Film Laboratory Manuals as Sources for the Reconstruction of Colour in Silent Film Restoration.

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ABSTRACT

Documentation is a fundamental phase of the film restoration process, essential for collecting information that supports decisions taken throughout the workflow. Sources may vary depending on the specific restoration project and can include film elements or film related materials such as photographs, posters, press clippings, ephemera, music scores, screenplays, censorship or copyright documents, technical documentations, archival and bibliographical references. Among these, film laboratory manuals represent one of the sources especially for technical information. In particular, this contribution focuses on the use of laboratory manuals as a reference for colour restoration of silent films.

Chemical formulas contained in manuals can provide critical information for the conservation, reconstruction, and restoration of historical colour processes. As with other sources, laboratory manuals must be cross-referenced with the other documentation collected for the project to ensure their reliability. A particularly effective approach involves comparing colour formulas with the results of scientific analyses conducted on film materials.

Understanding the nature of colour through scientific analysis is useful from both conservation and restoration perspective: identifying the composition and degradation of colourants contributes to make a better long-term conservation plan and allows a more accurate characterisation and reconstruction of original film colours. Moreover, comparing analytical data with historical formulas provides information for the development of a reference database to support future restoration projects.

As a case study, this contribution presents the recent collaborative research by the Cineteca Nazionale and the Chemistry Department of the University of Milan, introduced at the XIX Colour Conference 2024. The research applied spectroscopic analyses to the most common silent-era colouring techniques (pochoir, tinting, and toning) and compared the results with corresponding formulas published in laboratory manuals of the time.

KEYWORDS tinting; toning; pochoir; film restoration, colour restoration, spectroscopy.

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1. Introduction

The film restoration process is a complex operation that requires extensive documentation involving various sources from the analysis of available film elements to the study of film related materials all selected according to the most appropriate workflow. Similarly, the sources of information for the colour restoration varied on case-by-case basis.

Silent films were coloured using various techniques, the most common were pochoir tinting and toning, which we discuss in detail in Section 2.1 of this contribution. In the specific case of reconstructing of silent film colours, a primary source could be other film materials, such as positive prints. However, it is rare from this period of film history find two positive copies of the same version and print generation.

Film materials include also negatives that in some case contain indications for colouring positive prints. An example is in figure 1, a frame from an anonymous film shoot around 1915 and sent to the Ambrosio Film laboratory in Turin for the development of the negative and the printing of a positive. From the word “arancio” written in the first frame at the beginning of the scene, we assume that the positive was meant to be tinted in orange.

Fig. 1. Negative frame (author’s private collection).

This indication is not enough: the colour could have been changed later during the workflow and even if it had been orange we cannot determine the exact shade.

Film related sources could include books as laboratory manuals, photos, posters and press clippings, ephemera, music sheets or screenplays with indication of the colour for each scene, film reviews, administrative documents with instruction for film laboratories and working samples or copyright books. The last two are particularly interesting because usually contain samples directly from a positive coloured print. Working samples are cardboard album with frames applied as visual trace for editing, insert intertitles and as reference for colours [1]. Similarly, copyright books, as the example in figure 2, are detailed description of a film with a frame for every scene usually from a coloured positive print [2].

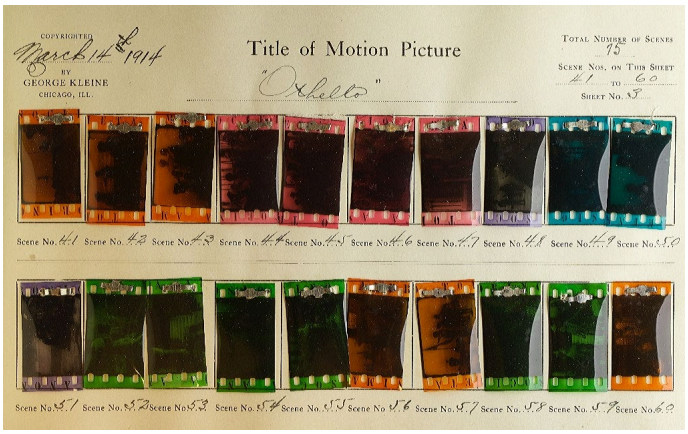

Fig. 2. A page from a copyright book (Timeline of Historical Film Color and Library of Congress).

In recent years, alongside these traditional sources, scientific analyses, especially spectroscopic techniques, have become more common for the characterisation of film bases, emulsions, and colourants.

