# Terahertz Imaging of hidden paint layers on canvas

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***Abstract*—We present terahertz reflection images of hidden paint layers in a painting on canvas. We compare these with results obtained using X-ray Radiography and near-infrared imaging. Contrary to other techniques, we show that terahertz imaging is capable of providing information on the thickness of the hidden paint layers. We also present early results on reflection measurement of different colored paints applied on a thick copper plate.**

## I. Introduction and Background

Art historians have discovered that many artists have, for example, recycled a canvas or panel and painted a new composition on top of an older one.[1] For many years, different techniques have been applied to study underdrawings or modifications to original paintings. Conventional imaging techniques, like X-ray radiography (XRR) and infrared imaging are used to study paintings and their substructure. These techniques, however, are unable to give any information on the thickness of the sub-layers. In addition, X-ray radiography cannot be used to study layers with high-density pigments, such as lead white paint. This last point is critical, since lead white was commonly used in old master paintings.

Recently, terahertz time-domain spectroscopy (THz-TDS) was used to study drawings and paint layers embedded in wall paintings.[2] Here, we show how similar techniques can be used to image the substructure of paintings on canvas, by monitoring the time delay between reflections of different layers on a home-made painting.

## II. Results From Paintings on Canvas

The test sample is a pre-ground canvas of 4x4cm$^2$. On Fig. 1(b), one can see the six strokes of raw umber with various thicknesses that were applied. The canvas is then covered with lead white paint making the raw umber patches completely invisible to the naked eye. Each layer (canvas, raw umber, lead white paint) may have a different index of refraction, thus giving rise to a possible reflection at each interface.

Fig. 2(b) - (c) shows the THz electric field as a function of time, along two lines indicated in Fig. 2(a). The sign and strength of the field is indicated by the color, as shown by the scale. This type of plot immediately allows us to observe the arrival times of the reflected THz pulses along a line.

In Fig. 2(b), where we plot the field along a line where two patches of raw umber are present, two separate lines are visible, indicated by the vertical arrows. The left line corresponds to the reflection at the canvas/ground layer-raw umber interface, the right from the interface between the raw umber and the lead white paint. These lines merge in a single broader line at the location between the two patches. In contrast, in Fig. 2(c), where there is no raw umber patch, a single, fairly broad positive electric field peak is observed everywhere along the line. This indicates that the presence of the two peaks is related to presenence of the raw umber and the corresponding additional interfaces.

By monitoring the peaks of the reflected THz pulses, we can deduce the presence of the interfaces. The time separation between these peaks gives an indication of the thickness of the paint layers.

In Fig. 3(a) we present the difference in arrival time between the reflections from the canvas/raw umber interface and the raw-umber/lead white interface for different positions on the canvas.

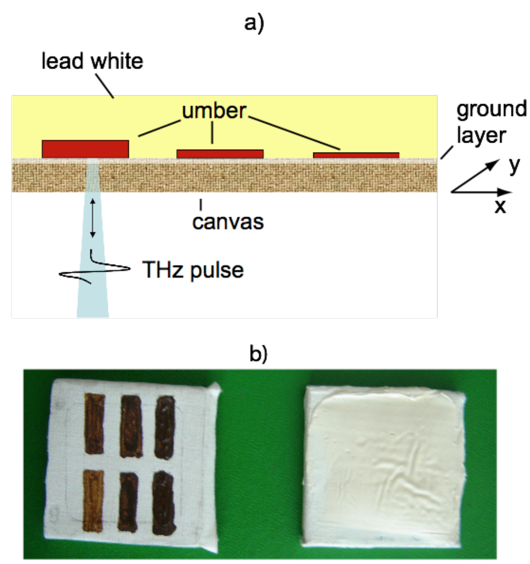


Fig 1. (a) Detail of the experimental setup to observe hidden paint layers in paintings on canvas. THz pulses are focused on the painting from the canvas side. THz pulses reflected from the canvas and from the different paint layers are detected in a standard electro-optic detection setup.(b) Photograph of a painting with six strokes of raw umber on canvas (left) and of the painting with six strokes of raw umber covered with lead white, used in the experiments.

We compare these results with 2D-images of the same sample obtained using X-ray transmission and near-infrared imaging, shown in Fig. 2(b-c). While the X-ray image doesn't show any clear evidence of the presence of the raw umber patches, the IR image is able to detect the presence of the hidden paint strokes but with a limited contrast. In comparison, the THz image allows us not only to distinguish 5 of the 6 patches but also to give an estimate of the different

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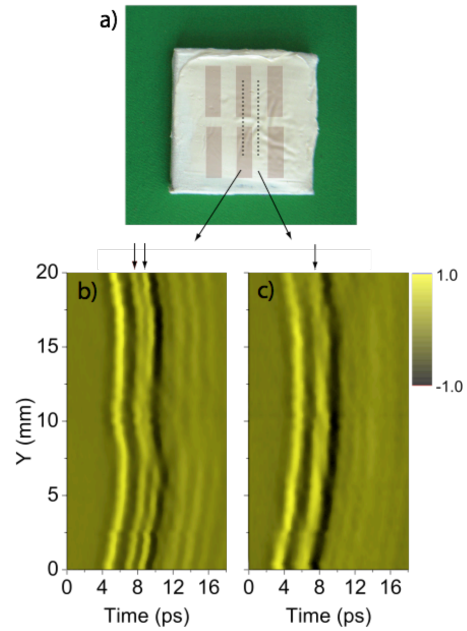


