Fibre optics reflectance spectroscopy (FORS)

Detailed view of the 8°/8° probe-head used to perform the non-invasive FORS measurements on selected panels of the artwork “Cartoline” at the Luigi Pecci Contemporary Art Center in Prato (Italy) (photo courtesy IFAC-CNR)

FORS is an analytical technique based on the use of portable spectrophotometers equipped with optical fibres accessories. The optical fibres are used to convey the light electromagnetic radiation from the instrumentation to the target and vice versa, thus making it possible to perform measurements in-situ, without any sampling. Thanks to the flexibility of optical fibres, any point of the object can be easily reached and measured non-invasively, without constraints due to size or shape of the artwork. In the conservation field FORS was originally proposed for non-sampling investigations on unmovable artworks (mainly frescoes and wall paintings, Bacci 1991) and subsequently, thanks to the technological advancements in development of high-performance portable spectrophotometers, its use has become widespread and has been extended to several categories of artworks (Dupuis *et al.* 2002; Bacci 2005 *et al.*; Leona 2001; Picollo *et al.* 2002). The working principle of FORS is illustrated in the following. A beam (Io) of radiation emitted by a broad band source (e.g., a tungsten halogen lamp) is sent to the object surface through a bundle of optical fibres connected to a probe head. The diffused radiation is then collected and returned to the spectrophotometer using the same or another bundle of optical fibres. The dispersive element such as a prism or a diffraction grating separates the wavelengths of light and focuses each of them onto the detector. The reflectance spectrum is obtained by reporting the percentage of the intensity of the reflected radiation (I) with respect to that one of the incident radiation I_o, (in other words, the ratio R=I/Io), against the wavelength. Practically, the intensity of the incident radiation I_o is obtained by measuring the diffused signal of a white reference standard (for example a certified diffusing Spectralon®), which is assumed to reflect the 100% of the incident radiation over the wavelengths range of interest.

FORS can be used to acquire reflectance spectra over different spectral regions, depending on the technical characteristics of the instrumentation used (light sources, detectors, optical components and fibres materials). Depending on the range of wavelength to be measured, a variety of detectors may be used. Often, several detectors are employed in the same instrument to record a wider UV-Vis-NIR range. In the picture, an example of FORS instrumentation is reported, with the typical experimental set-up adopted at IFAC-CNR also to perform the UV-Vis-NIR characterisation of plastics objects included in the SamCo.

In the acquisition of UV-Vis-NIR spectra an important aspect regards the geometry adopted for illumination and collection of the backscattered light. Different probe heads can be connected to the optical bundles in order to realize various measurements geometries according to the experimental needs and applications. One of the geometries most commonly adopted, and recommended by the CIE (Commission international de l'éclairage) for colour measurements, is the 0°/45° geometry, in which the incident beam is sent along the direction normal at the surface (0°), whereas the backscattered light is collected at an angle of 45° degrees with respect to the normal direction. This configuration is conceived to exclude the specular component of the reflectance which does not provide compositional information and does not inform about the colour. A simplest geometry, which still excludes the specular component, is the 8°/8°, in which the incoming beam is slightly tilted with respect to the normal direction. In this case the probe head is smaller, and suitable for measurements on bent surfaces and small areas. This probe-head is therefore suitable for applications on 3D objects of variable shapes and dimensions.

Instruments

A variety of spectrophotometers is commercially available to set up a FORS apparatus. Various spectrometers were employed to implement FORS measurements in POPART project.

IFAC used a compact portable system which included two spectroanalysers ZEISS MCS601 (operating in the UV-VIS-NIR) and MCS611 (operating in the NIR), and a Halogen light source CLH500 (colour temperature 2900 K). The module MCS601 operates in the 350-1200 nm range, ,whereas the MCS611 module operates in the 910-2200 nm range. This system is equipped with a bundle of quartz-silica optical fibres transmitting in the 350-2500 nm spectral region connected to a probe-head operating in the 8°/8° geometry.

MORANA used two portable spectrometers, LabSpec 5000 (ASD) and NIR256-2.5 Near-infrared Spectrometer (Ocean Optics).

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