Optical coherence tomography in the long wavelength range: a prospective method for art object diagnosis

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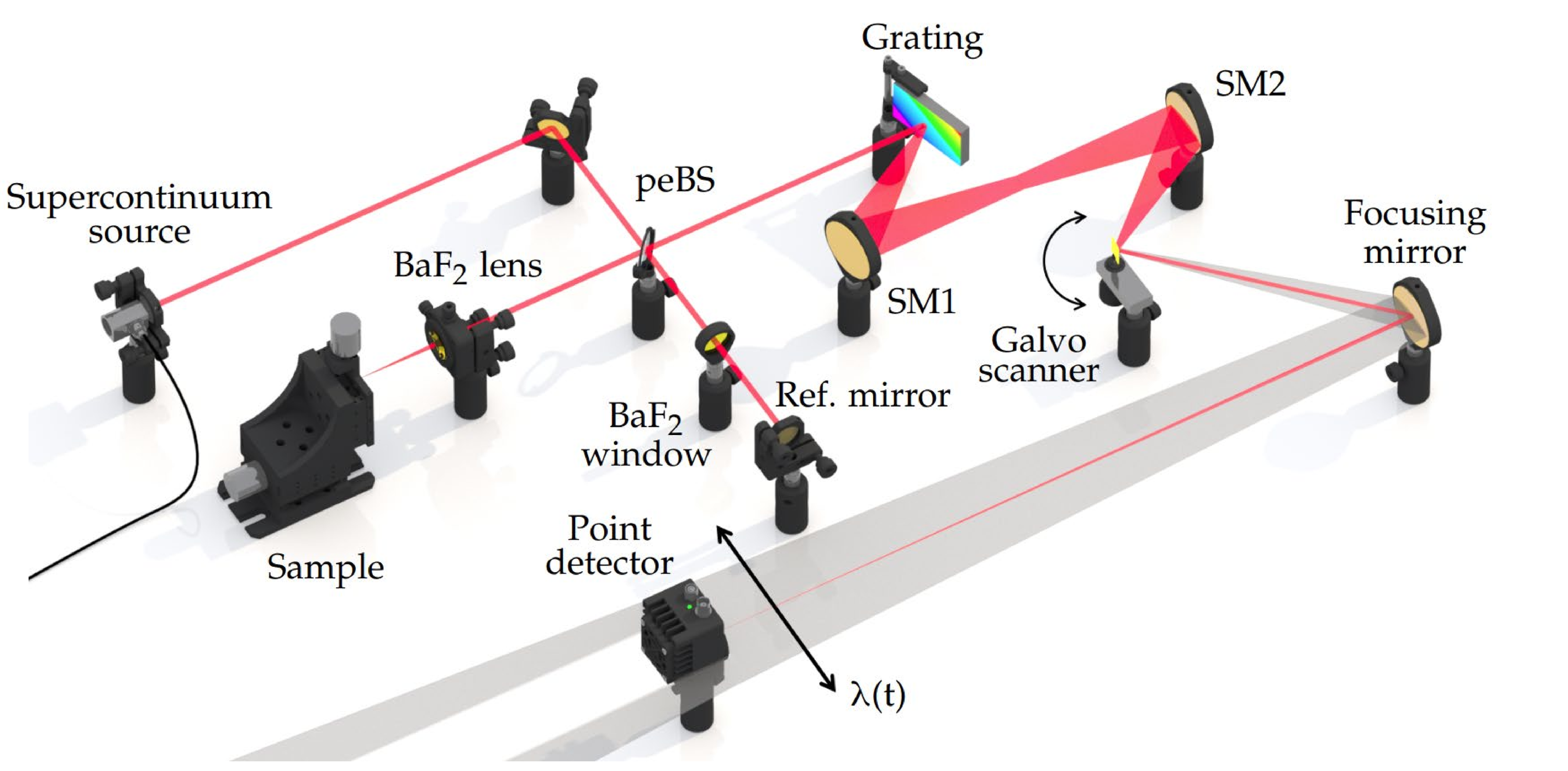
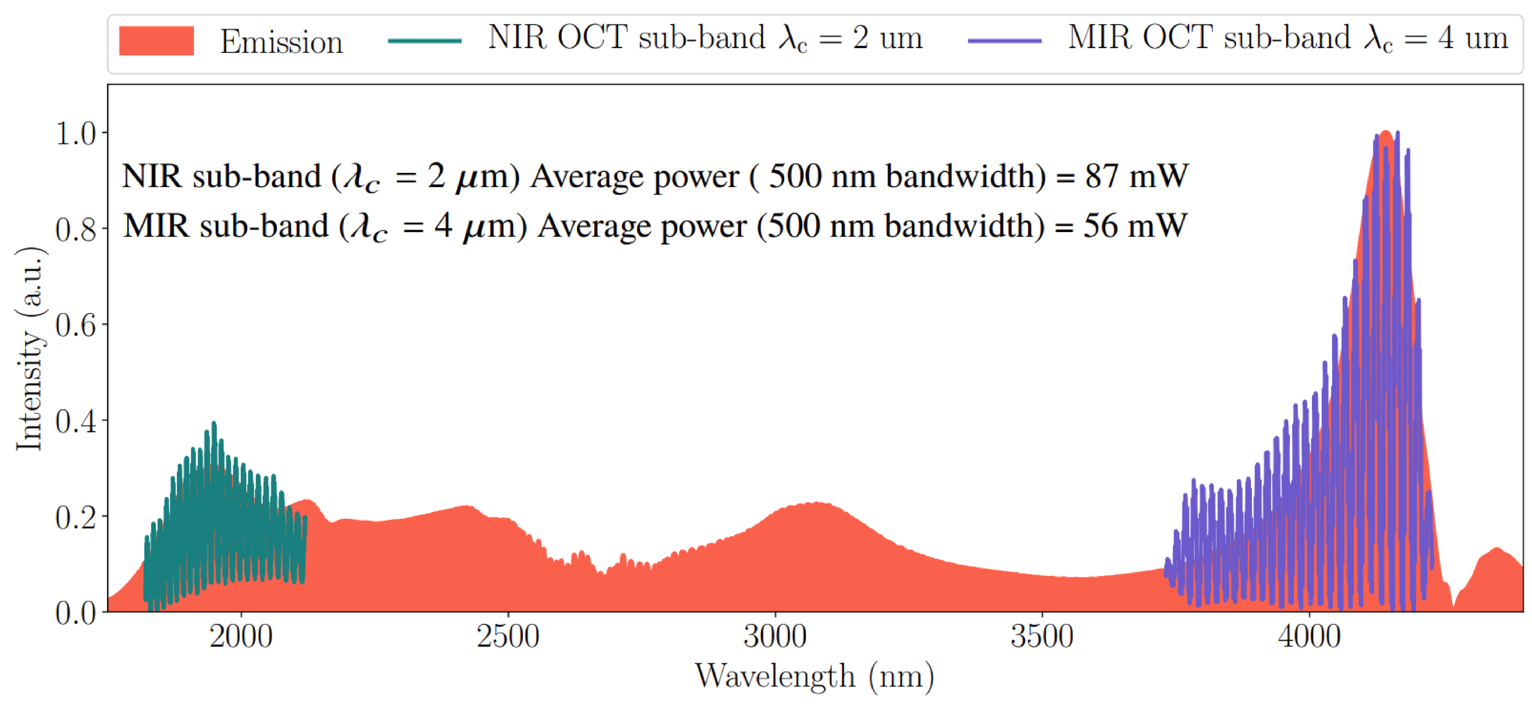
Optical coherence tomography