These are just some examples, documentation sources vary depending on the subject of the restoration and must have compared each other for mutual confirmation and for supporting restoration decisions.

Laboratory manuals can be one of the sources for colour reconstruction. However, as for other documentation, the formulas they contain must be cross-referenced. One of the most interesting comparisons is between manual formula and the results of scientific analysis of colours.

Following, a brief description of the main colouring techniques and of four representative laboratory manuals in use in the silent era. In Section 3, an overview of scientific studies on film colours followed, in section 4, by a case study from a research project of the Cineteca Nazionale in collaboration with University of Milan presented at the XIX Colour Conference (Rossetto et al., 2024).

2. Laboratory Practice and Manuals

A film laboratory is a technical facility for the film industry where specialists develop, print, and conform materials for productions and distributions. Film laboratories develop camera negatives, make negative and positive intermediates and at the end of the process print positive copies. Since the early days, the processing steps for the many different types of film are similar in principle, though there are variations in specific solutions and treatments.

Laboratory manuals from 1900 to 1929 contain all the information on film processing and colouring techniques are one of the topics covered. Often, in addition to the description of the process, there are also formulas for

preparing dye baths, indications of temperatures, duration of the immersion and sometimes also samples of the results.

Manuals are indeed a useful source of information for film colours, but they gave general indications, and all the labs could modify the original formulas according to specific requests. For this reason, while they can be a good reference for colour restoration, formulas must be confirmed by other sources.

2.1 *Historical Techniques for Silent Film Colouring*

In the silent era, films were coloured using a variety of processes, many experimental, some never actually applied, and others used just for few films. For an in-depth study of all these techniques, including samples and literature, the main reference is the online database *Timeline of Historical Film Color*, created in 2012 by Barbara Flueckiger and her collaborators (Flueckiger, 2012 ff.), alongside the recently launched *Film Atlas* (Layton, 2025 ff). Despite this vast variety of experimentation, pochoir, tinting and toning were the most common techniques because they were simple to achieve and could be standardised to fit in the workflow of film laboratories.

The first technique, in chronological order, is pochoir or stencil colour (an example in the frame in figure 3) obtained by colouring defined areas of the images frame by frame. Initially, frames were coloured by hand, a method that directly descend from photographic retouching and magic lantern slide painting. Colours were applied manually by hundreds of women [3] using stencil then, to speed up the process, by machines with a continuous velvet band saturated with colour dye.

Fig. 3. Pochoir colours (Brian Pritchard website).

Despite this improvement the pochoir process remain too slow and expensive, whereas the other two techniques, tinting and toning, were more successful and lasted longer. Tinting, in figure 4, is obtained by immersing the positive print into dye baths (the composition and proportions of which changed according with the colour) and homogeneously attaches over the entire film including the perforation area, darker parts remain black.

Fig. 4. Blue tinting (Brian Pritchard website).

There were also pre tinted positive film stocks commercialised in the 1920s by, among others, Kodak, Agfa and Pathé. The base of the positive film was not transparent but coloured, and the result was similar to tinting method, although this kind of colourisation was marginal.

Toning is a process obtained by immersing a positive print into a dye bath (that, also in this case, change according with the colour) where a chemical reaction replaces the neutral silver image with one consisting of coloured metal compounds. In toning, as shown in figure 5, the film base remains transparent, and the image is coloured.

Fig. 5. Copper toning (Brian Pritchard website).

Pochoir, tinting and toning were all applied on positive prints. These three techniques could be combined.

2.2 *Manuals*

Laboratory manuals chosen as examples for this contribution come from different geographical areas and were printed in different years, to provide an overview of the types of publications available during the silent era. All these manuals collect recipes from earlier sources and fixed practices already in use in film laboratories.

2.2.1. *Guida pratica alla cinematografia (1916)*

The first manual in chronological order is Vittorio Mariani's Guida pratica alla cinematografia (Mariani, 1916). The section thirteen is dedicated to film colourisation formulas

for tinting and toning considered part of broader process. Indeed, Mariani takes a comprehensive view of film production and covering almost all the activities connected to the film industry of the time from the construction of a studio and shooting to laboratory treatments and projection. When the film industry grew all these activities were separated in specific branches (as they still are today) but at the beginning of film history they were often integrate in one facility. Mariani also write about pochoir which he discourages from adopting, considering it a long and expensive process not necessary for a modern film laboratory. Mariani refers to the practices in French and Italian labs, with many references to the production chain of Cines, company founded in Rome in 1906 (the manual is dedicated to Alberto Fassini, the studio director) and to Lux film lab, active in Paris from 1906 to 1913.

