LUXONUS

Technology guide

Product concept design:
Actual product will differ

Luxonus Inc. is developing an imaging system that uses photoacoustic imaging (PAI) technology, a fusion of light and ultrasound, to obtain ultra-high-resolution three-dimensional (3D) images safely and conveniently without ionizing radiation. This new technology provides morphological and functional information on blood vessels and lymphatic vessels, enabling a comprehensive picture of the disease onset and healing process, as well as pre- and post-illness health conditions.

CONCEPT

We hope to contribute to medicine by providing innovative technologies in the fields of basic medicine and drug discovery research.

Technologies offered by our PAI

- non-invasive
- no exposure to ionizing radiation

- color
- 3D
- high resolution

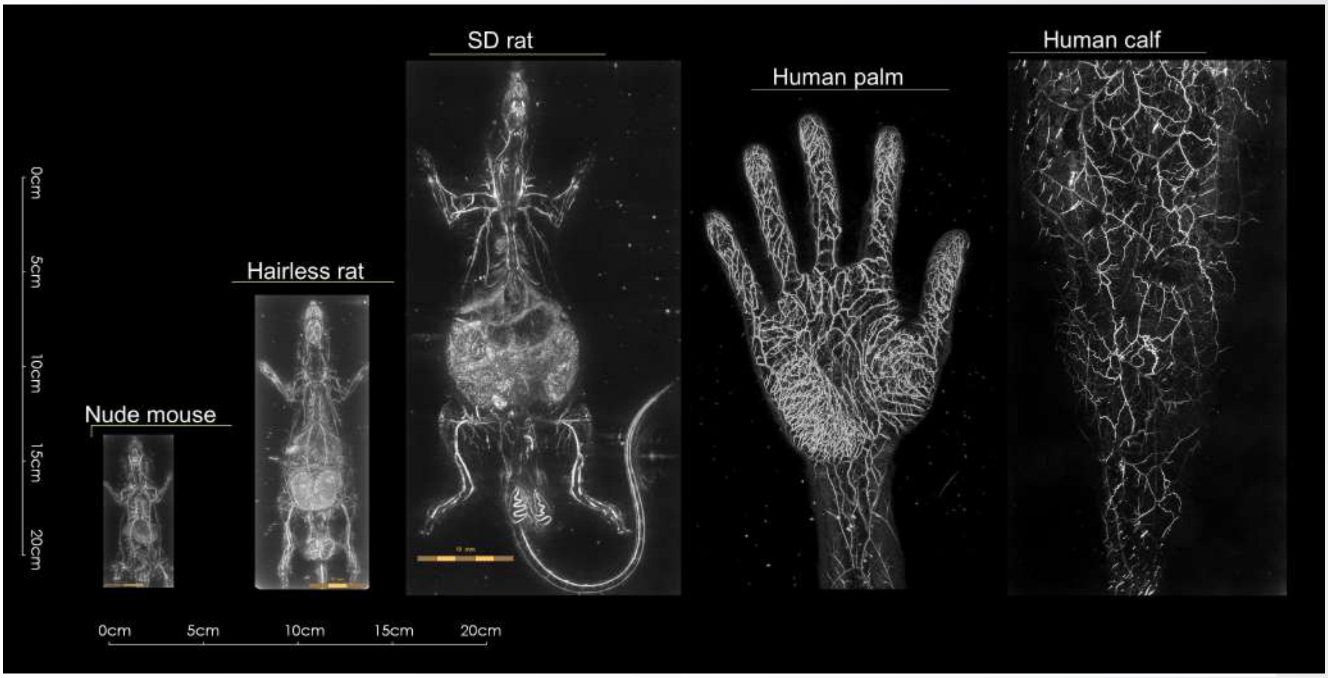
- Oxygen saturation imaging
- Spatial resolution
  - 0.1mm (HD type)
  - 0.2mm (Std type)

