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Shroud-like coloration of linen by ultraviolet radiation

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Introduction

In 1984, two organizers of the STuRP (Shroud of Turin Research Project), Jackson and Jumper, along with Ercoline published a paper entitled "Correlation of image intensity on the Turin Shroud with the 3-D structure of a human body shape" [1]. In this long paper (26 pages!) that I consider one of the most important works published by STuRP members, the authors describe in meticulous detail the creation of a gallery of images on linen fabrics using all the techniques potentially able to create a Shroud-like image. Note that this paper was published four years before the radiocarbon dating of the Shroud, and the authors, unaware that the cloth was woven in the Middle Ages, tested all the possible techniques, ancient and modern, not only those potentially available to the alleged medieval forger.
A list of techniques tested in this article include:

- Direct contact (a statue and a person coloured by inks, or chemicals, or powders, then draped by a linen cloth);
- Thermal colouration (bas reliefs heated in a furnace and placed in contact on both dry and wet linen);
- Visible light (faces covered with phosphorescent paints imaged on contoured sheets of a photographic film);
- Electrostatic field;
- Vapourgraphy (ammonia vapours on plaster face diffused on linen);
- Artists (professional artists, certified forensic with documented experience in realistic monotone imagery shade a Shroud-like face on linen, first free hand, then with anchor points);
- Hybrid mechanisms (different combinations of two or more techniques among those mentioned).

Jackson, Jumper and Ercoline compared the results of the above attempts with the macroscopic and microscopic features of the Shroud image, and argued that none of techniques tested can simultaneously reproduce its main features, from the 3-D property to the coloration depth, to the resolution of the spatial details. The conclusion was that the image on the Shroud of Turin is not the result of the work of an artist or forger.

Thoughts decant a few years, until 1990 when Jackson writes a paper entitled “Is the image on the Shroud due to a process heretofore unknown to modern science?” [2]. In this paper, Jackson notes the failure of all the hypotheses, both "naturalistic" and "fraudulent" (i.e., by an hypothetical forger) on the formation of the image on the Shroud. However, the image is there, observable and measurable, then it must have been produced somehow. According to Jackson, when known scientific phenomena and paradigm are not able to explain and create a Shroud-like image, we must look for a physical phenomenon *ad hoc*, not yet known to science. Jackson suggests the far ultraviolet radiation as a "physical" method suitable to obtain a Shroud-like coloration on linen. In fact, the fabric of the Shroud has undergone a process of selective aging. The cellulose of flax fibres, due to oxidation and other chemical processes that occur over centuries, undergo a change at

the molecular level that turns them yellow, as it happens for the cellulose pages of ancient books. In the case of the Shroud, the aging process is more evident in the fibres which constitute the image, so that these are more yellowish than fibres outside the image. Although the cause of this selective aging of the image fibres is unknown, Jackson thought the radiation in the far ultraviolet could reproduce the same effect, including the gradient of the image, due to the absorption of radiation by the air, which is proportional to the distance between the body and Shroud. Obviously, the hypothesis of the radiation moves the attention on what and how produced the radiation, and Jackson states that it would be a unique phenomenon, never observed so far, and possibly outside our knowledge.

The paper by Jackson provoked critical reactions from other STuRP members for several reasons, including the apparent abdication of Science in front of an "image impossible" to be replicated and the potential implications of a "miracle" about a hypothetical flash of radiation emitted from the body wrapped in the Shroud. In addition, in 1990 intense radiation sources in the far ultraviolet were not available and it was difficult to prove whether such radiation was able to generate a Shroud-like coloration. Some experiments with laser irradiation of linens in the near ultraviolet gave negative results, indeed [3].

In the early 2000s the Excimer Laboratory at the Research Centre ENEA Frascati had laser sources emitting radiation pulses in both near ultraviolet and far ultraviolet, so there was the possibility to test if the hypothesis of Jackson was viable, or if his opponents were right when stating that it was impossible colouring linen fabrics by ultraviolet radiation. Our results showed that Jackson was right. The radiation in the far ultraviolet is able to create a Shroud-like coloration on linen fabrics. Jackson was right as well considering this ‘radiative hypothesis’ outside current paradigm and known scientific phenomena, because we measured the amount of radiation energy and the ultra-short duration of laser pulses required to achieve a Shroud-like linen coloration, and these parameters cannot be generated by any natural phenomenon known to date.

