論文 / 著書情報
Article / Book Information

題目(和文)	光音響励起された共鳴によるソフトファントムに埋め込まれた液体で満たされた細い管の特性推定
Title(English)	Characterization of liquid-filled thin tubes embedded in soft phantom through photoacoustically excited resonances
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種別(和文)	論文要旨
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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子　系 ライフエンジニアリング　コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　学術　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Photoacoustic imaging has been intensively researched for vascular medical applications in these two decades. Not only the conventional in-vivo imaging application, but also the usage of contrast agent and the accomplishment of elasticity measurement function tend to be hot topics. However, the lack of evaluation platform for contrast agent remains problems. remain problems. To provide a solution to this problem, this study first focused on the characterization of the geometrical structure of a thin tube. The acoustic resonances in liquid-filled thin tubes embedded in a soft phantom through photoacoustic excitation were investigated. Based on these theoretical studies, an evaluation platform for the contrast agent was proposed, and then a novel method was investigated to estimate the inner diameter of the tube.

First, the principle of photoacoustic excitation and the acoustic modes in the stiff-boundary cylindrical hard tube were researched. The acoustic field and its corresponding resonance modes were studied and theoretically derived from the fundamental wave equation and the stiff boundary condition. Then, the transient acoustic response from this struture was investigated by combining photoacoustic short-pulse excitation condition into the consideration. A mathematical photoacoustic generation model was proposed. Using this model, the captured photoacoustic signal was predicted. The relationship between the excitation pulse width and the acoustic signal amplitude was clarified. A function describing the relationship between these two variables was presented in both time domain and frequency domain. Furthermore, a selection method of the optimal pulse width was discussed being based on the simulation results.

Second, a platform was designed for quantitative evaluation of photoacoustic sensitivity of liquid samples using a low power pulsed semiconductor laser and a MHz-range ultrasonic transducer to satisfy the demand of realistic evaluation. Sample liquid is confined in a thin glass capillary. The frequency dependence of the photoacoustic signal on the inner diameter of the capillaries was experimentally investigated. The influence of the pulse width was then discussed in association with the peak frequencies for many capillaries of different inner diameters. Furthermore, the influence of the pulse width on the amplitude of the generated photoacoustic signal was researched as well. To match the acoustic resonance of the target with the center frequency of the receiving transducer in a practical manner, several resonance modes were extracted and investigated. A series of experiments on the chosen resonance mode were conducted, and the relationship between the laser pulse width and the maximal amplitude of the resonance mode were experimentally studied. It was concluded that the selected pulse width should couple with the resonance frequency in the tube of the certain dimension. Moreover, it was demonstrated that the concentration of samples had very limited influence on the frequencies and the optimal pulse width. Finally, the directivity of the tube source in the section view was discussed. It was concluded that the acoustic power in specific directions vary from the resonance mode excited in the tube.

Third, the feasibility and the effectiveness of this newly developed platform were confirmed for several kinds of samples. The geometric configuration were adjusted and the driving parameters for the laser were optimized to 230 ns and 4.92 μs to maximize the signal-to-noise ratio in the generated ultrasonic signal. The performance of the platform was then quantitatively tested for several inks with different colors and a real contrast agent-Indocyanine green. The feasibility of the platform was verified by experimentally evaluating the relationship between the sample concentration and the photoacoustic signal level. Morevover, the effectiveness was further proved that the photoacoustic sensitivity of the samples behave good consistency with the optical absorbance under the same wavelength. The signal-to-noise ratio of the collected data was on average improved 2.5-fold by the resonance occurring in the glass capillary, and was superior to those obtained with the sample liquids confined in a soft tube, which occurring negligible resonance.

Finally, to provide a solution for precise measurement of thin blood vessels diameter, a novel method to measure the inner diameter of soft tube being was proposed based on the acoustic resonance perspective other than usual imaging-based method. In-vitro experiments were conducted for red-ink-filled soft tubes having diameter of less than 1 mm embedded in a tissue-mimicking phantom. Percentage error of 4% was marked in estimating the inner diameter of tube samples. Low-power laser diode and a MHz-band ultrasound transducer together with an external compressing device were used. The results demonstrated that the proposed method was feasible to detect a sub-milimeter deformation for thin tubes with an ultrasound transducer of relatively low center frequency and electronic circuit of limited temporal resolution.