An examination of the complementary use of optical coherence tomography (OCT) and non-linear microscopy

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As imaging and sensing technology advances with the availability of new lasers and detectors, non-invasive examination of cultural heritage is increasingly being explored for material identification, 3D surface structure and subsurface microstructure visualisation. Non-invasive examination is often the only allowed scientific examination of culturally significant historical objects.

Recent work has demonstrated the potential of non-linear microscopy for depth resolved imaging of materials in cultural heritage such as varnishes, parchment, paint and corrosion layer in metal-based artefacts. The non-linear microscopy modalities employed were multi-photon excitation fluorescence (MPEF), second harmonic generation (SHG) and third harmonic generation (THG). The 3 modalities were found to complement each other. MPEF depends on the intrinsic fluorescence properties of the material. Old varnishes, organic paints and binding media are known to fluoresce. SHG is produced only in non-centrosymmetric molecules and hence providing material information and a unique image contrast. THG is sensitive to refractive index and third order non-linear susceptibility and therefore sensitive to layer interfaces. Since only at the very focus of the laser spot would there be high enough photon intensity to initiate these non-linear effects, the tightness of focus determines the axial resolution. Non-linear microscopy is not affected by multiple scattering and cross-talk due to scattering from out of focus regions. The penetration depth is mostly limited by absorption.

In comparison, Optical Coherence Tomography (OCT) is a more established optical technique for non-invasive imaging of subsurface microstructure of cultural heritage such as old master paintings. OCT imaging is based on a fast scanning Michelson interferometer that uses a broadband laser. The axial resolution is determined by the coherence length of the laser source. It is most sensitive to changes in refractive index and therefore sensitive to the interface between layers. It can detect reflectivity of order 10-9. The penetration depth is limited mostly by multiple scattering and to a lesser extent by absorption.

The aim of this study is to compare systematically the two 3D subsurface imaging modalities for imaging paint and varnish layers used on historical paintings. A set of mockup paint and varnish samples were imaged by both OCT systems at NTU and a non-linear microscopy system at IESL-FORTH. An ultra-high resolution OCT systems at 810 m was used for the thin varnish samples and a long wavelength OCT at 1960 nm was used for the paint samples to measure both the sample thicknesses and their refractive indices. The measured refractive indices are then used to correct the non-linear microscopy images to compare with the OCT images. A study of the potential laser induced degradation due to the high laser intensity required in non-linear microscopy was also conducted.

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