to current and prospective clients. Similarly, the adoption of MFT by regional conservation centers would greatly expand access to the technique. The realization of such possibilities would provide institutions with an alternative to investing heavily in both MFT equipment and conservator time. A private MFT expert could also provide technical support through refresher courses for in-house staff where MFT has been idle.

Guidelines

In addition to trainings and workshops, the publication of guidelines presenting a range of MFT information can be influential. Written collaboratively, these documents would summarize fundamentals, technical aspects, and the interpretation of MFT data and would be shared via the proposed MFT website or as pre-workshop reading material.

The recent initiation of the GCI's Guidelines series may be well suited for this endeavor. This series seeks to present practical tools to advance conservation heritage. Available online, these relatively brief technical summaries can be presented as one document or as a series of related documents, updated as necessary. The first Guidelines publication focused on the documentation of painted surfaces for outdoor sculpture, and subsequent documents will describe the preparation of paint cross sections and the use of acoustic emission to monitor physical change in objects.

Potential Action Items

- Develop curriculum and identify instructors and partners for a potential MFT training course and workshop
- Explore the possibility of MFT lectures at the CAA and/or AAM meetings

Wrap-Up

The closing session of the MFT Experts Meeting offered participants an opportunity to reflect on the discussion during the previous day and a half, present ideas not yet shared, and contemplate the path forward to more widespread MFT use. Selected comments from this session are organized thematically.

Developing Community

- This meeting introduced a new cohort of MFT experts and solidified the connection between different generations of MFT users.
- It is important to identify and engage other colleagues and/or institutions in this MFT discussion; this effort can be paired with the identification of MFT users worldwide.
- There is strong interest for further MFT meetings, workshops, and guidelines to provide guidance to the cultural heritage field.
- Consideration should be given to how the knowledge of a small community of MFT users can be shared with the broader population of collection managers.
- The hands-on work of MFT should be a shared practice, so the responsibility does not fall on one person.
- MFT resides at the nexus of service and research and highlights divisions in priorities that can sometimes exist.

Technical Aspects

- This meeting highlighted various ways of conducting MFT analysis and interpretation, which should be shared with the field.
- There is potential for further development on the software side of MFT.
- While MFT can be automated to some extent, the need for thoughtfulness and care during measurement will always be present.
- The conservation field is open to lower-cost MFTs, but the potential disadvantages need to be clearly defined.
- Further investigation is needed on how one can manipulate the spectral power distribution of a lamp to reduce its impact on artwork.
- When examining alternatives to Blue Wool (BW) cards, consideration should be given to its application on a transparent base to accommodate transmission mode MFT.

Data Analysis

- Though the purpose of MFT is to obtain light-sensitivity data for a specific object, at some point the collective MFT data become valuable in a broader sense. It is important to consider how an MFT database might be utilized to aid risk assessment decisions.
- Further automation of MFT will allow more time to devote to data interpretation and communication of the results.
- There is potential to extract valuable and complementary MFT information by examining spectral changes and CIE L*a*b* data.

New Applications

- Commercial interest in MFT outside of the cultural heritage field exists. If this interest grows, it offers an opportunity to create a larger pool of MFT users who could be leveraged to benefit the conservation community.
- There is a need for a provider of MFT services to private collections or institutions without access to MFT.
- There is the potential to introduce light-sensitivity screening at auction houses.
- MFT results can help refine determinations of the Art Preservation Index, established by Emily MacDonald-Korth and James Korth.

References

Ashley-Smith, Jonathan. 2002. “The Continuing Development of a Practical Lighting Policy for Works of Art on Paper and Other Object Types at the Victoria and Albert Museum.” In *13th Triennial Meeting of ICOM Committee for Conservation, 22–27 September 2002, Preprints*, vol. 1.

Beltran, Vincent, Jim Druzik, Andrew Lerwill, and Christel Pesme. 2014. “An Examination of Light-Induced Color Change in Anoxia and Hypoxia Using the Microfading Tester.” In *Research and Technical Studies Specialty Group Postprints*, vol. 5.

del Hoyo-Meléndez, Julio M., and Marian F. Mecklenburg. 2011. “An Investigation of the Reciprocity Principle of Light Exposures Using Microfading Spectrometry.” *Spectroscopy Letters* 44 (1): 52–62.

Ford, Bruce, and Nicola Smith. 2017. “A Reality Check for Microfade Testing: Five Examples.” In *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4–8 September 2017*, ed. J. Bridgland, art. 1508. Paris: International Council of Museums.

Freeman, Sarah, James R. Druzik, M. Harnly, and Christel Pesme. 2014. “Monitoring Photographic Materials with a Microfade Tester.” In *ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15–19 September 2014*, edited by J. Bridgland, art. 1402. Paris: International Council of Museums.

Langenbacher, Julia, and Rachel Rivenc, with Contributions from Anna Flavin. 2017. *Documenting Painted Surfaces for Outdoor Painted Sculptures: A Manual of Laboratory and Field Test Methods*. Los Angeles: Getty Conservation Institute. http://www.getty.edu/conservation/publications_resources/pdf_publications/documenting_painted.html

Liang, H., R. Lange, A. Lucian, P. Hyndes, J. Townsend, and S. Hackney. 2011. “Development of Portable Microfading Spectrometers for Measurement of Light Sensitivity of Materials.” In *International Council of Museums, Committee for Conservation (ICOM-CC) Triennial Conference, 2011*. Lisbon: ICOM-CC.

