

Pursuing the Fugitive: Direct Measurement of Light Sensitivity with Micro-Fading Tests

Paul M. Whitmore

An essential element in the preservation of art objects is the protection of colors from damage due to light exposure. However, it has been extremely difficult to identify which objects have fugitive colors until fading has actually occurred, and uncertainty about fading risks has made it difficult to establish reasonable exhibition policies tailored to the needs of specific objects. Analysis of the material composition of an artifact is difficult, laborious, and often insufficient to define the details (such as pigment particle size or fading history) that can critically influence light stability. Alternatively, color monitoring programs (tracking the color changes in objects by color measurements repeated at intervals) can in principle detect very slight fading and provide warning of light sensitivity, but these efforts are also tedious, and the risk of fading damage depends on the precision and frequency of the measurements. There is a clear need for an alternative method that can rapidly assess the durability of an object's colors during exposure to light.

In response to this need, we have developed a new device – a micro-fading tester – that can perform accelerated light-aging tests rapidly and non-destructively on tiny areas of an art object. Details of the construction and performance of this instrument have been published, and the schematic design of the instrument is reproduced from that paper and shown in Figure 5.3.¹ In its essential function, this instrument is a reflectance spectrophotometer, capable of rapidly measuring the visible reflectance spectrum of very small (0.4 mm diameter) areas of an opaque colored material. The key feature of this device that allows it to serve as a fading tester is the high light intensity used for the probe beam of the reflectance measurement (about 7 million lux of visible light, provided by the focussed output of a filtered 75-watt xenon arc lamp). At these intensities, fugitive colors (Blue Wool scale #1 or #2) will fade measurably (CIE $L^*a^*b^*$ $\Delta E = 3-5$) within 5 minutes of exposure. Rapid spectral measurements and computation of color parameters and color differences are made possible by a photodiode array spectrophotometer controlled by a personal computer. During the test, the spectrum and color difference are updated every second, so that a “real-time” view of the course and extent of fading are provided. Thus, the fading test can be concluded after small but definite color changes have been produced, and before any perceptible change has occurred to the object. In our initial evaluation of this device, we studied the sensitivity of the measurements and precision of the fading test results. Those results (detailed in the above-mentioned paper) indicated that the instrument was capable of detecting very small color changes (about 0.1 ΔE unit), and the reproducibility of the test results on uniformly colored materials was very good.

Accuracy of test results

In evaluating the accuracy of the micro-fading test results, two questions are considered: 1) how the micro-