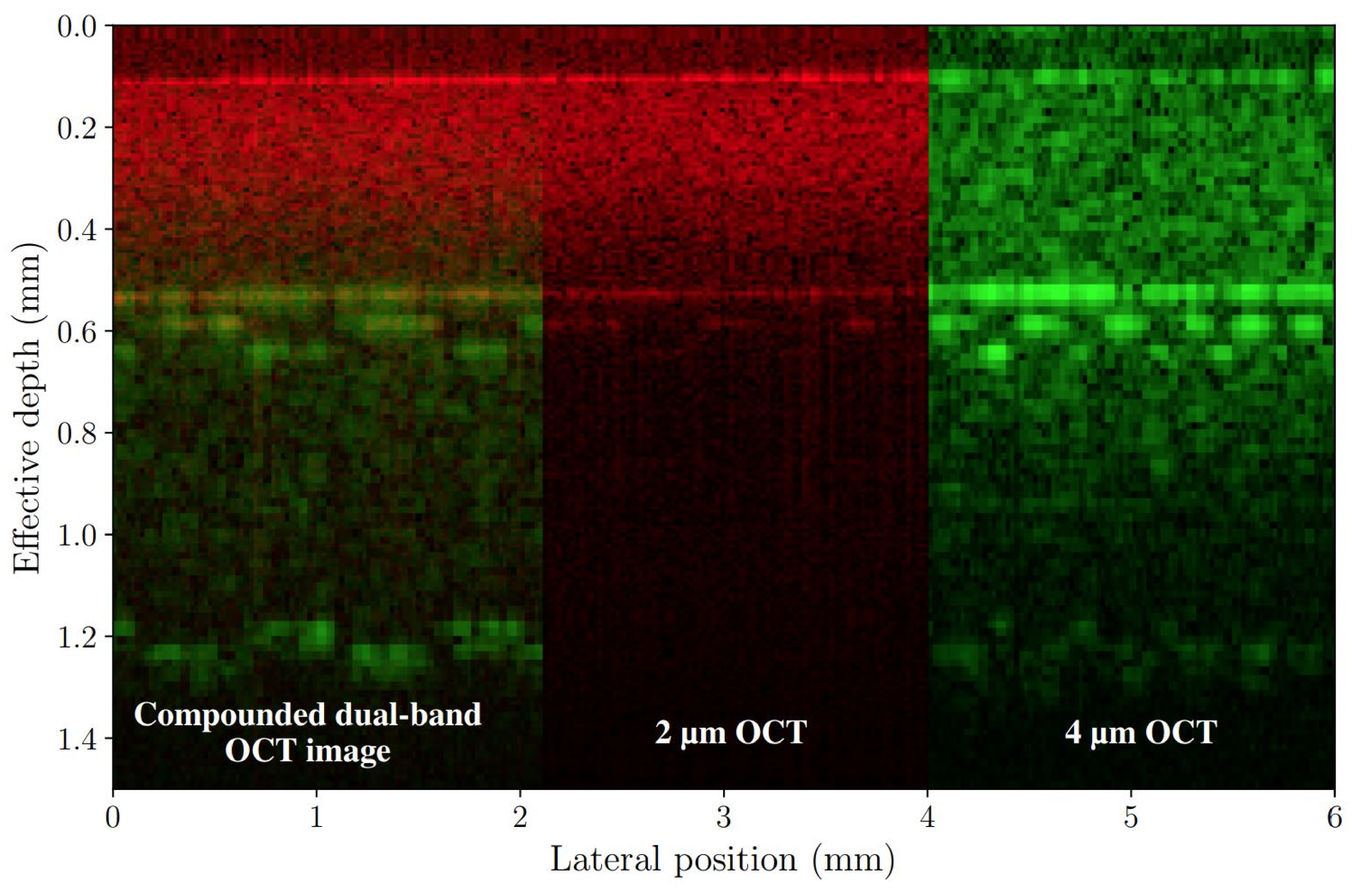


Optical coherence tomography (OCT) is a contactless non-destructive method for volumetric structural imaging of morphologically complex specimens. The technique employs the principles of low coherence interferometry to perform high-sensitivity and high-resolution measurements (the figure shows the schematics of the mid-infrared [mid-IR] OCT). Recent advances in the development of OCT beyond the standard biomedical field – in the long near-IR and mid-IR spectral ranges – have opened up many new applications aimed at probing high-scattering media. Among such applications are diagnostics and examination of art objects. In these scenarios, OCT can provide new insights into the research problem, as well as verify or supplement information as a complementary technique.

