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# Non-invasive quantitative characterization of varnish thickness on gilt leather by line-field confocal optical coherence tomography

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## ABSTRACT

Line-field confocal optical coherence tomography (LC-OCT) is an alternative to conventional OCT that combines OCT and confocal microscopy. This technique gives access to three-dimensional (3D) images with a micrometer resolution in the three spatial directions and enhances signal from the deepest layers within the material. After an experimental determination of the device characteristics, the technique is used for the investigation of 16<sup>th</sup> to 18<sup>th</sup> century fragments of gilt leathers wall-hangings. In these objects, the various layers within the varnish can be identified and the effect of a restoration treatment can be observed to validate the varnish removal process.

**Keywords:** OCT, gilt leather, stratigraphy, heritage sciences

## 1. INTRODUCTION

Optical Coherence Tomography (OCT) is today a well-established imaging technique based on white-light interferometry. This technique provides information on the various layers (interfaces between two adjacent layers) and on the presence of particles (scattering particles). The collected signals are based on the reflection or scattering of light, i.e. spatial variation of the refractive index. As standard non-destructive and non-invasive three-dimensional (3D) imaging technique, OCT can be brought on site for the study of cultural heritage artefacts. However, the most common OCT devices usually provide a lateral resolution between few to 10  $\mu\text{m}$  that impedes accurate measurements of micrometric structures as thin varnish layers or small particles.

In this study, we present a new 3D imaging technique: Line-field Confocal OCT (LC-OCT), which combines OCT with confocal microscopy, in order to provide improved spatial resolution and imaging speed, while still providing a similar penetration depth as in usual OCT setups [1]. We thoroughly characterize this new device and use it to characterize varnish layers in gilt leathers wall-hangings fragments dating from the 16<sup>th</sup> to 18<sup>th</sup> century.

## 2. RESULTS AND DISCUSSION

### 2.1 Characterization of the LC-OCT device

A LC-OCT is a Time Domain OCT combined to a confocal filtering to obtain a better resolution and imaging depth [1]. Our LC-OCT was specifically designed for cultural heritage applications by the company "Damae Medical" and allows non-contact imaging (Figure 1.a). This microscope allows a resolution of 1  $\mu\text{m}$  in the lateral and axial dimensions. The field of view is nearly 1  $\text{mm}^2$  and can be further enlarged up to few  $\text{cm}^2$  by stitching images using a motorized stage. 2D and 3D images are recorded automatically using a dedicated software. The typical acquisition time of 3D images is 3 minutes for the maximal 3D field of view.

### 2.2 Stratigraphy of ancient gilt leathers

Gilt leathers were luxurious decorations used often as wall-hangings between the 16th and 18th century in Europe. They are composed of silver leaves glued on a leather support and covered with a yellow varnish to give a gold appearance (Figure 1.b).

On most decors, polychromy was then added on top, but leaving part of the varnish visible. .

2D transverse LC-OCT images of the gilt leathers under study showed two interfaces, visualized as bright lines parallel to the gilt leather surface: a first one between air and varnish and a second one between varnish and silver leaf (Figure 1.c). Other interfaces are sometimes present when there are multiple layers of varnish. Bright dots within the varnish layers are pigment particles, as already observed by use of OCT in other artefacts [2]. Defects in the silver leaf or more complex stratigraphies in colored areas can also be visualized [3].

Finally, in order to obtain quantitative data about these varnish layers, an automatic image processing code was implemented to automatically detect the interfaces and measure the varnish thickness on the studied area

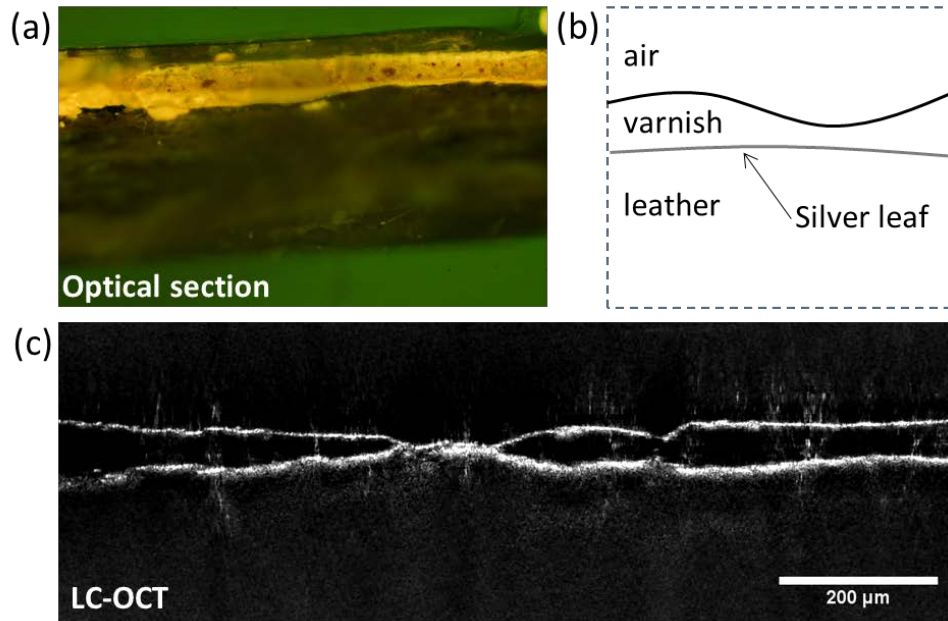


Figure 1. Gilt leather imaging. (a) Transmitted light image of a gilt leather transverse section. (b) Simplified schema of a gilt leather stratigraphy. (c) LC-OCT image of a gilt leather. The upper bright line corresponds to the air-varnish interface and the lower bright line to the varnish-silver interface.

### 3. CONCLUSION

LC-OCT imaging combined with automatic quantitative measure of varnish thickness provides an efficient tool for non-invasive quantitative characterization of gilt leathers stratigraphy. This unique information may be used by conservators to follow the progress of a conservation treatment (eg. modern varnish removal) and conservation scientists to orientate subsequent chemical analyses and their interpretations, in the investigation of the decors' provenance.

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