Nonlinear imaging techniques (NLO) for painting investigation

Alice Dal Fovo*, Raffaella Fontana, Jana Striova, Enrico Pampaloni, Marco Barucci, Marco Raffaelli, Luca Pezzati, Riccardo Cicchi

Istituto Nazionale di Ottica - CNR-INO, Largo Fermi 6, 50125, Firenze, Italy
*alice.dalfovo@ino.it

Nonlinear imaging techniques (NLO imaging), i.e. multiphoton excitation fluorescence (MPEF), second and third harmonic generation (SHG, THG), are high-resolution imaging modalities which may provide non-destructive determination of thickness and composition within multi-layer objects as a function of depth. Initially employed in the field of biomedical optics, these techniques have been only recently applied in artworks analyses, for the identification of corrosion layers in metal-based objects, for the visualization and characterization of wood microstructures and for the study of synthetic glue and varnish protective layers. Some tests have been also conducted on paintings, giving promising results that encouraged further investigations. In fact, since absorption by most materials employed in paintings is low in the near-infrared (NIR), the use of laser light in this spectral region enables deeper optical penetration and makes feasible the examination of underlayers. Besides, using a multimode operation scheme enabling the recording of complementary (MPEF, SHG, THG) images, it is possible to obtain the micrometric surface mapping, as well as the in-depth profiling of thin films on the basis of refractive index changes, variation of optical activity and presence of fluorescence chromophores. Such information are definitely useful for the analysis of painted objects, and can be also crucial for the monitoring of restoring operations, like the cleaning process, that modify surfaces micrometric morphology and coating layers thickness.

In this regard, we present the preliminary results obtained through the application of NLO imaging techniques on a series of single- and multi-layers systems simulating the real egg-tempera wood panel paintings. Each sample shows a sequence of stratifications as follows: wooden support (a “sandwich” structure made of fir and poplar), preparation layer (gypsum and animal glue), underdrawings (lead and tin stylus, natural carbon, iron-gall ink), first pictorial layer (egg tempera with different pigments), second pictorial layer (different lakes) and superficial protective layers (natural and synthetic varnishes, egg, and multi-layer coatings). The variability of paint and protective layers thickness and composition enables the evaluation of the NLO-signals as a function of depth and of chemical make-up. In order to assess the reliability of NLO measurements, data were complemented with other well-established techniques, such as Fourier Transform Infrared Spectroscopy (FTIR) and X-Ray Fluorescence (XRF) for the chemical characterization of materials, Optical Coherence Tomography (OCT) and confocal microscopy for the determination of layers thickness, and laser scanning micro-profilometry for the study of surfaces morphology. Colorimetric analyses, i.e. reflectance spectroscopy in the visible region, are also reported in order to chromatically characterize pigments and lakes. Finally, the transparency of the different materials is investigated by means of Scanning Multispectral Infra-Red Reflectography (SMIRR).

This work describes whether and to what extent the NLO imaging techniques prove useful in probing multilayer painted objects.