Spectral range and reasoning



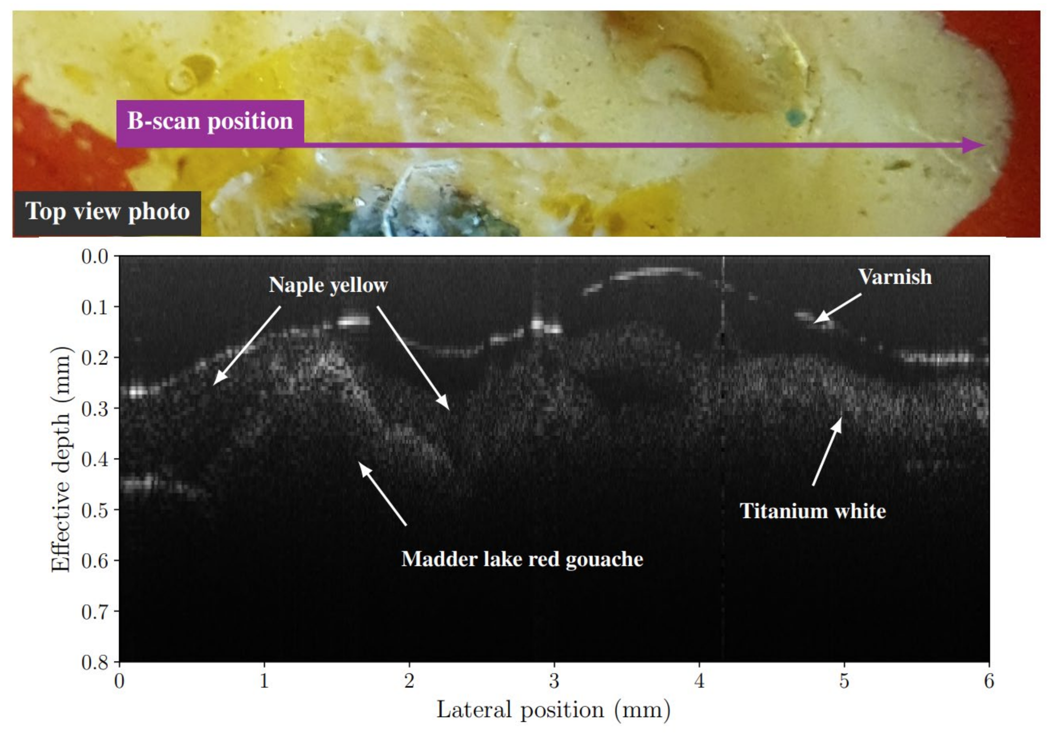
The performance of OCT systems depends on the operational spectral range. State-of-the-art systems occupy a technically rich and well-developed spectral range window that corresponds to optical communication bands – limited to the wavelength of of 1.5 μm. Such systems are highly sensitive, fast and relatively versatile. However, their effectiveness is often limited by scattering, as the magnitude of scattering is inversely proportional to the wavelength of light. This led to the development of OCT in the long wavelength mid-IR spectral range. A mid-IR OCT system is capable of imaging previously problematic specimens.



