ART MUSEUM OF ESTONIA

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CHANGING CONTEXTS: FROM ENVIRONMENT TO IDEAS

Examples of the use of UV-electromagnetic radiation to study selected paintings at the Art Museum of Estonia

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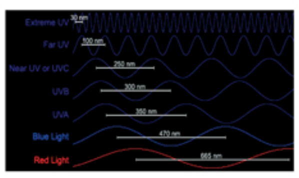
Ultraviolet radiation (hereafter UV) is defined as electromagnetic waves (380–10 nm; 7.9 × 1014–3 × 1016 Hz[1]) which are shorter than the light seen by humans (400–700 nm) and longer than X-rays. In the early 20th century, UV examinations, which were based on fluorescence, became one of the important methods for the qualitative examination of polychromatic surfaces in paintings. Painting materials absorb and reflect electromagnetic waves differently depending on their chemical composition, and fluorescence develops as a result of excitation. This is a subtype of luminescence.

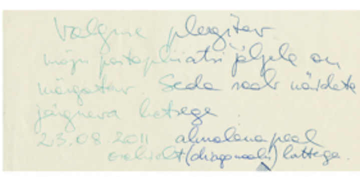
The goal of using UV in the analysis and interpretation of a work of art is to examine the colour layer and final coat (traditional varnish) on the surface, which reveals the traces of the repairs that have been made to the work[2]. The information obtained by fluorescing the additions made after the work's painting layer was completed that are acquired by non-destructive UV examination can be documented by photographic procedures and determined based on a comparison of the painting techniques, as well as the researcher's experience, reference standards and counterparts. The condition of the painting, its components, the thickness of the layers, the time when and extent to which the materials were used all result in different shades of fluorescence. The specific colouring and intensity of the fluorescence reveals the traces of the component layers (repairs, retouching and overpainting)[3].

We are familiar with several uses of UV rays. For instance, UV-A and UV-B cause tanning in solaria. On the other hand, UV-C has a bactericidal and disinfecting effect and primarily impacts single-cell organisms: viruses, bacteria, fungi and other unicellular organisms[4]. Today, a specific interval of UV wavelengths (200–315 nm) is used to disinfect storage environments; a good example is how this is employed at the Art Museum of Estonia (hereafter AME)[5].

It is generally known that certain UV wavelengths (A260–280 nm) are harmful to the sensitive tissue of humans. UV can irritate the eyes or skin of the researcher and radiation can also damage DNA. To protect the eyes, special glasses as well as protective screens, lab coats and gloves need to be worn[6].



Ill 1. UV wavelengths



Ill 3. The fading of ballpoint pen writing; the difference in the durability of the covered vs. uncovered sections of the paper and text is noteworthy

It is not known when UV rays were first mentioned. As early as the 13th century, the Indian philosopher Madhvacharya wrote in his book *Anuvyakhyanaś* that there were violet rays in the atmosphere above Bhootakasha which could not be seen with the naked eye[7]. In 1801, the Englishmen J. W. Ritter and W. H. Wollaston noticed a blue UV area in sunlight alongside violet light. Later, the Cambridge physicist Sir G. G. Stokes supplemented the discoveries in the field of luminescence. The applied approach and methodology in the art field were developed in the early 20th century[8]. At the British Museum, visible UV fluorescence was introduced in art research in 1903[9]. In the 1920s and 1930s, new tools supplemented non-destructive diagnostics. In 1929 in Vienna, R. Maurer patented the examination of the colour layers on paintings and objects using "dark ultraviolet light"[10]. The first analytical results achieved with an incandescent argon lamp (known as a "black light" or Nico lamp), and thereafter with a mercury lamp, were published in 1931 by J. Rorimer,[11] and in 1933 by J. A. Radley and J. Grant[12] at the Metropolitan Museum of Art, respectively. UV examination methods were implemented at the AME in the 1970s and they are still used today[13].

