Title: Development of Handheld Probe for Optoacoustic Imaging and Sensing: Algorithm and System

Abstract: Optoacoustic technique, also known as photoacoustic technique, is a powerful tool to "listen the sound of light" in physiological environment. Combining the rich optical-absorption contrast and high acoustic-resolution in a long penetration depth, optoacoustic imaging, as a multi-wave imaging modality, reveals a wide range of superiorities compared to other single-wave imaging modalities (e.g., optical coherence tomography, magnetic resonance imaging, and ultrasonography). In recent decades, optoacoustic technique witnessed tremendous growth in terms of mechanism exploration, system development, reconstructive algorithm, imaging and sensing applications, etc.

As one of the frontiers of optoacoustic research, development of portable, handheld, and wearable optoacoustic system attracts ever-increasing attention in these years. In general, in pursuit of the system miniaturization, efforts could be exerted mainly on three aspects—optical illumination method, acoustic detection method, and backend electronics. This Ph.D. dissertation will comprehensively investigate the handheld design in these three aspects and present a set of developed handheld optoacoustic imagers, from the prospect of optoacoustic system design, optoacoustic probe design and development of fast image reconstructive method.

After a brief overview of the optoacoustic technique, this dissertation sets out with the fundamental mechanism of the optoacoustic generation (section 2.1). In section 2.2, several mainstream implementations of optoacoustic system are introduced. In section 2.3, optoacoustic imaging effect using different reconstructive methods are presented. In parallel, analogue reconstruction methods in ultrasonography are also compared and summarized.

In the third chapter of the dissertation, several developed handheld optoacoustic imaging and sensing system are introduced. In section 3.1, an all-in-one handheld optoacoustic imager is proposed, in which all the optical and acoustic components are integrated into a compact handheld probe. In section

3.2, separating the bulky laser illumination and handheld optoacoustic probe, the miniaturized handheld optoacoustic imager, as the second generation, is presented. In section 3.3, employing modulated continuous wave laser illumination, a portable optoacoustic temperature sensing device is developed. In section 3.4, based on the previous continuous wave illumination design, a wearable optoacoustic imager is further developed, as the third generation.

In the fourth chapter of the dissertation, affiliated with the handheld volumetric imaging system, a dedicated fast reconstructive algorithm is developed. In section 4.1, GPU accelerated time domain 2D synthetic aperture focusing reconstructive method are proposed. In section 4.2, fitting the stratified acoustic environment in the handheld probe, a dedicated fast reconstruction algorithm based on the fast-phase migration (PSM) method is developed.

In summary, with the aim of the clinical translation of optoacoustic technique, this Ph.D. dissertation investigates the development of handheld optoacoustic technique with portable imaging system, compact handheld probe, and fast frame rate. This dissertation highlights the technological and scientific potential of the 3D optoacoustic imaging entering the new field of portability and handheld operation.