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# Bright-field Photoacoustic Tomography

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## 1. Introduction

Photoacoustic imaging (PAI) is a hybrid technique based on the photoacoustic effects that results from the formation of acoustic waves due to light absorption in sample [1,2]. When a short pulsed laser irradiates biological tissues, acoustic waves can be generated within the irradiated volume following the transient thermo-elastic expansion of the tissues. Using an ultrasound transducer, these acoustic waves can be detected and collected to reconstruct a photoacoustic image of the spatial distribution of light absorbers from the tissue compositions. Photoacoustic tomography (PAT) system can be classified into two illumination schemes: dark field and bright field. The dark-field PAT has a long optical path length on increasing irradiated surface to deeper PA signals. As a result, this method contains an unexpected dark regions. In contrast, the bright-field approach can deliver higher laser fluence to a targeted volume by using a short optical path length, which reduces loss due to strong light scattering inside biological tissues. Therefore, bright-field PAT illuminates the entire imaging plane of the ultrasound transducer and effectively combines the contrast of optical imaging techniques with the depth of penetration and resolution of ultrasound imaging. The modality allows deep imaging inside biological tissue that holds a promise for diagnostic imaging and guided for cancer treatment.

Here we designed a portable bright-field PA probe for PAT system by integrating an ultrasound transducer, an objective lens, a prism, and a multimode optical fiber. The proposed probe can provide deep PA imaging with the excellent image resolution at the microscopic level while retaining the advantages of being practical, cost-effective and portable. To demonstrate the feasibility of the system, *in vivo* imaging of mouse ear was performed to demonstrate the prospect of the system in clinical applications.

## 2. Materials and methods

Fig. 1 illustrates a schematic diagram of experimental set-ups for in vivo PAI. A 532-nm

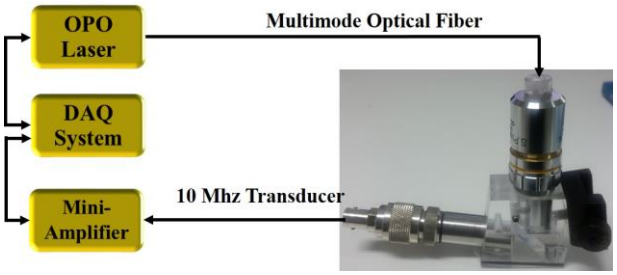


Fig. 1 Block diagram of bright-field photoacoustic tomography (PAT). OPO: optical parametric oscillator; DAQ: data acquisition.

Q-switched Nd:YAG laser (Surelite III, Continuum, CA, USA) with a pulse duration of 5 ns at 10 Hz was used as a pumping source in conjunction with a tunable optical parametric oscillator (OPO; Surelite OPO Plus, Continuum, CA, USA) with a wavelength range of 670~1064 nm. Then, laser light was coupled into a 600-μm core-diameter multimode optical fiber before being delivered to a 10X objective lens with the numerical aperture of 0.25 and illuminated into the imaging target. A 10-MHz, single-element ultrasound transducer (Olympus NDT, Waltham, MA, USA) was integrated with the objective lens as showed in Fig. 1. Lastly, a 20 mm x 20 mm optical prism was used to confirm that the laser beam was co-aligned with the ultrasound transducer to irradiate and image the same sample site.

The PA probe was mounted on a 2D linear actuator for raster scanning the water-immersion sample. A low-noise mini-amplifier was employed to amplify the received PA signals. Then, a 100-MS/s data acquisition (DAQ; PXI-5122, National Instruments, TX, USA) system digitized the amplified signals and recorded the digitized data to an embedded controller for post-processing PAT images.

## 3. Results

The *in vivo* image of the nude mouse ear acquired by bright-field PAT is shown on Fig. 2. The maximum intensity projection (MIP) PA image

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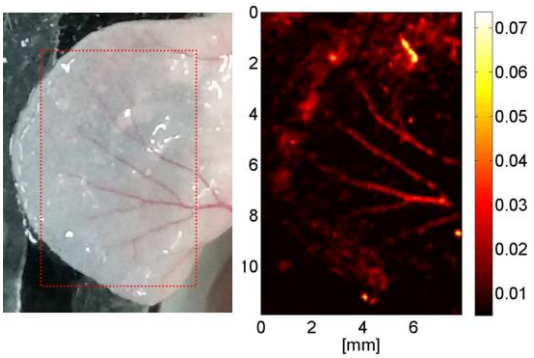


Fig. 2 In vivo bright-field PAT of a mouse ear. (left) Photograph. (right) Maximum intensity projection PAT image of the mouse ear at 700 nm irradiation.

acquired at 700 nm along Z-axis to the XY plane of the sample is displayed over a 12 x 8 mm field of view. The image clearly shows the blood vessels inside the sample.

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**References**

1. E. De Montigny: *Photoacoustic Tomography: Principles and applications* (OCIS, 2011).
2. N. Q. Bui, K. K. Hlaing, V. P. Nguyen, T. H. Nguyen, Y.-O. Oh, X. F. Fan, Y. W. Lee, S. Y. Nam, H. W. Kang, and J. Oh: Comput. Med. Imaging Graph. **45** (2015), 57-62.