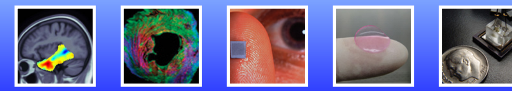
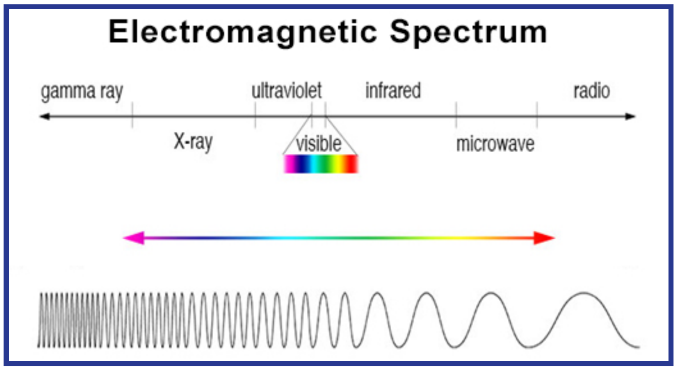
NATIONAL INSTITUTE OF BIOMEDICAL IMAGING AND BIOENGINEERING



Optical Imaging

National Institutes of Health

What is optical imaging?

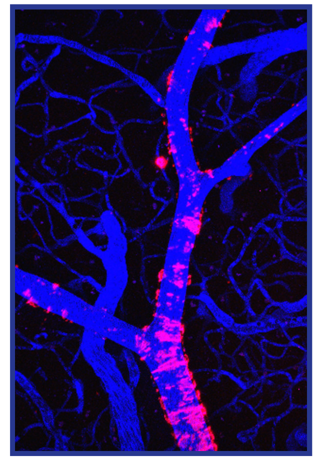


Optical imaging is a technique for non-invasively looking inside the body, as is done with x-rays. But, unlike x-rays, which use ionizing radiation, optical imaging uses visible light and the special properties of photons to obtain detailed images of organs and tissues as well as smaller structures including cells and even molecules. These images are used by scientists for research and by clinicians for disease diagnosis and treatment.

What are the advantages of optical imaging?

Optical imaging offers a number of advantages over other radiological imaging techniques:

Optical imaging significantly reduces patient exposure to harmful radiation by using non-ionizing radiation, which includes visible, ultraviolet, and infrared light. These types of light generate images by exciting electrons without causing the damage that can occur with ionizing radiation used in some other imaging techniques. Because it is much safer for patients, and significantly faster, optical imaging can be used for lengthy and repeated procedures over time to monitor the progression of disease or the results of treatment.



Multiphoton microscopy of amyloid deposits in mouse model of Alzheimer's Disease. Source: M. Garcia-Alloza, Massachusetts General Hospital

Optical imaging is particularly useful for visualizing soft tissues. Soft tissues can be easily distinguished from one another due to the wide variety of ways different tissues absorb and scatter light.

Because it can obtain images of structures across a wide range of sizes and types, optical imaging can be combined with other imaging techniques, such as MRI or x-rays, to provide enhanced information for doctors monitoring complex diseases or researchers working on intricate experiments.

Optical imaging takes advantage of the various colors of light in order to see and measure many different properties of an organ or tissue at the same time. Other imaging techniques are limited to just one or two measurements.

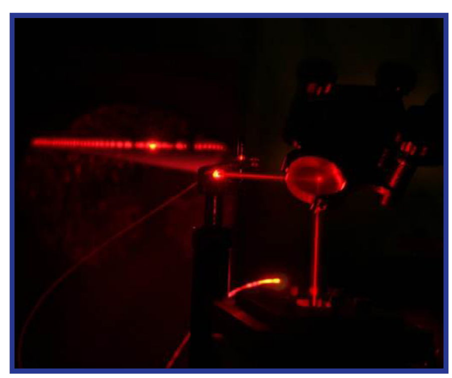
What types of optical imaging are there and what are they used for?

Optical imaging includes a variety of techniques that use light to obtain images from inside the body, tissues or cells.

- **Endoscopy:** The simplest and most widely recognized type of optical imaging is endoscopy. An endoscope consists of a flexible tube with a system to deliver light to illuminate an organ or tissue. For example, a physician can insert an endoscope through a patient's mouth to see the digestive cavity to find the cause of symptoms such as abdominal pain, difficulty swallowing, or gastrointestinal bleeding. Endoscopes are also used for minimally invasive robotic surgery to allow a surgeon to see inside the patient's body while remotely manipulating the thin robotic arms that perform the procedure.

- **Optical Coherence Tomography (OCT):** Optical coherence tomography is a technique for obtaining sub-surface images such as diseased tissue just below the skin. OCT is a well-developed technology with commercially available systems now in use in a variety of applications, including art conservation and diagnostic medicine. For example, ophthalmologists use OCT to obtain detailed images from within the retina. Cardiologists also use it to help diagnose coronary artery disease.

- **Photoacoustic Imaging:** During photoacoustic imaging, laser pulses are delivered to a patient's tissues; the pulses generate heat, expanding the tissues and enabling their structure to be imaged. The technique can be used for a number of clinical applications including monitoring blood vessel growth in tumors, detecting skin melanomas, and tracking blood oxygenation in tissues.