- Simple and convenient
- Real time

- Maximum scanning area of 180 x 290 mm can be taken within 5 minutes.
- Depth 30mm
- Video mode

Photoacoustic 3D Imaging (PAI) technology opens the door to a new world of imaging

Examples of various objects



Examples of nude mouse imaging


Torso in supine position (kidney)


Torso in prone position (liver)

An example of hairless rat imaging

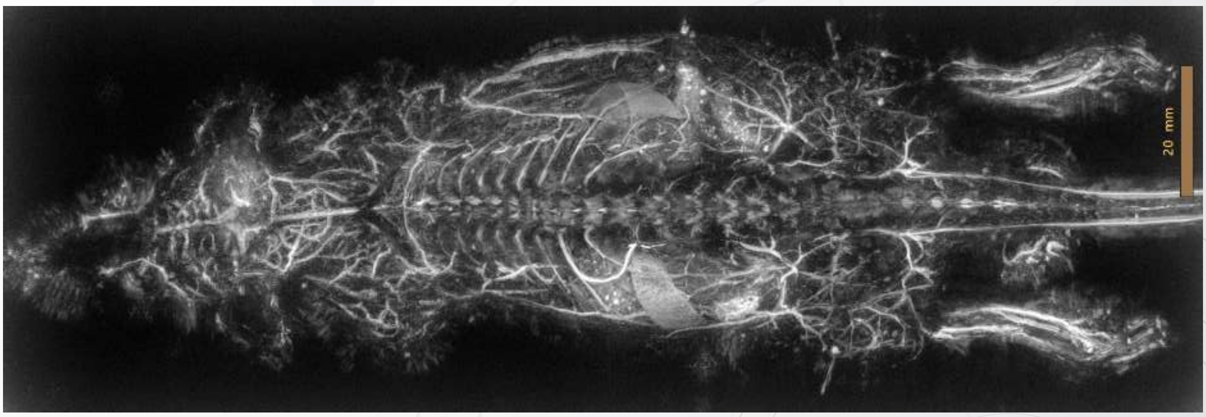
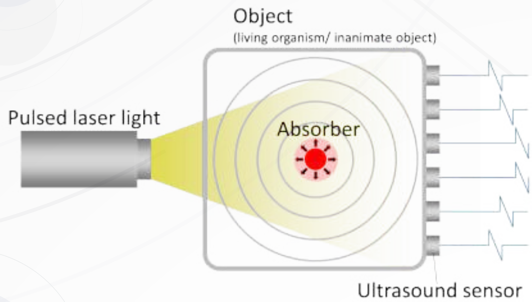


Image courtesy of
- School of Life Science and Technology, Tokyo Institute
- Department of Plastic and Reconstructive Surgery, Keio University School of Medicine. of Technology

Principle of photoacoustic imaging

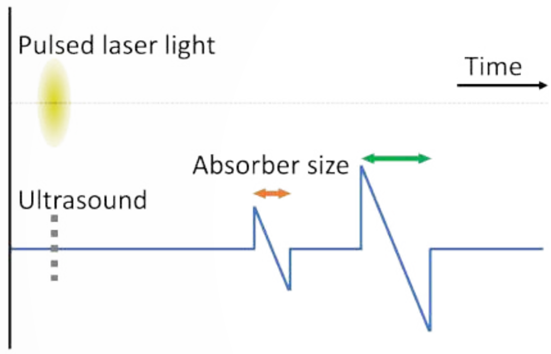
Ultrasonic wave generation by light irradiation

A pulsed laser beam from a laser is irradiated onto the object. The absorber inside the object absorbs energy from the light, causing it to rise in temperature and expand in volume. This results in the production of ultrasonic waves, which are then detected by multiple ultrasonic sensors.
In the process of changing from light energy to ultrasound generation, the color characteristics of the absorber (absorption characteristics) can be obtained as image information, similar to optical imaging.
Deep tissue visualization has been difficult with conventional optical imaging. Switching to ultrasound, which propagates throughout a living organism, enables clear visualization with high spatial resolution even at deeper areas.



