

## STUDY OF THE VARIOUS PIGMENTS CHROMATIC STABILITY AFTER CONTROLLED LASER IRRADIATION PROCESS

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### ABSTRACT

As a large number of studies reported, one of the most important problems in restoration of polychrome art objects by laser cleaning techniques is color alteration.

A complex study of the object which must be cleaned, including a serious analysis of the preliminary restorations (repainting, chromatic integration etc.), a well known history of the object and especially of the original materials and of the materials used for restoration at those stages are obligatory steps in object's examination. The chemical compositions of the pigments from different periods and from different schools of restoration are various and their individual behavior is not the same from chromatic aspects after the laser irradiation. This work is based on the chromatic analysis of some sorts of pigments with similar chrome before irradiation and analyzes the possibility to use laser cleaning methods on polychromatic surfaces of different art objects.

**KEYWORDS:** chromatic stability, laser, pigments

### 1. INTRODUCTION

It is a known fact that paints and pigments have an important place in cultural heritage preservation and conservation. Presently, little is known about the effects of laser radiation upon polychromic layers. The absorption properties of polychrome materials are likely to be different from those of the underlying substrates (paper, parchment, textile, wood, metal etc.), implying a high precision rate in order to avoid any damaging or discoloring phenomena.

The term *color* is used with different meanings in different technologies. To lamp engineers, color refers to a property of light sources. To graphics art engineers, color is a property of an object's surface (under a given illumination). In each case, color must be physically measured in order to record it and reproduce the same color.

The perception of color is a psychophysical phenomenon, and the measurement of color must be defined in such a way that the results correlate accurately with what the visual sensation of color is to a normal human observer.

*Colorimetry* is the science and technology used to quantify and describe physically the

human color perception. The basis for colorimetry was established by CIE (Commission Internationale de l'Eclairage) in 1931 based on visual experiments. Even though limitations are well recognized, the CIE system of colorimetry remains the only internationally agreed metric for color measurement. All the official color-related international standards and specifications use the CIE System.

### 2. CIE SYSTEM OF COLORIMETRY

By the early 19th century, it became known that there were three types of cones in the eyes to sense colors. It was also known that two light stimuli having different spectra could produce the same color (*metamerism*). It was inferred that each cone had spectral sensitivities corresponding to R (red), G (green), B (blue) (*Trichromatic Theory*, Young, 1800's) or sensitivities corresponding to opponent colors, W/Bk, R/G, and Y/B (*Opponent Theory*, Hering, late 1800's). The spectral sensitivities of the cones were yet to be known at that time, but a color could be matched by combination of three primaries, which could be used to specify color (Maxwell, 1860's).

The three attributes of color are hue, chroma (saturation) and lightness; they are expressed in a three dimensional space. In the chromaticity diagrams as mentioned above, lightness is missing, and the hue and chroma are laid out very nonlinearly. To allow accurate specification of object colors and color differences, CIE recommended three dimensional uniform color spaces – CIELAB and CIELUV in 1976.

These are called the *CIE 1976 (L\*a\*b\*) color space* or *CIELAB color space*, and the other, *CIE 1976 (L\*u\*v\*) color space* or *CIELUV color space*, and have similar structures as the Munsell color solid. In imaging applications, CIELAB space is commonly used. In CIELAB space,  $L^*$  shows the lightness, and  $(a^*, b^*)$  the color as shown in figure 1. The coordinate  $(L^*, a^*, b^*)$  is calculated from the  $(X, Y, Z)$  of the given light stimulus and  $(X_n, Y_n, Z_n)$  of the white point. Therefore, the CIELAB space has a function of correcting for chromatic adaptation to the white point, and is intended for object color and displays.

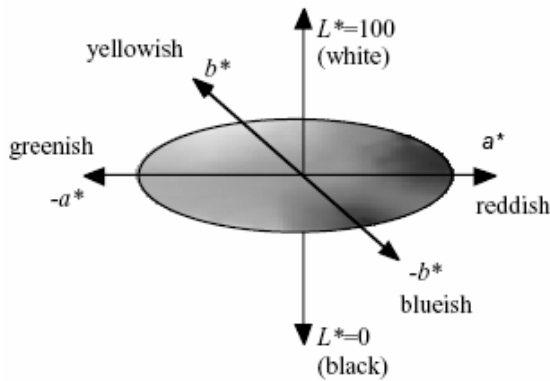


Figure 1 CIELAB Color Space

The color difference in the CIELAB space is calculated as the Euclidean distance between the points in this three-dimensional space, and is given by:

$$\Delta E_{ab}^* = \left[ (\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2} \quad (1)$$

This equation is called the *CIE 1976 (L\*a\*b\*) color difference formula*. The chroma  $C_{ab}^*$  and the hue angle  $h_{ab}$  are also calculated from  $(L^*, a^*, b^*)$  by:

$$C_{ab}^* = (a^{*2} + b^{*2})^{1/2} \quad (2)$$

$$h_{ab} = \tan^{-1} (b^*/a^*) \quad (3)$$

The CIELUV space is defined in a similar manner, and the coordinate  $(L^*, u^*, v^*)$  is calculated from the  $Y$  and  $(u', v')$  of the given light stimulus and the white point.

