RAPID DETECTION OF INHOMOGENEITY IN A TISSUE PHANTOM

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Abstract-**Detecting inhomogeneity in a turbid tissue using optical tomography technique as a non-invasive tool is of paramount importance in imaging and diagnosis of diseases and tissue abnormalities. In our approach, an ultrafast laser is used as the detecting source and the backscattered light signals are collected around the boundary of the target. We have developed a Monte Carlo program used to simulate time-dependent photon transport in inhomogeneous turbid media. As the laser pulse is attenuated by absorption and scattering, the detected temporal signal depends strongly on the optical properties of the medium and therefore leads us to the detection of inhomogeneity. Simulation results have shown that the presence of a small absorbing inhomogeneity in a highly scattering tissue will yield different log slopes in the temporal intensity profile. Further experimental studies in this paper yield similar results.**

Keywords – **Bioimaging, Optical detection, Monte Carlo simulation, Ultrafast laser experiment.**

I. INTRODUCTION

The application of near infrared ultrafast laser pulse in optical tomography has been studied intensively by various research groups because it offers a promising method in noninvasively assessing the optical properties of an internal tissue. However, image reconstruction based on inverse method to detect inhomogeneity is very time consuming and the calculation may not converge to yield any result. In an effort to reduce time in detecting inhomogeneity for potential real time applications, we have developed a novel idea to detect and locate localized spot with relatively high absorption compared to the surrounding tissue. Light shone into a turbid tissue will experience multiple events of scattering before exiting the medium and being detected by detectors located at the target boundaries. When a pulsed laser source is used, the absorption effect of the medium is characterized by the temporal decaying log slope intensity of either transmitted or backscattered signals. Therefore, we employ this knowledge to aid in the detection of inhomogeneity in turbid tissue and demonstrate it experimentally using a graphite cylinder embedded in a tissue phantom.

Fig. 1 shows the experimental model that we used to verify our method. The tissue phantom is made from a mixture of polystyrene matrix and silica microspheres of 1μm (±10%) in diameter with 1.46 refractive index value. Silica microspheres are used as scattering agent and have a concentration by volume of 0.86% of the entire tissue phantom measuring 16.1 x 96.6 x 39.1 mm^3. The above preparation of tissue phantom yields a quasi-homogeneous turbid medium with scattering coefficient of 0.37mm^{-1} and negligible absorption for visible wavelengths as no artificial

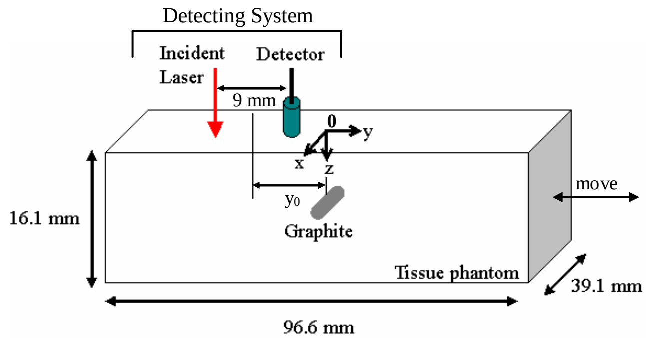

Fig. 1. -Sketch of experimental model: The laser and detector head is scanning over a tissue phantom with a graphite inclusion, through horizontally moving the sample.

absorbing agent is added during the process. The refractive index of this phantom matrix at 532nm wavelength is found to be 1.59. The tissue block is held on a translation stage and is free to move from left to right during scanning process. The incident laser is a Gaussian pulse with pulse width of 60ps generated via a Nd^{3+}:YAG mode-locked laser. The detector is located at a fixed distance of 9mm relative to the laser source to eliminate surface reflection signals.

II. RESULTS

A. Detection of Inhomogeneity

Fig. 2 shows the average log slope values plotted with respect to detecting positions from the center of coordinate system. The raw signals from both experiment and Monte Carlo simulation are normalized before their respective log slopes are calculated. The v-shape log slope profile has demonstrated the feasibility of detecting highly absorbing inhomogeneity in turbid media by utilizing decaying log slope characteristic. The tip of the profile indicates the position of the graphite inclusion, but the profile is not

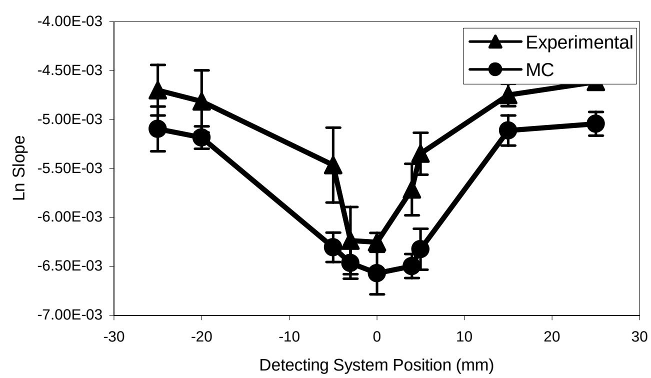

Fig. 2. – Experimental and Monte Carlo results: average log slope with error bar versus detecting system position.

symmetrical because of the 9mm gap between laser and detector in the experimental design. However, the exact size of the inhomogeneity (ϕ=1.6mm) is not clearly available in the v-shaped log slope profile. The affecting region is about 10mm and this may be caused by the fact that a 9mm gap separated the laser and detector.