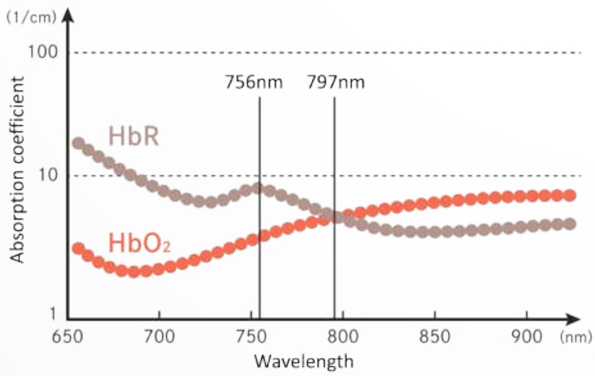
Reconstruction and 3D Imaging

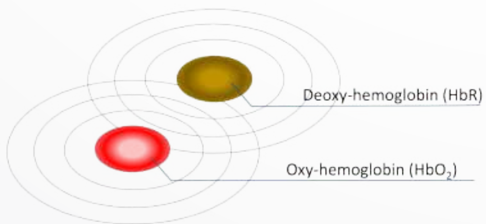
Ultrasonic waves generated by absorption of pulsed laser light from a variable-wavelength laser for 3D imaging are received by multiple sensors placed facing the absorber. For each sensor, the arrival time of the ultrasonic waves generated by the absorber is calculated based on the emission timing of the laser and the time until reception.
Based on the arrival time, positional information of each ultrasonic sensor, and propagation velocity of the object, it is possible to create a 3D image of the absorber using the back projection method (image reconstruction).
The size and shape of the absorber is reflected in the generated ultrasonic waveform. If the shape of the absorber is small, the generated ultrasound waveform will have a narrow time axis. If the shape of the absorber is large, the waveform will have a wider time axis. Using this waveform information, the size of the absorber can be measured.



Visualization of color

In photoacoustic imaging, color characteristics (differences in absorbance properties) of absorbers can be visualized by irradiating multiple combinations of pulsed laser beams with wavelengths that correspond to the optical properties of the absorber.
For example, hemoglobin (Hb) as an absorber has a different light absorption spectrum due to differences in oxygen saturation. By focusing on this difference and irradiating pulsed laser light at two wavelengths (e.g., 756 nm and 797 nm) that match the oxygen saturation of Hb, the intensity of the sound waves generated at each wavelength is different. By imaging this ultrasound intensity ratio, it is possible to image the difference in Hb color, i.e., the Hb oxygen saturation in vivo.

