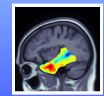
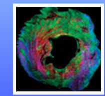
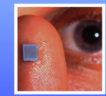
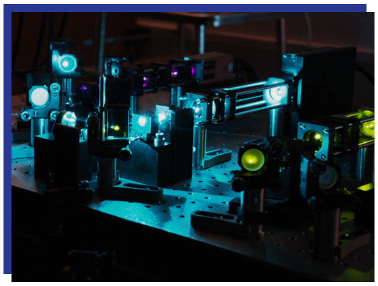
    

Optical Imaging

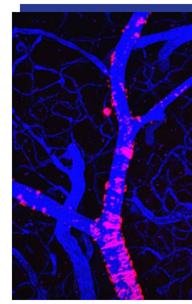
What is optical imaging?



Laser set-up in high resolution optical imaging laboratory
Source: Hari Shroff, NIBIB

Optical imaging is a technique for non-invasively looking inside the body, as is done with x-rays. 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?

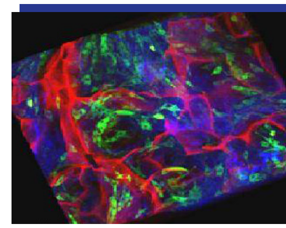


Multiphoton microscopy of amyloid deposits in mouse model of Alzheimer's Disease.
Source: M. Garcia-Alloza, Massachusetts General Hospital

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.
- 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.

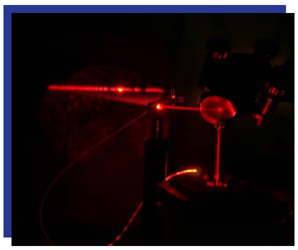
What types of optical imaging are there and what are they used for?



Source: Stephen Boppart, UIUC

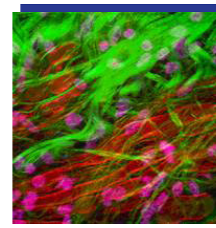
Optical imaging includes a variety of techniques that use light to obtain images from inside the body, tissues or cells.

- **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.



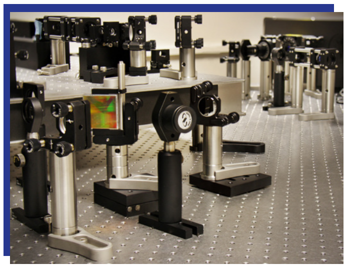
Back Scattering interferometry for molecular imaging.
Source: D.J. Bornhop, Vanderbilt University

- **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.
- **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?

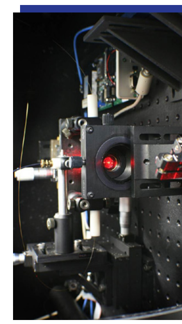


Source: Hari Shroff, NIBIB

Handheld OCT for diagnosis and monitoring: NIBIB-funded researchers are developing a hand-held OCT scanner for use by primary care physicians. The project is testing OCT for diagnosis of two common but potentially serious conditions: middle ear infections and diabetic neuropathy. For middle ear infections, the sensitivity of OCT will enable doctors to identify the specific bacteria causing the infection to allow for better decisions regarding treatment with antibiotics.

Diabetic retinopathy (damage to the retina of the eye due to diabetes complications) is a major health problem, as the number of overweight and obese individuals who develop nerve damage from high blood sugar increases. The OCT system will allow identification and monitoring of this condition by primary care doctors and enable rapid referral to the appropriate specialists. Swift diagnosis of diabetic retinopathy is critical, as loss of vision can occur if not aggressively treated.

Enhanced endoscopy for detection of precancerous lesions: Researchers have created an endoscope system capable of detecting abnormal but invisible cells that are likely to progress to cancers of the epithelium (layer of cells that covers most organs). The instrument uses an optical system known as light scattering spectroscopy (LSS). In early studies, the LSS endoscope successfully identified pre-cancer in the epithelial tissue of five different organs, including in patients with Barrett's esophagus, a condition featuring an abnormal change in the cells of the lower esophagus. The device will provide physicians with a tool to rapidly survey Barrett's esophagus patients, and identify precancerous regions. This non-invasive approach is vastly superior to the present strategies of performing random biopsies. Thus it will provide a powerful tool for identifying and starting early treatment of precancerous lesions.



Photoacoustic ultrasound imaging improves minimally invasive surgery: Scientists are using novel ultrasound imaging techniques for minimally invasive surgery and other interventions such as biopsies, tumor ablation, and robotic surgery. These techniques will enable fusion of intraoperative ultrasound (IOUS) images with video from endoscopic cameras, and preoperative CT or MRI images. Such multi-modal imaging will assist surgeons in performing surgery more accurately, quickly, and safely. Current research efforts examine the removal of kidney and liver tumors. However, the techniques developed will be broadly useful across a wide range of clinical applications.

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