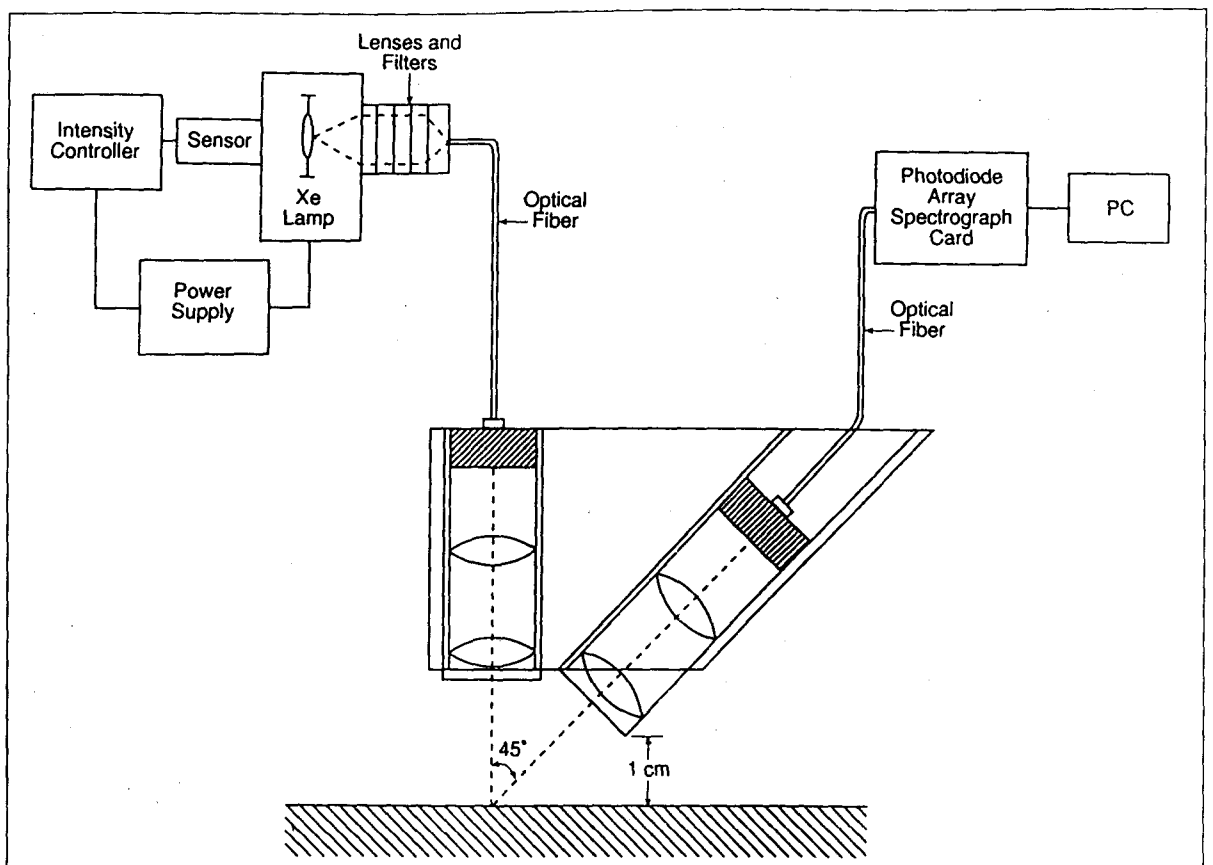


Figure 5.3 Schematic of micro-fading tester, from Whitmore et al. 1999. Reprinted with the permission of the American Institute for Conservation of Historical and Artistic Works, Washington, D.C.

fading tests compare to the conventional accelerated light-aging tests; and 2) how the results of the accelerated tests compare to actual fading upon exposure to ambient lighting in gallery settings. We have found that the accuracy of the color measurements themselves varied depending on the type of sample: smooth, opaque, uniformly colored materials were measured well (compared to a commercial reflectance spectrophotometer), but samples that did not conform to this ideal (e.g., textiles and unevenly colored or transparent samples) were only approximately described by the color measurements in the micro-fading tester. Despite these difficulties, the results produced in the micro-fading tests (the light-fastness ratings and color changes produced in the test samples) were generally in good agreement with the conventional destructive method for evaluating light-fastness (exposure to high-intensity light followed by measurement in a color-measuring instrument).

The accuracy of the micro-fading tests in predicting the future course of fading in gallery settings is less well established. To date we have very few comparisons of accelerated (in the micro-fading tester) and natural fading of materials, and that is a subject of current research. However, it is important to recognize that the accuracy of the prediction – or to put it another way, the validity of the accelerated aging test – is not an intrinsic feature of the test itself. Rather, it is a description of the performance of particular materials and objects in the

test, and generalizations to describe the “validity” of the test are unlikely to be possible. There are many factors that must be considered in attempting to simulate gallery fading conditions in an accelerated fading test, and there are ways to critically examine the test results to get a better sense of their accuracy. A thorough discussion of these factors is beyond the scope of this report, but it is the subject of current study.

Safety evaluation

In assessing the safety of the micro-fading tester when using it on works of art, we examined two risks posed by the test conditions: the risk of creating a faded test area that would disfigure the object, and the risk of heat damage from exposure to the very high light intensities. Tests of the perceptibility of the faded test area indicate that the areas are imperceptibly altered until a color change of $\Delta E = 15\text{--}20$ has been produced. This difference is much larger than the color changes usually accepted as being barely perceptible (usually on the order of $\Delta E = 1\text{--}2$). Since we have already verified the accuracy of the color measurements, we believe that the difficulty in perceiving small color differences lies in the extremely small size of the test area: at these size scales (approximately the size of the period at the end of this sentence), much larger color changes are needed to produce a spot that the eye can pick out as having faded. Consequently, if the micro-fading tests are monitored so

that they are terminated when a $\Delta E = 5$ has been produced (a change large enough to be considered definite), the risk of this area being perceptibly faded is extremely small.

We have measured the heat generated at the surface of materials during exposure in the micro-fading tester. The worst-case heating occurs for very dark materials that absorb nearly all of the incident light. In those cases, temperatures of 45–50°C were measured, both directly (by thermocouple) and indirectly (by apparent melting damage to waxes having specified melting points). Thus, the risk of heat damage is considered small for the majority of art materials, although objects created with low-melting materials such as wax media may suffer melting damage in the small test areas. Even for those materials that may melt, however, the damage is not immediate and the fading test may yet yield important information about the material's light sensitivity before melting occurs. Just as for other analyses in which sample removal leaves a tiny defect on an object, that damage may still be judged acceptable in exchange for the knowledge that will help preserve the object.