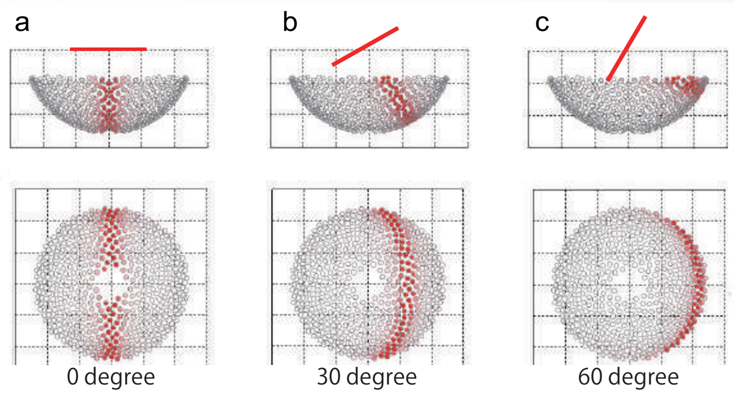




System Features

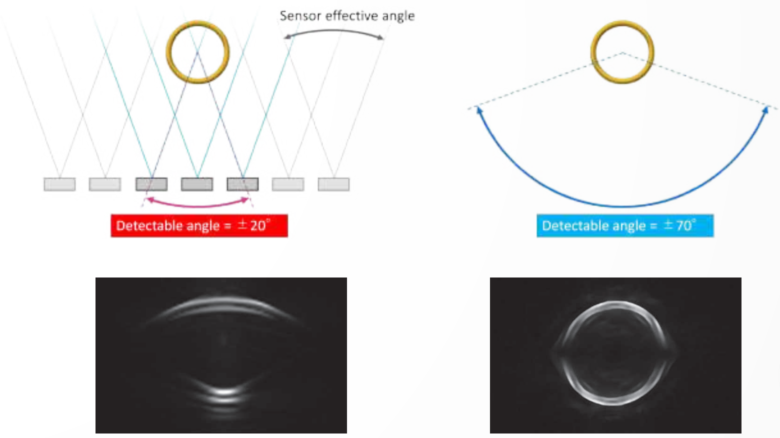
Utilization of hemispherical detector array (HDA): improvement of 3D imaging performance

It is known that ultrasonic waves generated by light irradiation on a linear optical absorber such as a blood vessel propagate in the orthogonal direction of the line.
We employed an HDA to improve the reproducibility of vascular vessel imaging.



Utilization of an HDA provides continuous morphological information by enabling virtually uninterrupted imaging of blood vessels and lymphatic vessels running in various directions.

Nagae, K. et al. Real-time 3D Photoacoustic Visualization System with a Wide Field of View for Imaging Human Limbs. F1000Research 7:1813 (2019).



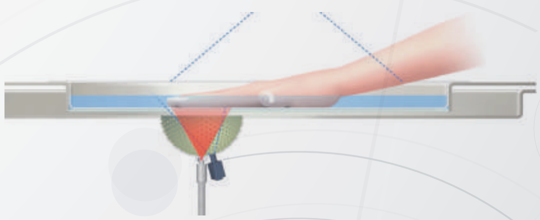
Linear (1D) probe

Hemispherical detector array (HDA)

When the object to be measured is ring-shaped, the linear probe of a conventional ultrasound system cannot reproduce the ring shape.
Using an HDA results in a more accurate 3D image reproduction.

Adoption of sensor scanning mechanism: expands imaging range while maintaining resolution

The area of 3D imaging obtained by a single light irradiation is only a cylindrical area with a 22-mm-diameter circle as the base. Therefore, we have adopted a system configuration in which the HDA is moved and scanned in the horizontal plane to capture images of an area of 290 mm x 180 mm at maximum.
By fixing the HDA in a specific position, it is possible to capture 3D motion images within a range of 22 mm in diameter. By fluctuating the sensor slightly, motion images with less artifacts can be obtained.

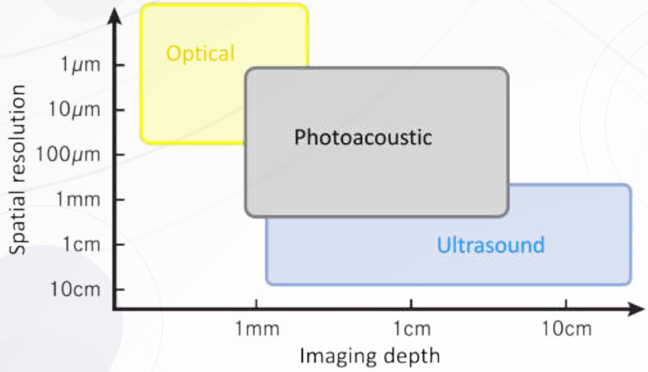


Comparison with other modalities

Positioning of PAI

Optical imaging, as represented by optical coherence tomography (OCT) and two-photon excitation microscopy, provides high resolution but shallow imaging depth, while ultrasound systems provide high depth but limited resolution.

PAI falls somewhere in between.