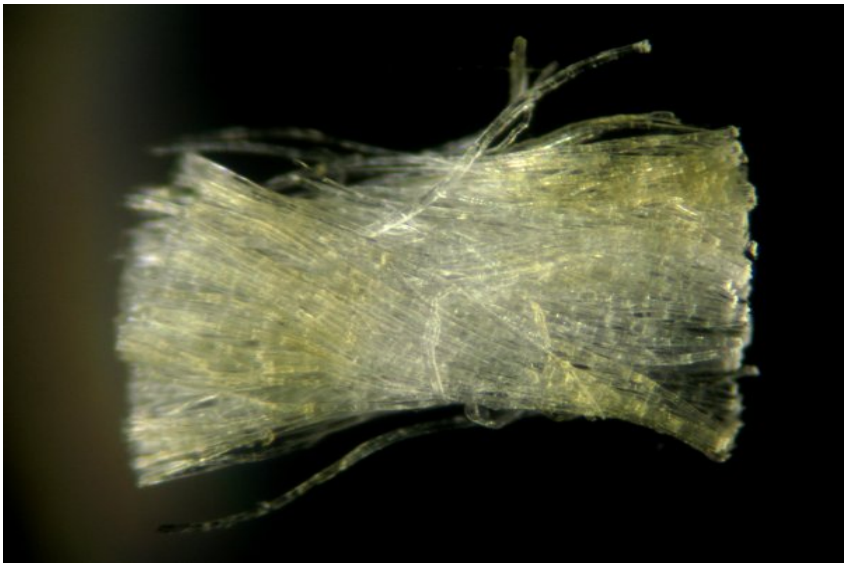
Let me point out that our effort has been focused on the complex photochemical phenomena in the linen cellulose that produce the coloration after irradiation. We never addressed the issue, that goes beyond our scientific expertise, on how it is possible generating these specific radiation pulses at the time of the formation of the Shroud image. We have dealt with only about a topic that is within our expertise, namely the understanding of the photochemistry processes able to generate a peculiar linen coloration that has many features in common with the image on the Shroud. The implications of our findings are left to scholars competent in theology, metaphysics and philosophy.

How and why ultraviolet radiation generates a Shroud-like coloration of linen?

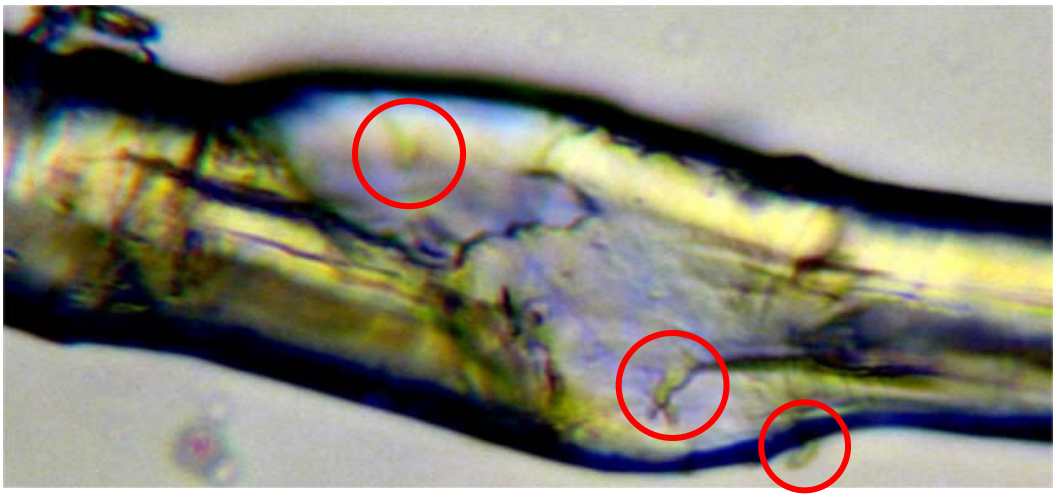
A laser system is a device that emits collimated bursts of radiation, a form of ***energy that propagates at distance from the source***. Just now, our Laboratory has thirty-five years experience of irradiation of various materials by ultraviolet radiation. The effect of these irradiations is always limited to the surface of the material, whether it be a metal, a plastic, a semiconductor or a fabric. In fact, the energy of the ultraviolet radiation impinging on an object is absorbed in the most superficial molecular layers, and then this energy changes the molecular structure ***only at the surface*** of the object. Ultraviolet pulses break the molecular bonds ***without heating*** the irradiated sample. Then, ultraviolet radiation and far ultraviolet radiation are a good candidate to obtain three characteristics of the coloration of the shroud image, namely the superficiality, the low-temperature of the process and the capability to colour areas by a contactless process.