The following three manuals are different from the Mariani's as they are from the tree main film manufacturers of the time: Kodak, Agfa and Pathé and specifically think for their products.

2.2.2. *Tinting and toning of Eastman Positive Motion Picture Film (1918)*

The first edition of *Tinting and Toning of Eastman Positive Motion Picture Film* was published in the United States in 1918 (Kodak, 1918) and, with subsequent re-edition, until 1927. This manual is specifically designated to colour for Kodak films. In the preface of the second edition, issued the same years as the first, the anonymous author writes that a revision was necessary due to the difficulty of obtaining foreign dyes for film as indicated in the previous version of the manual. Thanks to tests of the National Aniline & Chemical Company of New York the author can now recommended American products that are equal in every aspect to the one obtained abroad. The manual also provides a section of samples with frames from tinting and toning positive prints (figure 6).

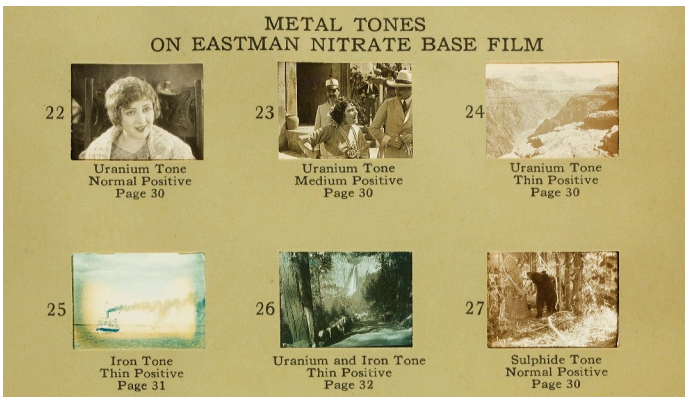

Fig. 6. Cardboard from Tinting and Toning of Eastman Positive Motion Picture Film (Timeline of Historical Film Color).

2.2.2. *The Agfa Kine Handbuch*

Agfa Kine Handbuch, published in Germany in 1925 (Agfa, 1925), is the main reference for Agfa's film products. It is worth underline that AGFA (an acronym for Aktiengesellschaft für Anilinfabrikation) was founded in 1867 as a manufacturer of aniline-based dyes and stains, which were also the base of colourants used for photography and film. In 1903, Agfa began producing its first cinematographic film, and by 1925 had become one of the main film production facilities in Europe. The Kine Handbuch contains, an extensive section dedicated to film colours that include, as the Kodak manual, a substantial collection of frames on cardboard as samples for showing tinting and toning and their combined effects. In figure 7, one of the cardboards with example of tinting frames with the correspondent colour formula.

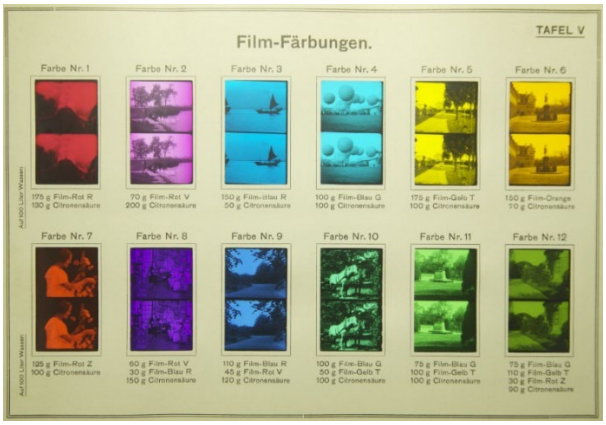

Fig. 7. Cardboard from Agfa Kine Handbuch (Timeline of Historical Film Color).

A detail of the yellow / orange tinting sample (in the figure 7 indicated as farbe nr. 6) is reproduced also in figure 12.