PAI does not use contrast media and expresses imaging of minute blood vessels better than MRI and CT using existing contrast media. It is noninvasive because it uses a laser of a strength that does not damage the skin. Since ultrasound is detected by irradiating light, the measurement can be repeated many times without exposure to ionizing radiation. Furthermore, the system does not require facilities or restricted areas for shielding from ionizing radiation or magnetism, as is the case with MRI and CT, making the hurdles to introducing the equipment low.
In addition, since the measurement can be performed simply by placing a specimen on the device, imaging is easy, and it is possible to image small animals such as mice as well as large animals including humans, regardless of the size of the specimen.

	Photoacoustic	ICG fluorescence	Ultrasound	MRI for mice	CT for mice
Non-invasive exposure-free	✓✓✓	✓✓	✓✓✓	✓✓	—
Visualization of vascular network	✓✓	✓	✓✓	✓✓	✓✓
Hb oxygen saturation	✓✓	—	—	✓	—
Visualization of lymphatic network	✓✓ (ICG use)	✓	✓	✓	✓
Visualization of melanin	✓✓	—	—	✓	✓
3D imaging	✓✓	—	✓	✓✓	✓✓
3D motion image	✓✓	—	✓	✓	✓
Simplicity and immediacy	✓✓	✓✓	✓✓	✓	✓
Small animals (mice, rats, etc.)	✓✓	✓✓	✓✓	✓✓	✓✓
Large animals (dogs, pigs, etc.)	✓✓	✓	✓✓	—	—

✓✓✓:Excellent, ✓✓:Good, ✓:Fair, —:Poor or N.A.

Related Papers

System	Nagae, K. et al. Real-time 3D Photoacoustic Visualization System with a Wide Field of View for Imaging Human Limbs. F1000Research 7:1813 (2019).
Breast cancer	Matsumoto, Y. et al. Visualising peripheral arterioles and venules through high-resolution and large-area photoacoustic imaging. Sci. Rep. 8 (2018).
	Toi M, Asao Y, Matsumoto Y, et al.: Visualization of tumor-related blood vessels in human breast by photoacoustic imaging system with a hemispherical detector array. Sci Rep. 2017; 7: 41970.
	Yamaga I et al., Vascular branching point counts using photoacoustic imaging in the superficial layer of the breast: A potential biomarker for breast cancer. Photoacoustics Volume 11, September 2018, Pages 6-13
Lymphedema	Kajita H. and Kishi K., High-Resolution Imaging of Lymphatic Vessels with Photoacoustic Lymphangiography, Radiology 2019; 292:35
	Kajita H. et al., Photoacoustic lymphangiography, J Surg Oncol. 2020; 121: 48-50
	Suzuki Y. et al., Subcutaneous Lymphatic Vessels in the Lower Extremities: Comparison between Photoacoustic Lymphangiography and Near-Infrared Fluorescence Lymphangiography, Radiology VOL. 295, NO. 2
Free flap	Tsuge I. et al., Photoacoustic Tomography Shows the Branching Pattern of Anterolateral Thigh Perforators In Vivo, Plastic and Reconstructive Surgery: May 2018 - Volume 141 - Issue 5 - p 1288-1292
	Tsuge I. et al., Preoperative vascular mapping for anterolateral thigh flap surgeries: A clinical trial of photoacoustic tomography imaging, Microsurgery, Volume40, Issue3, March 2020, Pages 324-330
Psoriasis	Ishida Y., Photoacoustic imaging system visualizes restoration of peripheral oxygenation in psoriatic lesions, J Eur Acad Dermatol Venereol. 2018 Dec;32(12):e449-e451.
Hand	Matsumoto Y. et al., Label-free photoacoustic imaging of human palmar vessels: a structural morphological analysis, Scientific Reports volume 8, Article number: 786 (2018)
	Saito S. et al., Digital artery deformation on movement of the proximal interphalangeal joint, Journal of Hand Surgery, Volume: 44 issue: 2, page(s): 187-195

COMPANY

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