OCT imaging of art objects

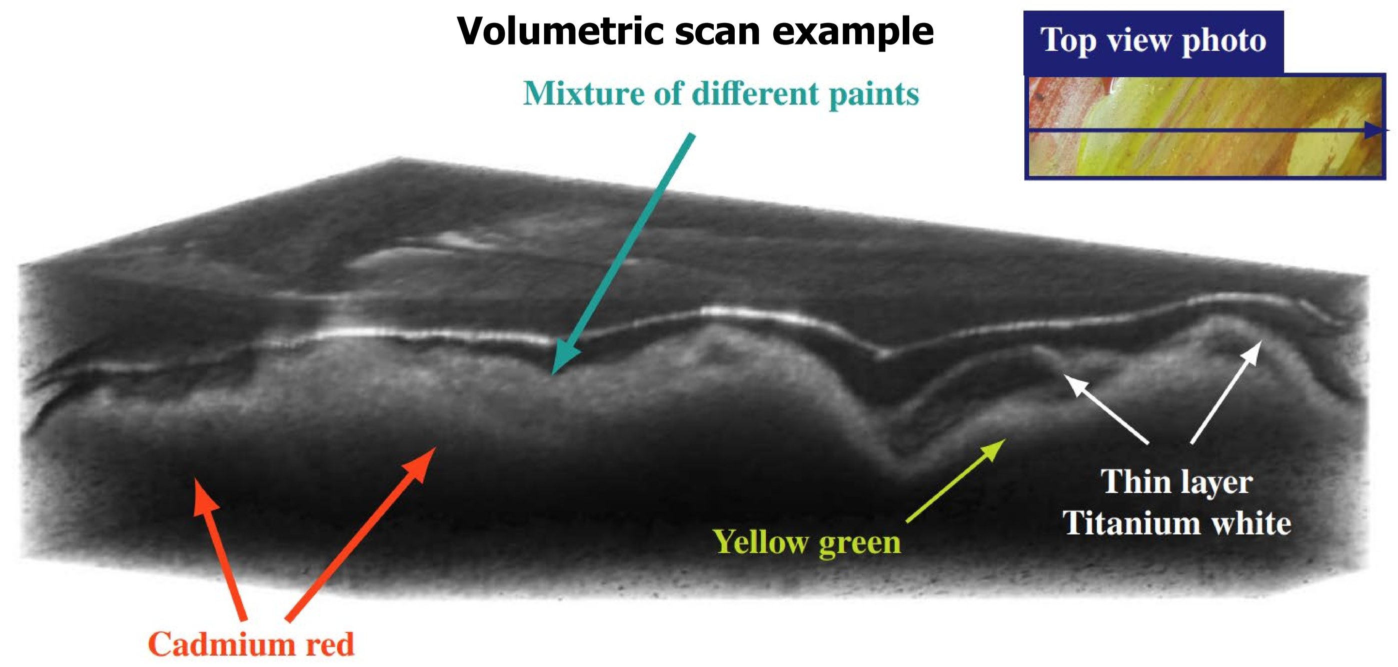
Standard commercial OCT systems are used for art object diagnostics and related studies, but their penetration depth is often confined by scattering down to tens to hundreds of micrometers, because materials are complex, turbid, consisting of an ensemble of pigments, binders, etc. It has been shown that the wavelength range of 2 μm and above (up to 4 μm) is well suited for OCT imaging of art objects.
By performing a linear scan over the surface of the sample, a cross-sectional image (B-scan) can be obtained, which reveals the subsurface structure. The contrast of the image depends on the optical properties of the volume. Since OCT measures back-reflected light, changes in refractive index, optical density, and scattering make the main contribution to contrast.

Cross-sectional scan of an art mock-up



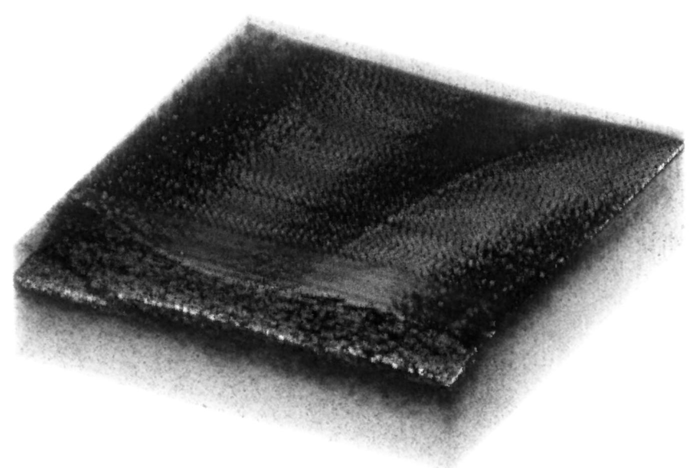
In order to record a volumetric scan, a sample area should be scanned. Such scans enable in-deep structural as well as functional analysis of the sample.