B. Effect of Graphite Inclusion Diameter

The effect of graphite inclusion diameter in inhomogeneity detection is being investigated numerically. The optical properties of tissue phantom, the position of graphite inclusion and the detecting system remain unchanged. Fig. 3 shows the average log slope plotted with respect to the position of detecting system for the case where laser and detector are separated by 9mm. The depth of v-shape groove begins to diminish with reduction in graphite diameter as expected because less radiative energy is absorbed. The minimum detectable graphite diameter presuming 3% standard deviation in log slope uncertainty measurement is found to be about 0.1mm. The depth of v-shape groove is strongly related to the diameter of the inclusion. The larger the diameter is, the deeper is the v-shape groove.

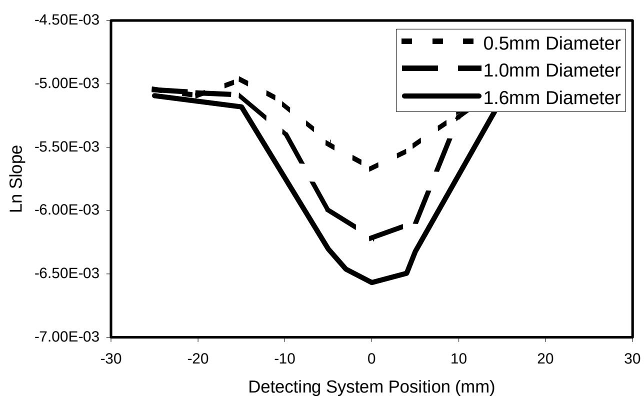

Fig. 3. –Effect of graphite's diameter on log slope: laser and detector separate.

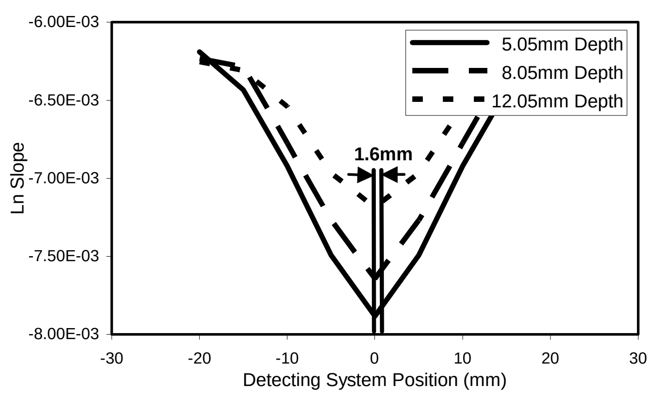

Fig. 4. –Effect of graphite inclusion's depth on log slope: laser and detector coincide and graphite diameter is 1.6mm.

C. Effect of Depth of Graphite Inclusion

The effect of depth of graphite inclusion in inhomogeneity detection is being investigated. Unlike the original experimental setup, the Monte Carlo program is modified to simulate the case when the position of laser and detector coincide with each other. Fig. 4 shows the v-shape grooves for graphite embedded at 5.05mm, 8.05mm and 12mm, respectively. The profile is now symmetrical along the centerline. The width of the groove is smaller as compared to the above plots. Apart from that, the overall magnitude of log slope has increased because the detected signal is less diffused and relatively narrower than the 9mm gap laser-detector counterpart. The percentage of graphite inclusion's volume over the entire volume of radiation propagation decreases dramatically as the depth of which it is embedded increases. The v-shape deepens when the inclusion is closer to the surface because of increase in absorption. It may be possible to estimate the depth and size by characterizing the strength of the v-shape.

III. CONCLUSION

The experimental investigation demonstrated that it is viable to utilize decaying log slope analysis as a quick preliminary technique to detect a small inhomogeneity in a turbid medium. The absorption effect of the graphite inclusion determines the steepness of the log slope and therefore tells us where it is located base on the v-shape profile. Manipulation in the Monte Carlo simulation allowed us to predict new results and investigate the effectiveness of our technique under different circumstances. Overall investigation revealed that it is possible to detect inhomogeneity under much harsher conditions. Current study only focuses on locating the position of an abnormal inclusion along the scanning positions, but 3-D image reconstruction to further pinpoint the location and size of the inhomogeneity is possible and will be our next research focus.

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