Optical Phantom FAQ

Short introduction to our Phantoms

An optical phantom is a material designed to mimic the optical properties of biological tissue, such as light absorption and scattering. Our phantoms can be used as reference standards to calibrate, validate, and benchmark optical imaging and spectroscopy systems under controlled and reproducible conditions. By replicating how light propagates through tissue, optical phantoms enable reliable testing of system performance without the need for in vivo measurements (testing on real tissue).

1. What phantom should I choose for my application?

Edmund Optics® offers different phantom families which are designed to support specific biomedical optical measurement techniques. The choice of phantom should be determined mainly by the kind of optical measurement or imaging system it will be used with.

Diffuse reflectance phantoms are typically used when calibrating or validating systems that measure tissue optical properties (e.g. absorption and scattering), including diffuse reflectance spectroscopy, spatial frequency domain imaging, and diffuse Raman spectroscopy.

Optical Coherence Tomography (OCT) phantoms are designed to evaluate OCT system performance, such as axial resolution, imaging depth, and image reconstruction accuracy.

Anthropomorphic fNIRS phantoms are intended for testing functional NIR spectroscopy systems and are designed with anatomically realistic geometry to replicate measurement conditions encountered in brain monitoring experiments. These phantoms provide reliable reference models for research and life science applications, supporting accurate and reproducible system benchmarking.

The following table below briefly summarises most common uses of each family of products that Edmund Optics® offers in the phantom category. Choosing the correct phantom that closely matches your intended measurement method helps ensure that system validation reflects realistic experimental conditions.

Phantom Type	Typical Applications	What Can It Be Used to Evaluate?
Diffuse Reflectance Phantoms	Diffuse reflectance spectroscopy, spatial frequency domain imaging (SFDI), diffuse Raman spectroscopy	Calibration and validation of systems measuring tissue optical properties, including absorption and scattering coefficients
OCT Phantoms	Optical coherence tomography (OCT) imaging systems	System performance metrics such as axial resolution, imaging depth, and image reconstruction accuracy
Anthropomorphic fNIRS Phantoms	Functional near-infrared spectroscopy (fNIRS), brain monitoring experiments, and life science research	Sensor placement, light propagation in tissue, and overall system performance under anatomically realistic conditions

2. What optical properties should I keep in mind when choosing a phantom?

Optical phantoms are generally characterized using key parameters that describe how light interacts with tissue-like materials (see question 3). The most important parameters which should be considered are the absorption coefficient (μ_a) and the reduced scattering coefficient (μ_s'). These parameters define how strongly light is absorbed and scattered within the material and are essential for calibrating optical imaging systems.

The choice of these parameters depends on the intended application. For example, in imaging techniques such as Optical Coherence Tomography, lower absorption coefficients are typically preferred to allow greater imaging depth, while scattering properties influence image contrast and resolution. In diffuse optical spectroscopy or reflectance-based measurements, both absorption and scattering must be carefully matched to the target tissue to ensure accurate quantification of optical properties.

Measurement values for these parameters are typically supplied on each product page under *Material Properties*. When appropriate, datasheets with detailed measurements across specific wavelengths are available under product downloads. Because these optical properties are carefully controlled and characterized, the phantoms can act as reliable reference materials for validating optical measurement systems.

3. How are the optical properties of my phantom measured and determined?

The absorption and reduced scattering coefficients are measured using an optical characterization technique known as time-domain diffuse optical spectroscopy. In this approach, short pulses of light are introduced into the phantom, and the time distribution of the detected photons is analyzed to understand how light propagates through the material.

To extract the optical properties from these measurements, the recorded photon time-of-flight data are analyzed using models commonly applied to describe light transport in scattering media, such as diffusion-based approaches. These analytical methods are widely used in tissue optics because they effectively model photon propagation in highly scattering materials such as biological tissue and tissue-mimicking phantoms.

By fitting the measured time-resolved data to these models, both the absorption coefficient (μ_a) and reduced scattering coefficient (μ_s') can be determined with high accuracy. This approach provides reliable and reproducible estimates of optical properties.

4. **Is the absorption coefficient defined according to the Beer–Lambert law?**

Yes. The absorption coefficient provided in each of our phantom datasheets follows the standard definition used in optical spectroscopy and is based on the Beer–Lambert law. As per the formula, the transmitted intensity of light decreases exponentially as it propagates through an absorbing medium according to the expression $\exp(-\mu_a \cdot z)$, where μ_a is the absorption coefficient and z represents the optical path length. The absorption coefficient is reported in units of cm^{-1}, which is the standard unit used for describing absorption in tissue optics and biomedical imaging applications.

5. **Is information available about the scattering anisotropy factor?**

The anisotropy factor (g), which describes the average direction of photon scattering, is not directly characterized for our phantoms. However, based on the materials and fabrication processes used to produce the phantoms, the anisotropy factor is expected to fall within the typical range observed in biological tissue. For most soft tissues, the anisotropy factor is commonly between 0.8 and 0.9, with values closer to 0.9 indicating strongly forward-directed scattering. Although this parameter is not explicitly measured for our phantoms, this estimated range is consistent with the optical behavior expected from tissue-mimicking materials.

6. **Is the full scattering phase function available?**

The full scattering phase function is not typically provided for these phantoms. Optical characterization focuses primarily on the reduced scattering coefficient and absorption coefficient because these parameters are sufficient for most diffuse optical modeling and calibration applications. In many biomedical optics applications, the reduced scattering coefficient is used instead of the full phase function because it already accounts for the anisotropy of scattering within the medium.

7. **Why are reduced scattering coefficients provided instead of the full scattering coefficient?**

In highly scattering media such as biological tissue, photon propagation is strongly influenced by both the scattering coefficient and the anisotropy factor. Instead of reporting the scattering coefficient alone, many optical characterization methods report the reduced scattering coefficient (μ_s'), which incorporates the anisotropy factor into a single parameter. This parameter is defined as $\mu_s' = \mu_s(1 - g)$, where μ_s is the scattering coefficient and g is the anisotropy factor. Using the reduced scattering coefficient simplifies optical modeling and is widely used in biomedical optics when analyzing light transport in tissue-like media.

8. How is the coefficient of variation determined in phantom measurements?

The coefficient of variation reported during phantom characterization is calculated by performing a series of repeated optical measurements at a specific wavelength. The standard deviation of these measurements is then divided by the mean value of the measured parameter. This ratio provides a normalized measure of variability that reflects the repeatability and stability of the measurement. A low coefficient of variation indicates that repeated measurements produce consistent results, which is important for ensuring that the phantom can serve as a reliable reference standard during system validation. In fact, in most optical measurement applications, a lower coefficient of variation is typically preferred, as it reflects higher measurement stability; however, acceptable values may vary depending on the sensitivity and precision requirements of the specific application.

9. Can I expect any differences in optical properties between the diffuse reflectance phantoms (Family ID 4542) and OCT phantoms (Family ID 4543)?

The core optical parameters (absorption coefficient and reduced scattering coefficient) are defined in the same way across different phantom types. However, the phantom design and intended application differ significantly between families. Diffuse reflectance phantoms are typically homogeneous materials designed to provide stable optical properties for calibration and spectroscopy measurements. OCT phantoms, on the other hand, can include internal structures or layered geometries to evaluate the depth-resolved imaging capabilities of OCT systems. As a result, while the optical characterization methods are similar, the phantom structure and intended measurement applications differ.

Reference list

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