Since 2005, our laboratory has carried out a large number of irradiations of ultraviolet radiation on linen fabrics woven in the years between 1930 and 1950 that were never used, never washed with detergent, in order to avoid the presence of chemicals which may alter the optical properties of the tissue. “Irradiation” means sending laser pulses on the linen, which alter the chemical bonds of the linen cellulose itself, which in turn changes its surface properties and appearance. After many irradiations and with great difficulty we found the combination of laser parameters (pulse duration, intensity, energy density and number of shots)

that allows a Shroud-like linen coloration . We got a hue of colour, a coloration limited to the crown of threads, coloured next to not coloured fibres, the reduced fluorescence, the negativity of the image, and other properties that are similar to those measured on the Shroud of Turin images by STuRP. The following photos show some images illustrative of the results obtained. More details and other meaningful images can be found in references [4, 5, 6].



Linen warp thread after irradiation in the far ultraviolet. In the middle we see an area not coloured because it was covered by a weft thread. The individual yellow fibres are also visible.



High-magnification microscope view of a single fibre that was mechanically damaged in the middle after irradiation in the far ultraviolet. The inside of the fibril is not coloured, while the outer sheath (called primary cell wall) became yellowish due to far-ultraviolet irradiation. The circles indicate yellow shreds of primary cell wall, whose thickness is one fifth of a thousandth of a millimetre, This means we obtained a colour superficiality similar to that of the Shroud image. The diameter of the fibre is 20 thousandth of a millimetre.

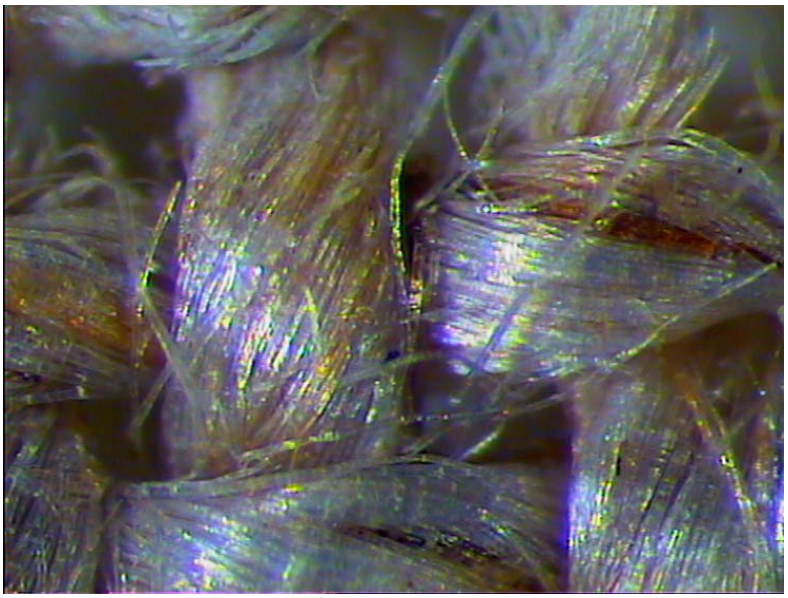


Photo under the microscope of the linen fabric after laser irradiation. We see coloured fibres are adjacent to fibres not coloured, similar to the alternation of coloured and non-coloured fibres observed on the Shroud image.