2.2.3 *Le film vierge Pathé. Manuel de développement et de tirage*

Le film vierge Pathé. Manuel de développement et de tirage (Pathé, 1926) illustrates all the laboratory work carried by Pathé at Vincennes with detailed description of procedures for developing, printing and colouring film. The colouring process is described in the section ten dedicated to the development of positive prints. This section covers all the techniques, particularly tinting and toning and is focused on Pathé products as dye baths or pre tinted films. The manual contains formulas, but process isn't described in deep. For this reason, Jessie Martin (Martin, 2013) in his study on colour in silent cinema from the point of views of film manufacturers, writes that this publication seems more geared towards promoting Pathé products than providing useful information for professional. *Le film vierge Pathé* also present samples from positive prints on cardboard (figure 8) similar to those in Kodak and Agfa manuals.

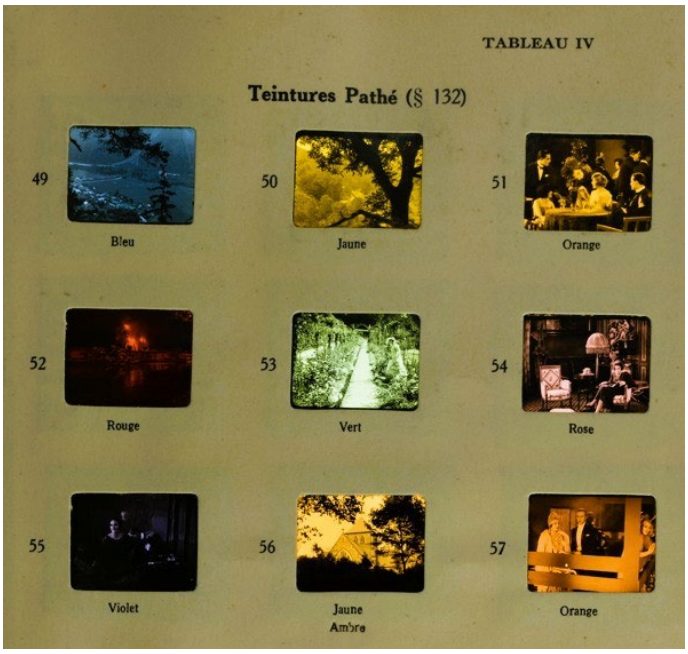

Fig. 8. Cardboard from Le film vierge Pathé (Timeline of Historical Film Color).

3. Scientific studies applied to film preservation and restoration

The different activities related to film conservation, preservation, and restoration have developed in relative isolation and have only recently been connected to the broader field of cultural heritage conservation practices. Paolo Cherchi Usai write that the main reason of this isolation and lack of scientific studies is due to the short history of the medium and to the "idea of moving image carriers represents an 'art of reproduction' and therefore do not possess the 'uniqueness' required to warrant the conservation treatment given to other artifacts" (Cherchi Usai, 2010).

For this reason, non-invasive and micro-invasive analysis, common practices in the cultural heritage field have been very rare in film conservation and have only recently been adopted. According to Cherchi Usai the change occurred with the transition to digital technology in film preservation and restoration, when analogue film materials acquired the status of unique objects previously denied to them.

As result of this change in perspective the interest in scientific studies applied to films materials increase. Examples include research from the IPI (Image Permanence Institute of the Rochester Institute of Technology) or from the Berlin University of Applied Sciences (HTW Berlin) [4] and the growing use of spectroscopic analysis among film archives as part of documentation for film preservation and restorations. Recently, the working group "Preservation/Restoration Documentation" of the Fiaf (Fédération Internationale des Archives du Film) included a dedicated section for "spectroscopical analysis" in its guideline for documenting film restoration process [5]. The addition of this session shows the improvement of this practice in the film archive community for identify film bases, reconstruct colours and assessing deterioration levels.

In parallel the specific field of colour analysis has been increased. The mentioned website Timeline of Historical Film Color (Flueckiger, 2012 ff.) is also a valuable resource for both old and new research and case studies on colour analysis. For example, the website feature results of the recent research project of the University of Zurich and HTW that microscopically investigated in transmission and cross-sections film material from Koshofer Collection [6]. Another example is the study of the Pathé metal and mordant toning in the films of the Turconi collection carried by Ulrich Ruedel using the x-ray fluorescence (Ruedel, 2017).

Colour analysis is an essential tool both for conservation and restoration of films. From the long-term conservation perspective, understanding the nature of the components of a colour and how they decay is important for creating a better long-term preservation plan. From the perspective of the film restoration (whether photochemical, digital or hybrid), it is relevant for a more precise characterization and reconstruction of colours. For example, the frame below (figure 8) is an unknown Ambrosio film, with a faded yellow tinting and traces of another colour on the side. In this case we have an isolated fragment, and we don't have a colour reference in other scenes, so we don't know the shade of the original yellow (light yellow, orange / yellow, acid green / yellow etc) and if the red in the side is a trace of the colour from another scene or another kind of pigment.

