Effective Extraction of Absorbers in Scattered Medium by using Intensity Ratio of Time-Resolved Signal

Toshihiko Yamaoki, Masaya Nonaka, Kouichi Nitta, Osamu Matoba

Kobe University E-mail: matoba@kobe-u.ac.jp

1. Introduction

Measurement of three-dimensional (3D) absorption distribution in a scattered medium is very useful for biomedical applications. Optical coherent tomography (OCT) is a very powerful tool, but the measurement depth is limited to a few mm due to the multiple scattering. Optical diffused tomography (ODT) is alternative method to measure the absorption distribution in deeper depth than that by OCT. In ODT, numerical way is applied to reconstruct a 3D absorption distribution. For successful reconstruction, it is important to develop a way to extract effectively the information of absorbers in output scattered light.

For 3D reconstruction of absorbers, we have presented a method to use output scattered light distributions in a measured object and a reference medium in artificial scattering media [1, 2]. The reference medium is an ideal scattering medium that has the same scattering coefficient distribution as the measured object [1]. Especially, it is effective to extract the absorber information by taking a ratio between the output scattered light distribution in the object medium and the reference medium [2].

In this work, we present a more effective method to extract the absorber information by using a temporal gate in the output scattered light. By using a temporal gate, ballistic or snake light can be detected. By taking the intensity ratio between temporally gated output scattered light distributions, numerical results showed that the reconstruction profile of the absorber is much improved.

2. Reconstruction of Absorbers in Scattering Medium

In this work, a homogeneous scattering medium is used. To calculate the transmitted scattered light, a time-dependent optical diffusion equation is numerically solved.

$$\frac{1}{c}\frac{\partial\phi(x,z,t)}{\partial t} = D\nabla^2\phi(x,z,t) - \mu_a(x,z)\phi(x,z,t) \quad (1)$$

In Eq. (1), ϕ is fluence rate, $D=(3\mu_s)^{-1}$, μ_s is the scattering coefficient distribution, μ_a is the absorption distribution, and c is speed of light. By applying a time-gate in Eq. (1), the detected signal is described by

$$I(x;z_{0}) = \int_{0}^{t_{0}} \phi(x,z_{0}) dt, \quad (2)$$

where z_0 and t_0 are output depth position and accumulated time, respectively. We calculate the ratio of signals with

and without absorbers. Numerical parameters are presented in Table 1. From the result, the peak propagation of the signal caused by the absorber is in line. This characteristic is good for the numerical reconstruction using backprojection method. Figure 1 shows examples of the reconstructed absorber when the accumulated time is 600 ps or 100 ps. From the results, it is better to use the short accumulated time of 100 ps.

Table 1 Simulation parameters.	
Pixel size	50.0 × 50.0 μm
Medium size	30 × 10 mm
Scattering coefficient	10 mm ⁻¹
Absorption coefficient of medium	0.1 mm ⁻¹
Absorber size	1.05 × 1.05 mm
Absorption coefficient of absorber	10 mm ⁻¹
Beam width of input	768.0 μm
Number of input lights	11
Interval of each input light	1.5 mm
Time interval	5.0 fs
Maximum number of iterations	120,000



(b)

Fig. 1 Reconstructed absorption distributions when output scattered light is accumulated until (a) 600 ps and (b) 100 ps.

3. Conclusions

The combination of a ratio of output scattered light distributions with and without absorber and a temporal gate in the scattered light is effective to reconstruct successfully the absorber.

Acknowledgements

A part of this work was supported by grants of HWY2012-1-315 from JST, Japan and 08A16006d from NEDO, Japan. **References**

- [1] O. Matoba et al., Opt. Lett. 34 (2009) 998.
- [2] T. Yamaoki *et al.*, to be presented in Information Optics & Photonics in The 74th JSAP Autumn Meeting 2013.