Back Scattering interferometry for molecular imaging. Source: D.J. Bornhop, Vanderbilt University

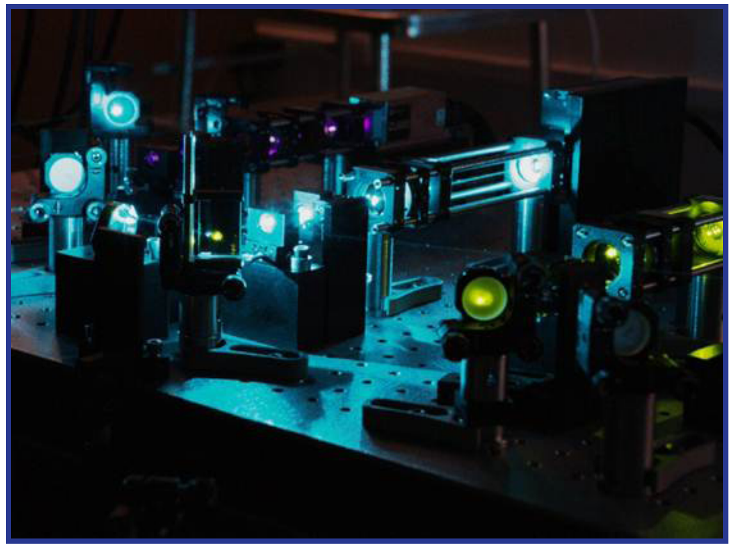
- **Diffuse Optical Tomography (DOT):** DOT can be used to obtain information about brain activity. A laser that uses near-infrared light is positioned on the scalp. The light goes through the scalp and harmlessly traverses the brain. The absorption of light reveals information about chemical concentrations in the brain. The scattering of the light reflects physiological characteristics such as the swelling of a neuron upon activation to pass on a neural signal.

- **Raman Spectroscopy:** This technique relies on what is known as Raman scattering of visible, near-infrared, or near-ultraviolet light that is delivered by a laser. The laser light interacts with molecular vibrations in the material being examined, and shifts in energy are measured that reveal information about the properties of the material. The technique has a wide variety of applications including identifying chemical compounds and characterizing the structure of materials and crystals. In medicine, Raman gas analyzers are used to monitor anesthetic gas mixtures during surgery.

- **Super-resolution Microscopy:** This form of light microscopy encompasses a number of techniques used in research to obtain very high resolution images of individual cells, at a level of detail not feasible using normal microscopy. One example is a technique called photoactivated localization microscopy (PALM), which uses fluorescent markers to pinpoint single molecules. PALM can be performed sequentially to create a super-resolution image from the series of molecules isolated in the sample tissue.

- **Terahertz Tomography:** This relatively new, experimental technique involves sectional imaging using terahertz radiation. Terahertz radiation consists of electromagnetic waves, which are found on the spectrum between microwaves and infrared light waves. They are of great interest to scientists because terahertz radiation can "see" what visible and infrared light cannot, and holds great promise for detecting unique information unavailable via other optical imaging methods.

What are NIBIB-funded researchers developing in the area of optical imaging to improve biomedical research and medical care?



Source: Hari Shroff, NIBIB

Scanning laser microscope to identify cancer of the epithelium without painful biopsies: Scientists are building a miniature scanning laser microscope that can identify skin cancer cells and can also be attached to an endoscope (a thin illuminated tube) to examine cells on the epithelium of the oral cavity, GI tract and elsewhere. The device combines high resolution images showing cellular detail, with wide-field color video images of the surrounding tissue. The two views will allow the clinician to see the exact position in the tissue where the microscopic images are being taken, which is essential for accurately identifying and sampling the cells most likely to be cancerous. The instrument will improve early cancer diagnosis leading to higher survival rates at lower health care costs.

Near infrared brain imaging for guiding treatment in children with cerebral palsy: Cerebral palsy affects a child's ability to develop typical motor skills and to engage fully in play, and routine daily activities. Currently, treatments are tried blindly and as a result many pediatric patients undergo futile, prolonged and taxing treatments that have no benefit. This project uses functional near infrared (fNIR) imaging to detect brain activation patterns in the cortex, located at the top of the skull. The images will allow researchers to identify strong cortical activation patterns, which indicate a positive response to therapies. Ultimately, the scientists hope to refine the system so that physicians can readily use it to assess the initial severity of cerebral palsy and help them decide which specific treatment is likely to have a positive outcome for each individual patient.

Digital holograms to test response to therapies for ovarian cancer: Ovarian cancer is often not detected until late stages, when it is difficult to treat and can be fatal. Scientists are using a new technique called tissue dynamics imaging (TDI) to measure the sensitivity of ovarian tumors to chemotherapy and biological treatments. TDI constructs 3D holograms inside ovarian cancer tissue samples that measure cellular function and growth of tumors in response to drug treatments. The method predicts the clinical outcome expected following each round of treatment and determines the best subsequent treatment. The approach of analyzing the changing cellular properties of ovarian tumor tissue is designed to determine the optimal therapy for each patient. The ultimate goal is to establish TDI as a novel drug-response monitoring system that could transform personalized ovarian cancer care.

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