Fig. 9. Yellow tinting frame (author's private collection).

In other cases, the colour is not visible or only few traces remain as in the frame in figure 9 from the Pathé film *La naissance de Vénus* (1897 – 1899 ca): the shell was hand coloured, and some traces are still present, but we don't know if it was a yellow or an orange and if there were other colours no longer visible.

Fig. 10. Frame from La naissance de Vénus (AIRSC film collection).

In digital preservation and restoration, the use of scientific analysis is essential for setting rigorous digitization strategies and for interpreting the signal of colours registered by film scanners. An example for scientific analysis applied to the digitization workflow is the mention research on the Koshofer Collection (Trumpy et al., 2021). The MIPS Lab, in the Department of Informatics at the University of Milan, has been conducting research in this field for several years. One particularly interesting study focused on the digital restoration of degraded colours, using a prefilter based on a fading model derived from the analysis of deteriorated film colours (Rizzi et al., 2008). Recently, the hyperspectral imaging technique has been used for acquiring, restoring, and preserving the colours of damaged positive films. This technique was applied to *Ivan Turbincă*, a film produced by the Romanian studio Animafilm in the 1980s, (Nobili et al., 2025) and it shows potential for application to silent film colours as well.

4. Manual formulas and spectroscopical analysis: The Case of the Yellow Tinting of an unknown French silent film

An example of research that compare colour recipes contained in laboratory manuals with the results of non-invasive and micro-invasive methods is the one presented at the Color Conference in 2024 by the Cineteca Nazionale and University of Milan (Rossetto et al, 2024). The aim of the research is to understand the real components of colours and compared them with the original formulas. All the information collected in the research will serve as a guide for characterizing colour, understanding colour deterioration, and establishing better conservation and restoration strategies.

The frames selected for this research are five, all from French and Italian films to have a precise comparison with the colour formulas contained in two manuals used in these areas: Vittorio Mariani *Guida pratica alla cinematografia* and *Le film vierge Pathé. Manuel de développement et de tirage*. An additional reference is the *Agfa Kine-Handbuch* to highlight similarity in formulas for the same colours. All these manuals are previously described in section 2.2.

The colours of the five frames (pochoir, tinting and toning) were analysed by different spectroscopic techniques with non-invasive and in some cases micro-invasive methods.

Raman spectroscopy was applied in micro mode and with low incident power to preserve the highly flammable cellulose nitrate film support. Raman is a non-invasive analysis based the inelastic scattering of radiation by the sample molecules and associated with molecular vibrations. For this reason, Raman is a technique allows to univocally recognize the analysed compound. The micro-Raman spectra were acquired using a Jasco TRS 300 triple monochromator spectrometer, equipped with an Andor CCD detector and interfaced with an Olympus BH-2 microscope. A Cobolt Twist TM 25 laser with emission at 457 nm (blue) was used as excitation source. The spectral region 800-1800 cm-1 was considered.

To overcome the fluorescent emission that could hide the signals in the final spectrum (one of the major limitations in Raman), surface-enhanced Raman spectroscopy (SERS) was also used. SERS is a micro-invasive technique, in which the signal is amplified by the interaction between the analyte molecules and a nanostructured metal substrate. If a selected excitation wavelength that corresponds to the absorption band of the sample is used, a further amplification is observed due to the resonance effect. In this case a colloidal suspension of silver nanoparticles was used, prepared according to the Lee and Meisel procedure (Lee et al., 1982-86). The analysis was conducted using a micro-Raman probe equipped with a notch filter and an Olympus 50X objective, connected to Lot-Oriel MS 125 spectrometer. The probe is also connected to a laser source with emission at 532 nm (green).

To perform the analysis, a micro-sample was taken from the perforation area by scratching the film with a scalpel and the powder was placed on a glass slide with a drop of the solution containing the colloid and an aggregating agent (sodium perchlorate).