Fig. 2. (a) Photograph of the front surface of the painting on which the six raw umber strokes, hidden underneath the lead white, have schematically been drawn. The dashedlines represent the location of the line scans of which the results are shown in (b) and (c). (b) and (c) THz electric field (color coded) reflected from the canvas side of the painting, as a function of time and as a function of position along the lines indicated in (a). Yellow indicates positive electric field, black indicates a negative electric field.

optical thicknesses of these patches.

We find that, without using deconvolution techniques, the

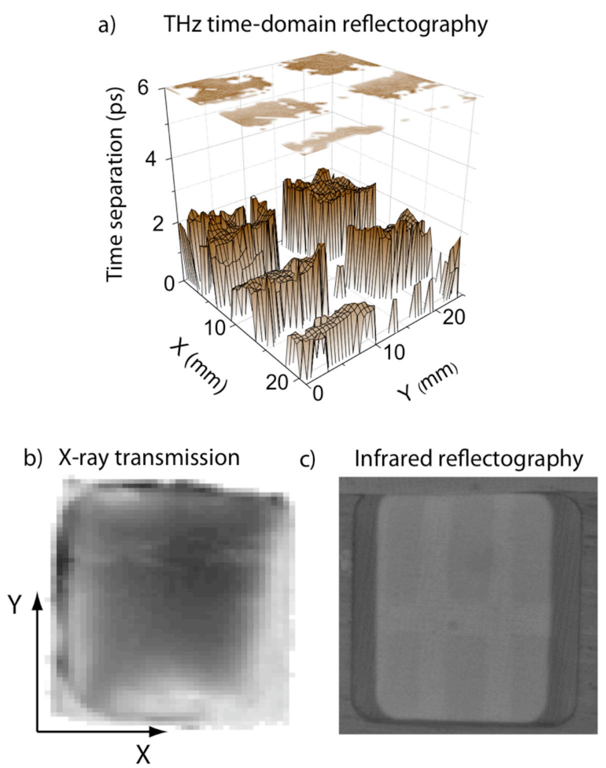


Fig 3. (a) Time separation between the second and the third positive peak in the reflected THz signal, as a function of position on the canvas, which is a measure of the optical thickness of the raw umber strokes. (b) X-ray transmission image of the paint sample. (c) Near infrared image of the paint sample.

minimum detectable thickness is around 50 µm, assuming a (measured) refractive index of 1.9 for the raw umber. Thickness variations can be observed down-to values of about 12 µm.[3]

## III. Preliminary Results From Paintings on Copper Plate

The same setup is used with different layers of paint deposited on a thick copper plate. In this case, it is not possible to access the paint layers from the back because the copper is a perfect reflector for THz radiation. Therefore we need to focus our THz beam on the front surface. We've fabricated a mock-up, see Fig. 4, made of a thick copper plate, covered partly with lead-white paint as pre-ground. On top of this, we‘ve applied different colored paints used typically by artists of the 17th century.

This mock-up imitates original paintings on copper where the artist has covered parts of the older painting. As a preliminary results, we show that we are able to detect the presence of the different layers on the mock-up by processing the reflection data.

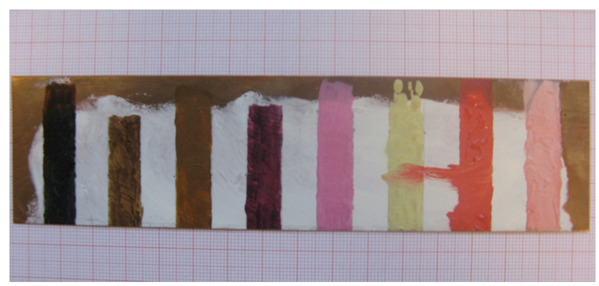

Fig. 4. Picture of a copper plate with patches of different colors applied to a thin layer of lead-white paint.

The final stage of this project will be to perform a THz reflection measurement on a genuine masterpiece.

## References


[1] J. Dik, K. Janssens, G. Van Der Snickt, L. van der Loeff, K. Rickers, and M. Cotte, "Visualization of a Lost Painting by Vincent van Gogh using Synchrotron Radiation based X-ray Fluorescence Elemental Mapping," Anal. Chem. 80, 6436-6442 (2008)

[2] J.B. Jackson, M. Mourou, J.F. Whitaker, I.N. Duling III, S.L. Williamson, M. Menu, G.A. Mourou, "Terahertz imaging for non-destructive evaluation of mural paintings," Opt. Commun. 281, 527-532 (2008)

[3] A. J. L. Adam, P. C. M. Planken, S. Meloni, and J. Dik, "TeraHertz imaging of hidden paint layers on canvas," Optics Express 17, 3407-3416 (2009)