We have also examined whether the test areas alter over time after the completion of the test, either by further fading that accentuates the faded color of the test area or through post-irradiation discoloration. In our laboratory tests, we have never been able to produce a significant post-irradiation color change on a tested material, even for those such as lignin-containing papers where such effects are well known. We believe that the photochemical changes produced in the test area are so small, particularly if the color changes are kept below $\Delta E = 5$, that the areas are unlikely to evolve as a significantly different color from the surrounding areas. This monitoring of the tested areas on artifacts is a continuing effort, but to date we have not seen any indication that the test areas age differently enough from the original to produce a perceptible spot.

Results of field tests

More recently we have been evaluating the performance of the micro-fading tester when measuring a variety of artifact types, including easel paintings and works on paper, textiles, sculpture and ethnographic objects, and photographic materials. In general, as noted above, the micro-fading tester functions well when measuring materials that are smooth, rigid, and opaque. Measurements on artifacts having textured or irregular surfaces, such as textiles, have occasionally proven to be difficult, particularly when the artifact is so delicate that it cannot be held securely in a fixed position. With one exception, no object that has been tested in these museum visits has been damaged from the testing. The one object that was disfigured was a re-creation of an early photographic process, and this object's light sensitivity was so great that the color was completely bleached in the test area while the tester was being positioned, before the fading test had even begun.

Clearly there are limits to the types of objects that will survive the test in its current configuration, and the testing of such ultra-sensitive objects would require a drastic reduction in light intensity before being considered safe. Fortunately such cases of extreme light sensitivity are likely to be recognized before a micro-fading test is attempted, and the possibility of accidental discovery of instability is unlikely.

As expected, in its current design the micro-fading tester is incapable of reliable measurements on transparent materials such as stained glass, dyed plastics, or even thick paint glazes – materials whose color is observed (and must be measured) in transmission rather than in reflection. The adaptation of this device to operate in transmission mode (monitoring loss of color from transmission measurements while being probed with high intensity light) is straightforward and the subject of current research.

Research possibilities

The main objective of the field trials was to demonstrate the utility, simplicity, and safety of this technology in assessing the preservation needs of individual objects. An additional benefit of these site visits was the stimulating discussion with colleagues who envisioned other possible applications for the device. One such interesting possibility was the prospect of accumulating evidence on the actual fading behavior of classes or types of objects, and thus putting to the test some vague but persistent "intuitions" about light stability, such as whether fading occurs steadily over time, or whether previously faded objects will tend to be more stable by having already lost the most fugitive components. During our field trials, both behaviors were observed. In some cases where faded and relatively unfaded areas of the same colorants could be tested (or in one case, where we had duplicate prints, one of which had been exhibited and faded while the other had been in storage), the faded colors tested to be just as fugitive as the unfaded. On other objects, where the fading had clearly removed most if not all of a very fugitive colorant, the object tested to be quite resistant to further fading. With such object-specific information, it might eventually be possible to construct a better, information-based "intuition" of the average behavior of groups of objects.

Another interesting idea offered during a site visit was the proposed use of the micro-fading tester as an analytical tool, essentially to discriminate between closely related materials (such as organic colorants) on the basis of their fading rates and the colors to which they tend to fade. While a considerable amount of testing would be needed to build up a database of fading behaviors, the possibility of a rapid, non-destructive analytical tool that may be free of interferences from other components in the colorant system (such as the medium) is an intriguing possibility.

Based on our use of the micro-fading tester in our laboratory and in several museums over the last few

years, we remain optimistic about the promise of this technology to assess the light stability of specific artifacts. The device has proven safe and capable of fulfilling its original purpose, to detect extremely light-sensitive materials on objects before they are unwittingly subjected to inappropriate exhibition conditions. Other uses for this device – in predicting the results of particular exhibition conditions, or as an analytical tool – are intriguing future possibilities. We are continuing the development of the micro-fading tester to improve its performance and to explore some of these applications.

Endnote

1. P. M. Whitmore, X. Pan, and C. Bailie 1999. "Predicting the fading of objects: Identification of fugitive colorants through direct non-destructive lightfastness measurements," *Journal of the American Institute for Conservation* 38, no. 3, pp. 395–409.