The absorption spectra in the UV-visible spectral region of the five frames were acquired as well. It is a non-invasive technique useful for the study of compounds that impart colour thanks to the presence of chromophore groups in the molecular structure. The analysis was conducted in transmission mode using a Jasco V-570 benchtop spectrometer with an acquisition range from 350nm to 800 nm. Unlike the Raman spectrum, the absorption spectrum has broad bands and therefore is not specific for a given compound, but allows for some important considerations,

such as the use of mixtures rather than pure compounds in the colour formulation. Finally, to study the colour of the blue-toned film, Fourier transform infrared (FT-IR) Spectroscopy in specular reflection was used using a compact Alpha spectrometer from Bruker. The measurement was carried out on an area of approximately 6 mm in diameter on the emulsion side of the frame.

Following, an example of the methodology applied on a specific sample: a yellow tinting frame from an anonymous French film.

Fig. 11. Yellow tinting frame (author's private collection).

The frame is print on an unknown film stock, datable post 1909 due the presence of the KS (Kodak Standard) perforations introduced from that year. The photographic sign of perforation from previous film materials indicate that is not a first generation print but a following copy. The colour of the frame is a yellow tinting.

For this frame, the use of an orange dye was at first hypothesized from the Uvvisible spectrum despite the yellowish colour of the film. In fact, its absorption maximum is located at about 480 nm, while the yellow dyes normally used for tinting absorb at slightly lower wavelengths (AAT Bioquest, Inc., 2024). The concrete assumptions about the nature of the dye used for the tinting were possible through the SERS technique which made it necessary to take a powder sample in the low perforation area. The obtained SERS spectrum shows clear analogies in the trend and intensity of the signals with a SERS spectrum of the Orange G dye (Acid Orange 10), a synthetic mono-azo dye attested for use in tinting formulations in several manuals. For example, Gregory in Motion Picture Photography (Gregory,1927) registers a list of standard dyes which have been chosen as fulfilling the tinting conditions as nearly as possible and the Orange G is one of them for the "Cine Orange" tint. The use of this dye is also attested in the Agfa manual (Agfa, 1925

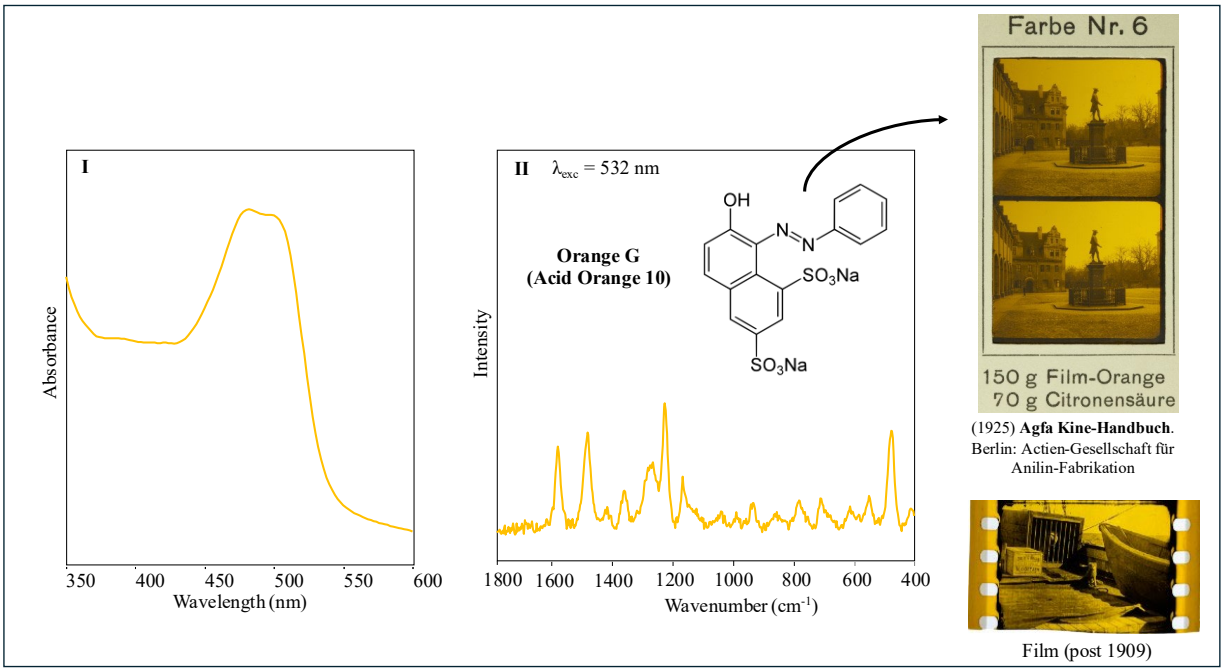

Fig. 12. UV-visible (I) and SERS spectrum (II) with identification of the dye in the sample with a yellow tinting (conference proceeding Silent Film Colourisation Process: From Recipes to Film Laboratories).

