World's Deepest-Penetration and Fastest Optical Cameras: Photoacoustic Tomography and Compressed Ultrafast Photography

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We developed photoacoustic tomography to peer deep into biological tissue. Photoacoustic tomography (PAT) provides *in vivo* omniscale functional, metabolic, molecular, and histologic imaging across the scales of organelles through organisms. We also developed compressed ultrafast photography (CUP) to record 10 trillion frames per second, 10 orders of magnitude faster than commercially available camera technologies. CUP can tape the fastest phenomenon in the universe, namely, light propagation, and can be slowed down for slower phenomena such as combustion.

PAT physically combines optical and ultrasonic waves. Conventional high-resolution optical imaging of scattering tissue is restricted to depths within the optical diffusion limit (~1 mm in the skin). Taking advantage of the fact that ultrasonic scattering is orders of magnitude weaker than optical scattering per unit path length, PAT beats this limit and provides deep penetration at high ultrasonic resolution and high optical contrast by sensing molecules. Broad applications include early-cancer detection and brain imaging. The annual conference on PAT has become the largest in SPIE's 20,000-attendee Photonics West since 2010.

CUP can image in 2D non-repeatable time-evolving events. CUP has a prominent advantage of measuring an x, y, t (x, y, spatial coordinates; t, time) scene with a single exposure, thereby allowing observation of transient events occurring on a time scale down to 100 femtoseconds, such as propagation of a light pulse. Further, akin to traditional photography, CUP is receive-only—avoiding specialized active illumination required by other single-shot ultrafast imagers. CUP can be coupled with front optics ranging from microscopes to telescopes for widespread applications in both fundamental and applied sciences.

Selected publications

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16. Nature Communications 6, 5904 (2015).
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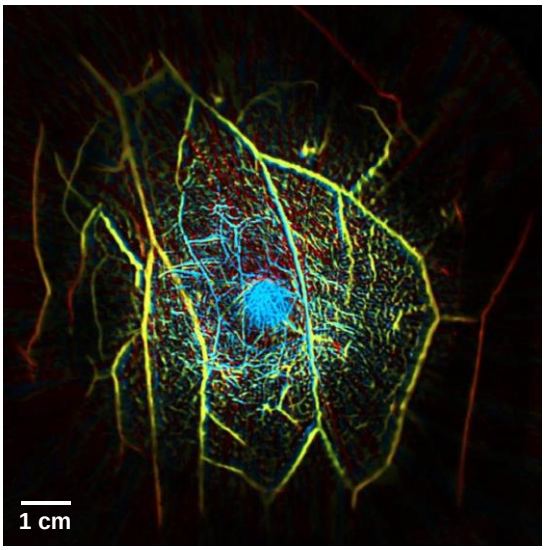

***In vivo* 3D photoacoustic tomography image of a human breast**