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Simulations of Thermally Induced Photoacoustic Wave Propagation Using a Pseudospectral Time-Domain Method

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Physical models used to evaluate thermally induced photoacoustic waves in biomedical applications are mostly approximations based on certain hypotheses, such as the thermal and stress confinements, for the sake of obtaining analytical results. On the other hand, using numerical methods to solve the general photoacoustic wave equations gives detailed information of wave phenomena without making as many assumptions. The photoacoustic wave generated by thermal expansion involves the heat conduction theorem and the state, continuity, and Navier-Stokes equations. In this study a numerical approach was developed in 2.5D axis-symmetric cylindrical coordinates using a pseudospectral time-domain (PSTD) scheme. The method is efficient for large scale simulations in that only two grids for the smallest wavelength are required, where in conventional methods 10∼20 grids are typically needed. The numerical techniques include Berenger's perfectly matched layers (PMLs) for free wave simulations, and linear-perturbation analytical solutions are used to validate the simulation results. The numerical results using 2 grids for the minimum wavelength in simulation domain agree with theory to within an error of 7×10^{-3} in the absolute differences. On the other hand, conventional methods such as finite-difference time-domain method requiring 10 grids result in an error of 1.3×10^{-3}.