5. Conclusions

In the case study of the Cineteca Nazionale and University of Milan, the application of non-invasive and/or micro-invasive analytical methods to the study of the colour of silent films has been useful to obtain some important information. First, for most of the samples, these methods have enabled us to uniquely identify the dyes used in the tinting formulations, finding a direct correspondence with the historic manuals available in the literature. In cases where the dye has not been identified, because of the impossibility of taking a sample or due to the overlapping of tinting and pochoir, these techniques still allowed the

identification of the chemical family to which the dye belongs. Micro-invasive methods confirmed some hypotheses based on the results obtained by non-invasive ones, validating their effectiveness as well.

As previously wrote, the study and the identification of synthetic dyes used during the silent era is fundamental for film conservation and restoration. Moreover, in the context of the ongoing debate around both photochemical and digital restoration of audiovisual heritage, the results of these analyses could be an important starting point for creating a database of technical data available for restorers aiding in the reconstruction of original colours.

Some databases collecting technical and sensitometric data on films are available, particularly for sound films. Examples include the FIAF Madrid Project, based on technical sheets and labels from manufacturers, and the similar Photo Fire2 [7]. The next step could be to match the collected documentation with scientific analyses of the same film materials.

Spectroscopic data can provide the colorimetric coordinates, essential for digital restoration. Furthermore, due to the frequent lack of clear references in the literature, analyses of this kind help clarify the types of dyes used in historical film laboratory process enriching the documentation collected for a restoration project.

These results demonstrate how scientific analysis can serve as a valuable resource in preparing a film restoration project, corroborating, and confirming formula in laboratory manuals as well as film related sources, archival and bibliographical documentations.

6. Conflict of interest declaration

The author declares no conflict of interest.

7. Funding source declaration

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9. Biography of the author

Valentina Rossetto - Film historian and archivist specializing in film preservation and restoration. She works as film archivist at the Cineteca Nazionale in Rome and as adjunct professor of Film Restoration in the MA program at ICPAL, the Italian Central Institute for the Restoration and Conservation of Archival and Library Heritage. Since 2024, she has been collaborating with the Department of Historical Studies at the University of Turin.

Notes

[1] Working samples from Itala Film laboratory were presented by Stella Dagna at the 2020 Domitor Conference available at: https://domitor2020.org/en-ca/the-working-samples-function-and-accidental-beauty-from-italian-silent-cinemas-manufacturing-machine/

[2] Examples preserved at the Library of Congress, as the one reproduced in figure 2, and available on Timeline of Historical Film Colour website.

[3] During the silent era, women were in charge of hand colouring film in all labs. They entered the film industry from photographic studios where they retouch photos, and before from magic lantern slides or miniature paintings. The reasons for this preference are not clear and exist several hypotheses. One is that women are more precise than man in these activities, while another is that their works was cheaper, which was an important factor for an activity that requires long hours of labour. For an overview, with a focus on the case of Cines in Rome, see Pierotti Federico, Colorare le figure. Il lavoro femminile sulla pellicola (Bianco e Nero, n. 570, maggio – agosto 2011, pp 111-118).

[4] In 2017, during Il cinema ritrovato film festival, Ulrich Ruedel, professor at the HTW Berlin held a workshop for the Fiaf Technical commission titled “Analyzing Color Processes with Scientific Tools: Multicolor / Ufacolor / Sirius Color” in which he discussed the approaches employing methods of using these classical conservation and restoration disciplines (as X-ray Fluorescence, spectroscopy and classical visual microscopy) in the moving image field.

[5] The Preservation/Restoration Documentation Task Force of Fiaf was borne inside the Cataloguing and Documentation Commission with the addition of support members from the Technical Commission. For more information on the project, result and future development: https://github.com/FIAF/preservation-restoration-events/

[6] Images are available on Timeline of Historical Film Colour website https://filmcolors.org/filter/?_sft_ubercategory=htw&post_types=gallery

[7] Fiaf Madrid Project https://www.fiafnet.org/pages/Divers/The-Madrid-Project-Intro-en.html and Photo Fire2 https://mips.di.unimi.it/photofire/

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