Image of the logo of the Shroud Exhibition in 2010 obtained by laser scanning on linen. The low-contrast image is yellowish and it is almost invisible when viewed in the sunlight (left). In the middle, its visibility improved when observed in shadow. On the right, the negative of the same image is clearly visible, being a pseudo positive, as it is the Shroud image.

Based on our decades of experience of irradiations and interaction of radiation with many materials, this is the first time we have found a so narrow range of values to get the desired effect. In fact, during the irradiation of the linen fabric is sufficient to vary a few percent only one of the laser parameters mentioned above to not get any linen coloration. Amazing.

Reducing to practice

Obtaining a linen coloration by ultraviolet laser radiation that reproduces many of the microscopic complexities of the Shroud image is a fascinating result, suggestive about the hypothesis of image formation,

but cannot lead to definitive conclusions, as noted by some scholars. In principle, I agree with this observation. However, there are some consequences and implications of our results that deserve to be highlighted and commented. A first implication is having measured the precise amount of ultraviolet radiation capable of generating an accelerated aging of the fibres of the linen threads, especially if the radiation is associated with the presence of oxygen in the air. Based on these data we were able to study the risk associated to the direct and indirect exposition of the Shroud to ionising radiation, which has consequences on the boundary conditions for a proper long term conservation of the Shroud. The results of this study are summarized in reference [7]. The comparison of our proposals with the technical characteristics of the reliquary where the Shroud is currently preserved, suggests that the present conservation conditions are optimal, although we recommend a prudential measure more, which consists of a systematic control of the amount of gas Radon in the neighbourhood of the reliquary.

A second important consequence of our results is that the modern linen fabrics coloured and aged with ultraviolet laser irradiations (that is, a linen colouration having a sub micrometer depth, the alternation of fibrils coloured and not coloured, the "right" hue and contrast) can be used as a test to prove the non-invasiveness of both chemical reagents and physical technologies potentially suitable to study the Shroud. In fact, after the application of the reagent or of the spectroscopic technique, if the microscope observation of linens coloured by laser shows a change of the coloured fibrils, it means that the technique is invasive and must not be used on the Shroud. Vice versa, if the microscopic observation post-treatment reveals no changes, the technique is non-invasive and could be used on the Shroud.

We recently used our linen fabrics coloured by laser to check whether three equipment (the ENEA LIF system for measuring laser-induced fluorescence, the topological radar patented by ENEA and the system Avantes for measuring the absolute reflectance) are not invasive. After the test, we checked the linen fabric under the microscope and found the three systems have left intact our sub-micrometer linen coloration, so we were authorized to use them in the optical and non invasive study of the shroud of Arquata, a precious copy of the Shroud which dates back to 1653. The shroud of Arquata is interesting because it contains a double human image that was not made by pigments or dyes, or by scorching. These three technologies, complementary and synergic each other, allowed to establish the methods used to achieve these images and the other stains, as detailed in reference [8]. All without damaging the cloth and the stains on it.

Other studies

In addition to the experiments of Shroud-like linen coloration by laser irradiation, we faced the problem of the many invisible images that some scholars are able to highlight after a digital processing of the contrast and brightness of the photographs of the Shroud. Our results suggest that in some cases (e.g., the alleged letters, the alleged face on the back) they are illusory perceptions, possibly related to the psychological phenomena of Gestalt and pareidolia, which are well known to scholars of human perception and optical illusions [9]. Sometimes, our eye-brain system perceives what we expect or wish to see based on our experience. These mechanisms are "automatic", in that they are especially rapid, non-conscious, mandatory and capacity-free. In other words, usually we are not aware when pareidolia deceives our perception.

Our results have been presented in detail in several articles published in international scientific journals of great impact factor, and therefore they are available to all scientists and scholars interested in checking/reproducing our results and maybe obtaining better ones. In the website of our Laboratory you may find the web page http://www.frascati.enea.it/fis/lac/excimer/sindone/sindone.html that collects all our experimental results, papers, publications, interviews and movies of Shroud-related studies in ENEA.

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