Chapter 1

Photoacoustic Tomography: Deep Tissue Imaging by Ultrasonically Beating Optical Diffusion

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PHOTOACOUSTIC TOMOGRAPHY: Deep Tissue Imaging by Ultrasonically Beating Optical Diffusion

Conventional PAM

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Photoacoustic tomography has been developed for in vivo functional, metabolic, molecular, and histologic imaging by physically combining optical and ultrasonic waves. Broad applications include early-cancer detection and brain imaging. High-resolution optical imaging—such as confocal microscopy, two-photon microscopy, and optical coherence tomography—is limited to superficial imaging within the optical diffusion limit (~ 1 mm in the skin) of the surface of scattering tissue. By synergistically combining light and sound, photoacoustic tomography provides deep penetration at high ultrasonic resolution and high optical contrast.

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In photoacoustic computed tomography, a pulsed broad laser beam illuminates the biological tissue to generate a small but rapid temperature rise, which leads to emission of ultrasonic waves due to thermoelastic expansion. The unscattered pulsed ultrasonic waves are then detected by ultrasonic transducers. High-resolution tomographic images of optical contrast are then formed through image reconstruction. Endogenous optical contrast can be used to quantify the concentration of total hemoglobin, the oxygen saturation of hemoglobin, and the concentration of melanin. Exogenous optical contrast can be used to provide molecular imaging and reporter gene imaging as well as glucose-uptake imaging.

Motivations for Imaging with Light

- Light-matter interaction uniquely positioned at the molecular level
- Fundamental role of molecules in biology and medicine
- *In vivo* functional imaging analogous to functional MRI
- *In vivo* metabolic imaging analogous to PET
- *In vivo* molecular imaging of gene expressions or disease markers
- *In vivo* label-free histologic imaging of cancer without excision

Oxy- & deoxy-hemoglobins

Brain activation

Glucose uptake

Melanoma hallmark

Photoacoustic microscopy of cell nuclei

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Challenges in Optical Penetration

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The annual conference on photoacoustic tomography has become the largest in SPIE's 20,000-attendee Photonics West since 2010.

Wavefront engineering and compressed ultrafast photography will be touched upon.

Selected Publications:

1. Nature Biotechnology 21, 803 (2003).
2. Nature Photonics 5, 154 (2011).
3. Science 335, 1458 (2012).
4. Nature Methods 13, 67 (2016).

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