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Characterization of a Low-Cost, Handheld Photoacoustic System with Simulations

Javier G. Muñoz[1,+], Alejandro Ariza-Carrasco[1,2,+], Joaquín L. Herraiz[1,2], José M. Udias[1,2], Paula Ibáñez García[1,2] and Mailyn Pérez-Liva[1,2,*]
[1]Nuclear Physics Group and IPARCOS, Department of Structure of Matter, Thermal Physics and Electronics, CEI Moncloa, Universidad Complutense de Madrid, 28040 Madrid, Spain
javiga25@ucm.es, alariza@ucm.es, jlopezhe@ucm.es, jose@nuc2.fis.ucm.es, pbibanez@ucm.es, mailyn01@ucm.es
[2]Health Research Institute of the Hospital Clínico San Carlos, C/ Profesor Martín Lagos, 28040 Madrid, Spain
[+]both authors contributed equally and shared the first authorship
*corresponding author: M.P-L: mailyn01@ucm.es

Extended Abstract

Photoacoustic imaging (PAI) is a promising technique that combines optical and ultrasound imaging to provide high-contrast images of biological tissues [1-3]. Utilizing laser diodes as the light source, PAI systems can be designed to be low-cost and handheld, making them accessible for various clinical applications [4,5]. In this study, we developed a numerical model to characterize and optimize a low-cost, handheld photoacoustic system based on semiconductor laser diode panels. The simulation of the panels included the technical characteristics of the diodes and the physics of the optical propagation in the red and infrared spectra using ValoMC, a Monte Carlo software [6]. Additionally, we simulated the broadband ultrasound probes of our system, which is a 128-element probe with a center frequency of 7.5 MHz, a pitch of 0.3 mm, an elevation of 4 mm, and an elevation focus of 20 mm from Vermon. Acoustic simulations were performed with k-Wave [7], including an absorbing heterogeneous acoustic medium.

We implemented the reconstruction of the simulated signals with the Delay and Sum algorithm [8] with refraction correction based on ultrasound maps obtained from complementary sequences using scatter tracking in multi-angle imaging in planewave sequences. Time reversal [9] with attenuation correction reconstructions was also applied. Our simulation-reconstruction framework aimed to optimize the spatial resolution and image quality of the photoacoustic system. The expected spatial resolution was found to be approximately 200 micrometres, with high-contrast images demonstrating the system's potential for detecting small-scale features within biological tissues. The combination of ValoMC and k-Wave provided a comprehensive simulation environment, allowing us to evaluate the performance of the photoacoustic system under various conditions. The results indicated that the system could achieve high spatial resolution and image quality, making it suitable for clinical diagnostics and research applications. By integrating semiconductor laser diodes with advanced acoustic imaging techniques, we demonstrated that it is possible to create a cost-effective, handheld photoacoustic imaging device that maintains high performance.

In conclusion, our numerical model successfully characterized a low-cost, handheld photoacoustic system based on semiconductor laser diode panels. The simulations and reconstructions validated the system's design, showing that it can produce high-resolution, high-contrast images suitable for clinical use. This study lays the groundwork for further development and optimization of affordable photoacoustic imaging systems, potentially expanding their use in medical diagnostics and other applications.

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