Light is a flux of photons (little bundle of energy who oscillate with frequency  $(\nu)$ )

Light result from sensation produced by electromagnetic waves in a spectral field, contents 400nm – 800nm, so-called *visible spectrum*.

To each wavelength is corresponding a perceptive sensation, which is perceptible at level of cerebral cortex, so-called *color*. Colors could be obtained by decomposition of white light that cross in a prism.

The parameters that determine a color are:

*The dominated wavelength*: is wavelength of monochromatic radiation which gives by comparison, the pure color near accounting color.

*Luminosity* of colors: characterize intensity of luminous radiation from one source, in a give direction, on unit of area perpendicular in that direction.

*Factor of purity*: express dilution of a pure light with white light.

The laws of mixing colors are:

*Law of continuance*: at continuous variation of radiations, color varies continual.

*Law of additivity*: color of two radiations depends only of color of radiation that composes them and don't depend of their spectral composition.

*Three-dimensionality*: either four colors are linear dependents, but exist three colors linear dependents that can be used for make a new real color.

Equation in RGB system:

$$c'C = r'R + g'G + b'B; \quad R, G, B - \text{amount}$$

unity of light:

$$c' = r' + g' + b'; \quad \text{all amount of light;}$$

$$C = rR + gG + bB, \quad \text{where:}$$

$$r = r' / (r' + g' + b'); \quad \text{coefficients}$$

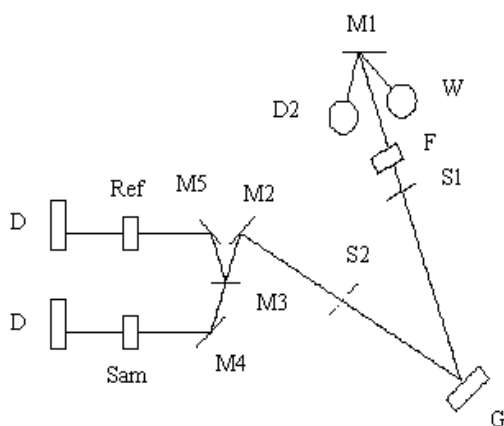
$$g = g' / (r' + g' + b'); \quad \text{trichromic}$$

$$b = b' / (r' + g' + b'); \quad \text{unity;}$$

In conclusion we can say:  $r + g + b = 1$

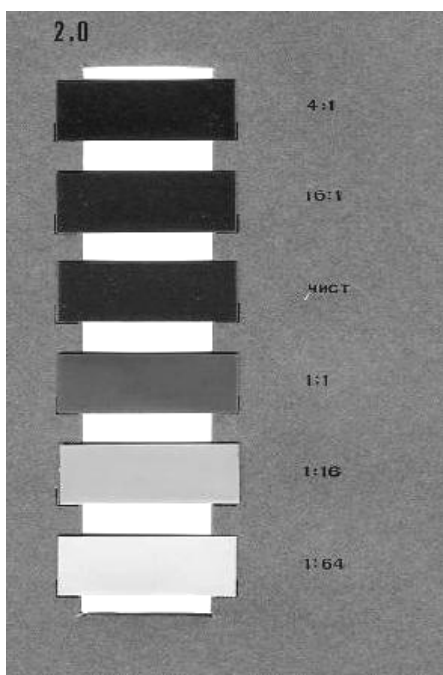
### 3. EXPERIMENTS

Spectrophotometer used for experiments is an instrument for spectral reflection curve measurement and show measured values graphic and numerical.



**Figure 2 Spectrophotometer Optical System**

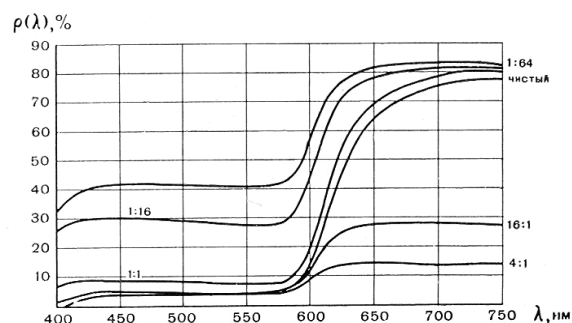
Light sources of spectrophotometer are: deuterium lamp for UV domain (190 nm – 350 nm) and tungsten lamp for visible domain