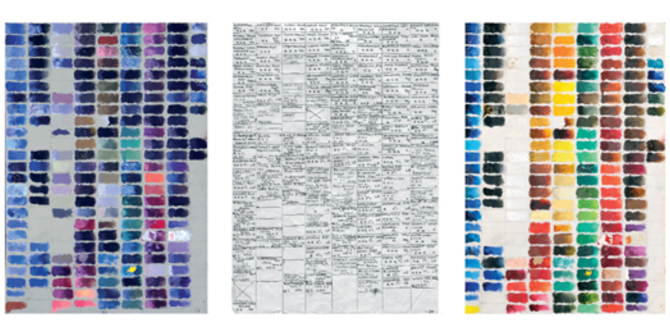
Just as for living organisms, the long-term and continual use of UV radiation also has a destructive effect on works of art. It reflects certain colours and damages materials (e.g. paper and canvas fibres) which art works are comprised of[14]. The examples provided below show the traces of fading on watercolours that have been exposed to daylight for years in a living room, some of which are quite conspicuous (see Ill 2. Karl Burman. *View of Tallinn*. Watercolour on paper. Private collection).

Ill 2. Karl Burman. *View of Tallinn*. Under dispersed light; detail under dispersed light and UV.

The next example is the author's experiment with a ballpoint pen on paper that continued for three years (August 2011 to August 2014), and which suffered similar damage (see Ill 3. The author's experiment with traces of fading).

The above confirms the perceived risks and limited application of UV as a research method. The author has continued to research specialised literature to find examples of critical analysis related to the damage caused to works of art by UV examinations.

In addition to the aforementioned examples, we can also mention biological damage: pockets of mould that fluoresce (see Ills 4 and 5). Under UV, we can see the clear traces, location and frequency of the mould, which is an especially complicated preservation issue related to pastels (Ill 4. Ants Laikmaa. *Abyssinian Woman*. Pastel on paper. Estonian Art Museum, M 3232 and Wauters. *Portrait of a Lady*. Pastel on paper, VM 492). Along with pink, purple and yellow chalk pastel fluorescence, pockets of mould fluoresce as spots and stains, as if they were retaining pieces of colour. On the *Portrait of a Lady*, pockets of mould have formed as an unexpected aggregate in areas where specific colours were used.



Ill 7. Alar Nurkse's oil paint samples under dispersed light, under UV, the list of colours that were used

Ill 4. Ants Laikmaa. Abyssinian Woman. Under ordinary light and UV; detail in the same

Ill 5. E. Wauters. *Portrait of a Lady*. Under dispersed light; UV, details

Ill 6. *Monkey with a Cat* after a test cleaning under dispersed light; under UV before the removal of the varnish coat and overpainting; in the left column, third from the top, dammar varnish, in the middle column, the two lowest, shellac; the conserved and cleaned painting

Ill 8. Johann Köler. *Italian Woman*. Under dispersed light; detail under UV, in which the yellow and red fluorescence is clearly differentiated

Ill 10. *Christ Driving the Money Changers from the Temple*. Overall view in dispersed light, UV and UVR

Ill 11. Passion Altar; UVR detail

Ill 12. Konrad Mägi. *Field of Flowers*. Under ordinary light; under UV

Since the absorbance of UV varies based on the painting materials, the fluorescence also differs. We see the same thing on old and new colour materials, retouching and overpainting. Yet the aged retouching is not only visible under UV[15].

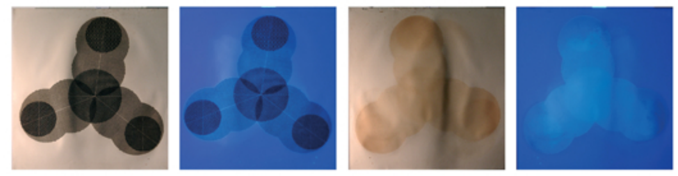
UV helps to differentiate and identify varnishes. Fresh varnish is darker. Oil varnishes, based on their age, can vary from a pale milky blue to a bright milky finish[16]. The fluorescences of various varnishes are intensive in colour; for example, older mastics and dammar varnish are yellowish-green, and shellac is a distinctive orange-brown, as in the painting *Monkey with a Cat* (see Ill 6. Ma52 AF16, unknown artist, *Monkey with a Cat*, 17th c., oil on wood, The Netherlands).