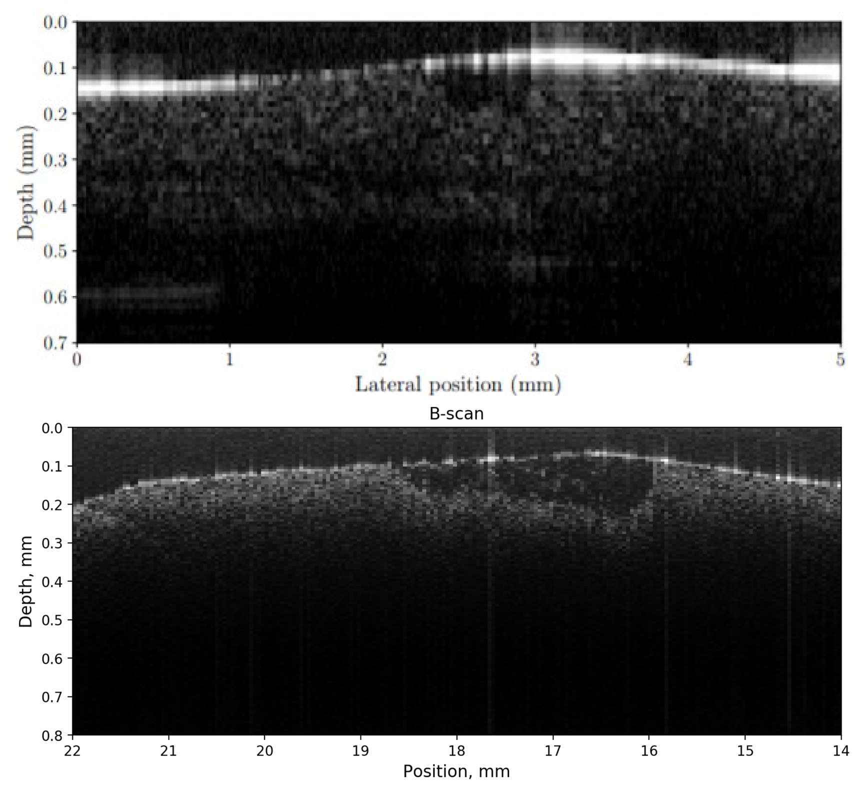
Volumetric scan example



Correlative OCT and spectroscopic imaging

OCT operating in long-wavelength mode is a still emerging technique with a variety of application scenarios. The measurement principle requires no sample preparation and imposes no restrictions on sample size, allowing it to be used both in the laboratory and in the field, for example in production or in museums.





[1] Zorin et al., "Mid-infrared fourier-domain optical coherence tomography with a pyroelectric linear array," Opt. Express 26, 33428–33439 (2018).
[2] Zorin et al., "Dual-band infrared optical coherence tomography using a single supercontinuum source," Opt. Express 28, 7858–7874 (2020).
[3] Zorin et al., "Multimodal mid-infrared optical coherence tomography and spectroscopy for non-destructive testing and art diagnosis," in Optics for Arts, Architecture, and Archaeology VII, vol. 11058 H. Liang, R. Groves, and P. Targowski, eds., International Society for Optics and Photonics (SPIE, 2019).
[4] Zorin et al "Time-encoded mid-infrared Fourier-domain optical coherence tomography," Opt. Lett. 46, 4108-4111 (2021).

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