High-resolution volumetric optical imaging modalities, such as confocal microscopy, two-photon microscopy, and optical coherence tomography, have become increasingly important in biomedical imaging fields. However, due to strong light scattering, the penetration depths of these imaging modalities are limited to the optical transport mean free path (~1 mm) in biological tissues. Ultrasound-mediated optical imaging (photoacoustic imaging, optoacoustic imaging, or acousto optical imaging), emerging hybrid modalities that can provide strong endogenous and exogenous optical absorption contrasts with high ultrasonic spatial resolution, have overcome the fundamental depth limitation while keeping the spatial resolution. The image resolution, as well as the maximum imaging depth, is scalable with ultrasonic frequency within the reach of diffuse photons. In biological tissues the imaging depth can be up to a few centimeters deep.

In this Lecture, the following topics will be discussed; (1) various multi-scale ultrasound-mediated optical imaging systems (i.e., photoacoustic microscopy and tomography, intravascular photoacoustic/ultrasound catheter, photoacoustic/ultrasound endoscopy, clinical photoacoustic/ultrasound scanner, acousto optical imaging, photothermal strain imaging, X-ray induced acoustic tomography, and photoactivated atomic force microscopy), (2) morphological, functional, and molecular ultrasound-mediated optical imaging, and (3) current and future clinical applications.

Keywords: Ultrasound imaging-Photoacoustic/Optoacoustic/Thermoacoustic, Optical Imaging, Multimodal Imaging, Multimodal Molecular Imaging
High Performance Clinical Photoacoustic/Ultrasound Image Processing: from Conventional to Deep Learning Approach

Photoacoustic imaging (PAI) has gained great interest in a variety of clinical applications. The principle of PAI is based on the photoacoustic (PA) effect, which is energy transduction from light to ultrasound (US) waves. Thanks to the natural combination of optical and ultrasound imaging (USI) techniques, PAI can be easily integrated into a conventional clinical US machine because the signal receiving and image generation procedure of these two modalities are similar. Thus, the dual-modal PA/US images provide complementary information for accurate clinical diagnoses. To make clinical studies successful, it is critical to develop advanced PA/US beamforming techniques in real time.

In this Lecture, the following topics will be covered: (1) principles and comparisons of various PA/US beamforming techniques in the time-domain (e.g., delay-and-sum, back projection, delay-multiply-and-sum, and nonlinear $p$-th root delay-and-sum), frequency-domain (e.g., Fourier and nonlinear spectral magnitude), numerical (e.g., model-based reconstruction and time reversal), and adaptive (e.g., minimum variance) beamforming algorithms. (2) More interestingly, recent progresses on machine- or deep-learning beamforming algorithms will be discussed. These machine- or deep-learning beamforming methods have been explosively investigated to improve spatio/temporal resolutions and SNRs beyond physical limitations. (3) Lastly, real-time computation in CPU and GPU will be introduced.

Keywords: Photoacoustic/Optoacoustic/Thermoacoustic, Image reconstruction and enhancement - Machine learning / Deep learning approaches, Multimodal image fusion
Biomedical optics is a rapidly growing area of research. Particularly, optical imaging is currently emerging as a promising new addition to medical imaging. The main reasons for optical imaging include: (1) Optical photons are nonionizing and safe. (2) Optical spectra are unprecedentedly sensitive to molecular conformation of tissue. Thus, various optical imaging modalities have been developed and clinically applied in both microscopic and macroscopic domains.

The contents of this Lecture are divided into two main parts: (1) basic principles of photon migration in biological tissue and (2) advanced optical imaging. The first part will cover the fundamentals of tissue optics, numerical Monte Carlo simulation of photon migration, analytical radiative transfer equation, and diffusion theory. Hands-on experiences on numerical simulations will be provided. The second part will cover confocal microscopy, multi-photon microscopy, optical coherence tomography, and diffuse optical tomography. Per each modality, the following topics will be covered: the principles, systems, and applications. Each part requires three hours of lecture.

Keywords: Optical Imaging, Confocal Microscopy, Two-photon Microscopy, Optical Coherence Tomography, Diffuse Optical Tomography