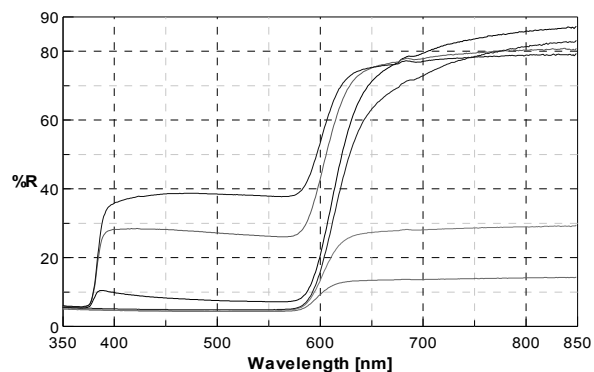
**Figure 3 . Cadmium purple as was presented in the atlas**

(350 nm – 900 nm). It can be used for reflectance, absorbance and transmittance measurements. Curve tracing can be: slow, medium, fast. Scanning speed is 8000 nm/min. The detector is a photomultiplier tube. Optical system (Figure 2) contain five mirrors (M), two slits (S), one filter (F), one sample compartment ( Sam ), one blank test compartment (Ref), deuterium lamp (D2), tungsten lamp (W) and detectors (D).

This spectrophotometer was used to recalibrate the samples from a colorimetric atlas the samples were measured with the new UV-VIS spectrophotometer from JASCO and new reflectance graphs were recorded and compared with the old ones.



**Figure 4 The original reflectance curves**



**Figure 5 The new reflectance curves.**

UV VIS spectrophotometer as a reliable tool for color characterization measurements were recorded on UV irradiated paint samples in order to identify color changes and to establish if UV irradiation is or is not harmful to art objects

As a conclusion it was established that reflectance spectra comparison is a useful method to identify color alteration during light – art object interaction. Following this aspect a new method was developed to future improve laser matter interaction monitoring.



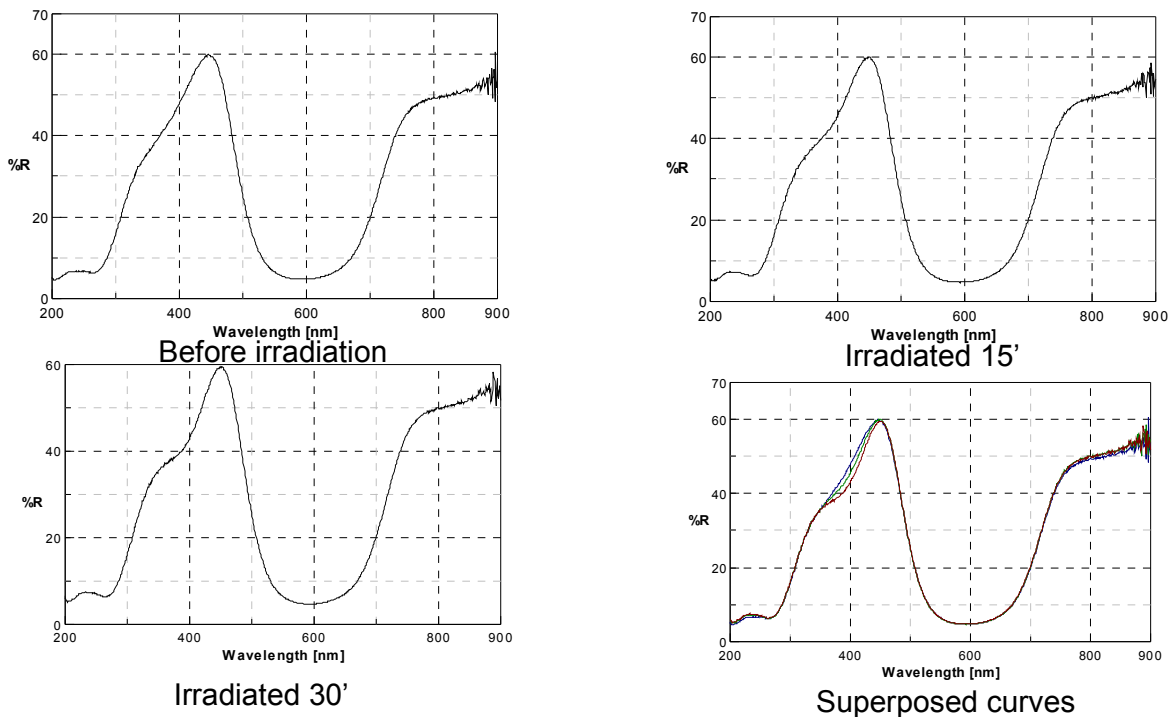
Before irradiation

After 15' irradiation

After 30' irradiation

Blue ultramarine

**Figure 6 Paint sample with three regions of irradiation exposure**



**Figure 7 Reflectance spectra of the blue paint shown above.**

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