Light Damage Calculator. 2013. Government of Canada. Last modified November 6, 2013. https://app.pch.gc.ca/application/cdl-ldc/description-about.app?lang=en.

Łojewski, T., and B. Łydżba-Kopczyńska. 2019. "Spectroscopy in the Analysis of Artworks." In *Molecular Spectroscopy—Experiment and Theory: From Molecules to Functional Materials*, ed. A. Koleżyński and M. Król. Cham: Springer Nature Switzerland.

MacDonald-Korth, Emily, and James Korth. n.d. Art Preservation Index. https://www.art-preservationindex.com/

Michalski, Stefan. 1997. "The Lighting Decision." in *Fabric of an Exhibition: An Interdisciplinary Approach.* Ottawa: National Gallery of Canada.

———. 2018. "Agents of Deterioration: Light, Ultraviolet and Infrared." https://www.canada.ca/en/conservation-institute/services/agents-deterioration/light.html (accessed 1/12/2019).

Microfading Workshop & User Meeting: Program. 2016. Rathgen Laboratory. https://smart.smb.museum/media/news/58688/program_MFT_Berlin_Nov_2016.pdf

NYCF & EAS Conservation Science Annual: Program. 2016. https://www.facebook.com/events/1657648877893044/

Pesme, Christel, Andrew Lerwill, Vincent Beltran, and James R. Druzik. 2016. "Development of Contact Portable Microfade Tester to Assess Light Sensitivity of Collection Items." *Journal of the American Institute for Conservation* 55 (2): 117–37.

Whitmore, Paul M., Xun Pan, and Catherine Bailie. 1999. "Predicting the Fading of Objects: Identification of Fugitive Colorants through Direct Nondestructive Lightfastness Measurements." *Journal of the American Institute for Conservation* 38 (3): 395–409.

Appendix 1: MFT Experts Meeting Participants

Vincent Laudato Beltran (Moderator, Assistant Scientist, Getty Conservation Institute)

Mark Benson (Assistant Conservator, Getty Research Institute)

Ashley Freeman (Note Taker, Research Lab Associate, Getty Conservation Institute)

Sarah Freeman (Associate Conservator, J. Paul Getty Museum)

Eric Hagan (Scientist, Canadian Conservation Institute)

Julio M. del Hoyo-Meléndez (Head, Laboratory of Analysis and Non-destructive Investigation of Heritage Objects, National Museum of Krakow)

Capucine Korenberg (Senior Conservation Scientist, British Museum)

Thomas Lam (Physical Scientist, Museum Conservation Institute)

Bertrand Lavedrine (Professor, Muséum National d'Histoire Naturelle; Director, Centre de Recherche sur la Conservation des Collections)

Tom Learner (Moderator, Head, Science, Getty Conservation Institute)

Haida Liang (Professor, Nottingham Trent University)

Michal Łukomski (Senior Scientist, Getty Conservation Institute)

Christopher Maines (Senior Conservation Scientist, National Gallery of Art)

Laura Maccarelli (Assistant Conservation Scientist, Los Angeles County Museum of Art)

Christopher McGlinchey (Senior Conservation Scientist, Museum of Modern Art)

Christel Pesme (Senior Conservator, M+)

Cindy Connelly Ryan (Conservation Scientist, Library of Congress)

Jacob Thomas (Assistant Professor, University of Gothenburg)

Season Tse (Senior Conservation Scientist, Canadian Conservation Institute [retired October 2018])

Paul Whitmore (Director, Aging Diagnostics Lab, Institute for the Preservation of Cultural Heritage, Yale University)

Appendix 2: Program for March 13 Public Seminar

Presentations

Opening Remarks
Vincent Laudato Beltran (Assistant Scientist, Getty Conservation Institute)

Microfadeometry for Works of Art on Paper and Photographs in the Conservation Labs at the Getty
Sarah Freeman (Associate Conservator, J. Paul Getty Museum) and Mark Benson (Assistant Conservator, Getty Research Institute)

A Microfading Survey of the Lightfastness of Blue, Black, and Red Ballpoint Pen Inks in Ambient and Modified Environments (recorded)
Bruce Ford (Researcher, National Museum of Australia; independent consultant)

Implementing Lighting Policy for Sensitive Collection Items: How to Use Microfade Testing Results in the General Framework
Christel Pesme (Senior Conservator, M+)

Reciprocity Issues in MFT: Are Exposure Effects Independent of Time or Light Intensity?
Julio M. del Hoyo-Meléndez (Head, Laboratory of Analysis and Non-destructive Investigation of Heritage Objects, National Museum of Krakow)

Microfade Testing: Its Use and Benefits among Canadian Heritage Institutions
Season Tse (Senior Conservation Scientist, Canadian Conservation Institute [retired October 2018])

The MoMA Microfader: Design and Applications
Chris McGlinchey (Senior Conservation Scientist, Museum of Modern Art)

Automated Portable MFT: To Measure Colour or Spectral Change?
Haida Liang (Professor, Nottingham Trent University)

Instrument Demonstration

Whitmore MFT
Vicki Lu (Applications Engineer, Newport Corporation)

MFT with Retroreflective Head
Automated MFT
Jacob Thomas (Assistant Professor, University of Gothenburg)

MFT with Contact Head
Mark Benson (Assistant Conservator, Getty Research Institute)

The Getty Conservation Institute