Old albumen or oil binding agents fluoresce in a white or yellowish glow; the interim layer of collagen glue fluoresces actively, or very weakly, depending on the origin of the material and the time it was put into use. Wax is whitish[17]. The older the dried oil, the more intensive the fluorescence usually is [18].

An examination using UV can provide additional information to help identify the paint colour pigments, but only some of them have a clearly discernible fluorescence [19].

The luminosity of a fresh coat of paint is different than one that is varnished or covered with a cultural layer, or a surface that has been changed by ageing. In watercolours, the colours have a clear fluorescence, because there is no surface coat or "mass" disturbing the "cultural layer" (see Ill 8. J. Köler, *Italian Woman*, watercolour on paper, private collection). UV is absorbed strongly by many paints and, depending on the length of time the work is on exhibit or exposed to daylight, splotches and changes in colour will develop. This applies to both organic (krapplack, indigo, Indian yellow etc.) and inorganic paint, of which some are nigrescent[20] (vt Ills 2, 8). The UV fluorescence of lead white is greyish, that of zinc white is yellowish, and that of krapplack is velvety black. The luminosity of paper, as a material, especially now, depends on its composition and the damage to it (see Ill 9. Raul Meel. *Typostructure. Morning Star I*. Paper, printing, G 30057).

The paint additives used by manufacturers, the age of the paint and the painting mixtures affect the fluorescence of oil paints. Several colour pigments can be differentiated (see Ill 9), for example cadmium paints, Indian yellow and natural organic madder, which is bright red[21]. Cadmium red fluoresces as bright red[22]. Of the uniform whites, lead white can range from an extremely bright white to a yellowish brown under UV. This colour (Ill 7, in the third column from the left with white colours, third from the top) has been part of the artist's palette for centuries, starting in antiquity; in the 20th century, few manufacturers produced lead white and it was used by few artists. Under UV, the paint is greyish. Zinc white (Ill 7, 2nd and 13th from the top) has been used since 1780 and has been produced industrially since 1850. Under UV, the paint can vary from a bright yellow to a faded yellowish green[23]. Titanium white (Ill 7, 1st and 14th from the top) has been used since 1916, and under UV the paint can range from violet to brownish violet.[24]. This explains why the results of non-destructive fluorescence often need to be clarified by chemical analysis.



Ill 9. Raul Meel *Morning Star* I, front and back; under UV, there is a fluorescent blotch of unknown origin in an unexpected place in the middle of the front and back, the shape of which does not conform to the print; several splashes of printing mixture also fluoresce

The UV examinations are documented by photography and the observations are recorded in colour and black-and-white. Firstly, the examination, similarly to forensic science, can provide hints about the modern synthetic ingredients or additives that are contained in the painting materials. Secondly, the materials used in the painting are outlined. By the excitation of photons, a distinct fluorescence develops in the luminescence, which is characteristic of only certain substances[25]. In reaction to UV, some absorb and some fluoresce; both reactions enable a non-destructive comparison to be made with the standards of substance composition. Thirdly, UV reflectography (cf. IR reflectography[26]) deserves a separate discussion, because this method is often confused with the UV fluorescence visible in the painting. The examination of the surface layer with UV reflectography (hereafter UVR) is based on the phenomena of reflection and absorption when recorded with a UV filter[27]. Under filtered UV that is not impacted by visible light, we see an unusual recording, which is illustrated by the following examples (see Ill 10. VM661/M3148, *Christ Driving the Money Changers from the Temple*, overall view; UV; UVR; Ill 11. M5172 *Passion Altar* 16th c., oil, wood, detail).

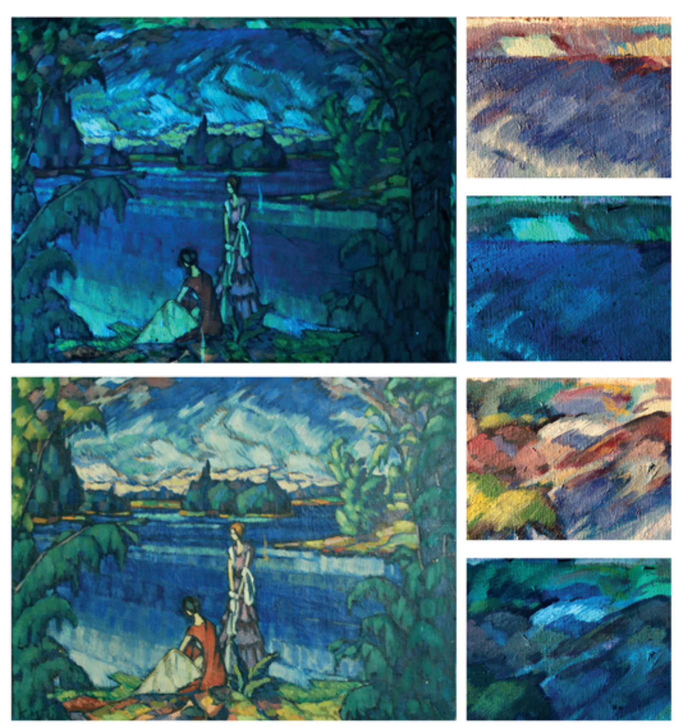
Based on **UV examinations** and analysis of cross-sections of *Christ Driving the Money Changers from the Temple*, we can state that the sky, with colour repairs, and the four domestic animals, which have been totally painted over, are covered with overpainting. The darkened yellowish brown surface varnish is comprised of several layers and within the layers there are dirt and paint repairs. Under UV, the surface acquires an intense greenish-blue fluorescence, evidence of the last time that dammar varnish was used, and the uneven thickness of the mass of the final coat indicates that the painting was restored several times during various eras (Ill 10b). The later retouching can be clearly discerned in the form of dark splotches, while the extensive prior overpainting is barely visible under the coat of varnish.

The UVR examination (Ill 10c) reveals splotches located in the uneven tonality of the mass of varnish, and traces of a multi-layered flow of unknown origins leading to the varnish mass covering the feet, as well as dirt, and various overpainting in the thick layer. Some of these have been executed deliberately and professionally in order to hide damage, but others have been executed by broadly painting over the damaged area.

Under **UVR,** the old thick coat of varnish is very dark, almost black. Unevenness and even traces of the brush strokes from applying the varnish are visible. Various surface defects (signs of friction, scratches etc.), as well as blotches of surface dirt can be discerned (see Ill 11b). The painting is partially covered with another coat of varnish, which was revealed by the examination. The toning between the layers, unlike the dark varnish, is distinguished as light splotches.

A UV examination can also provide an analysis of the various stages of contemporary art creation. While in the rest of Europe Pablo Picasso's paintings have been thoroughly examined[28], in Estonia a vivid example would be Konrad Mägi's work (e.g. Ill 12. M4141, Konrad Mägi, *Field of Flowers,* and Ill 13. *Lake Pühajärv Motif with Figures*, private collection). In the former, various material traits are clearly expressed, for example the pinkish-purple with an actively strong fluorescence, colour-changing red, the black-green colour, green, yellow etc. The fluorescence is characteristic of works completed in a specific period. In the second painting, two landscapes were painted, and the edges of the bottom layer, which was painted over, show traces of the use of different materials, which are visible when fluoresced. These traits enable the different completion times of the paintings to be identified.

For centuries, communicating with works of art has relied on the credibility of visual contact. A work, the composition of the substances used to complete it, and the traces of the changes that have occurred – the ageing, decay and repair of the material, etc. – could be discerned with good lighting, visibility and tools. The latter also includes ultraviolet electromagnetic radiation. The UV examination method plays an important role in looking into a work of art and choosing suitable conservation techniques.



Ill 13. Konrad Mägi. *Lake Pühajärv Motif with Figures*. Under ordinary light; under UV, same with details