

Photoacoustic imaging with multiple-wavelength LEDs

多波長 LED を用いた光音響映像法

Yoshitaro Adachi and Tsutomu Hoshimiya[†]

(Graduate School of Engineering, Tohoku Gakuin Univ.)

安達 吉太郎, 星宮 務[†](¹東北学院大院工)

1. Introduction

In nondestructive evaluation with photoacoustic (PA) imaging, apparatuses with monochromatic light sources have dominantly used until now. However, imaging of micro-scale spectroscopic objects such as pollen [1] with a photoacoustic microscope (PAM) requires multiple-wavelengths optical source. We have tried to apply LEDs with multiple wavelengths to PAM light source [2].

The serious problem in the application of LED to PAM is the source size, i.e., image-formation via objective lens of finite-size LED degrades PAM image spatial resolution. Fundamentally, spatial resolution of an image and spectral availability of LED and laser seems to be a trade-off relation. In the present paper, multiple fiber-coupled LEDs lights are combined to incident microscope objective. The image sizes of LEDs improve spatial resolution of the multiple-wavelengths PAM.

2. Experimental apparatus and specimens

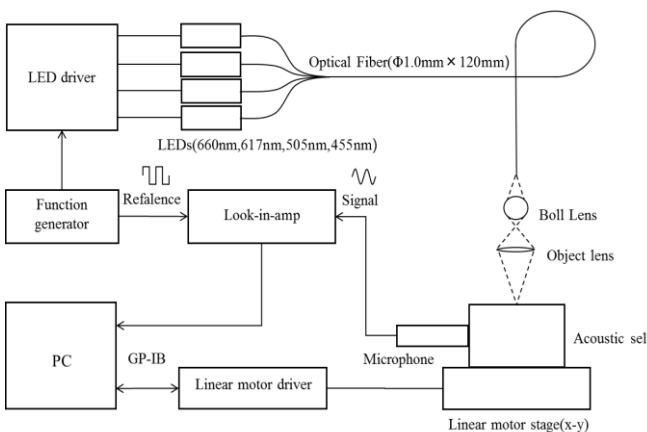


Fig. 1 Basic experimental setup

As optical sources, high-power fiber-coupled LEDs (Thorlabs) were used. A 4-channel

modulator (Thorlabs, DC4104) was used to modulate them. The wavelengths and powers of red, orange, green and blue colors were (660nm/ 4.15mW), (617nm/ 4.75mW), (505nm/ 5.02mW), (455nm/ 14.23mW), respectively.

Plastic optical fibers with a 1mm diameter (Mitsubishi Rayon, SK-40) were used to guide light beams to incident a microscope objective lens (x 20). Between combined fibers and an objective, a 10 mm diameter ball-lens was inserted. The basic experimental setup is shown in Fig. 1.

The other apparatus is the same as the previous publications [2,3]. As solid state specimens, a color-printed OHP sheet (sample #1) and powder-shaped color dyes (sample #2) were used.

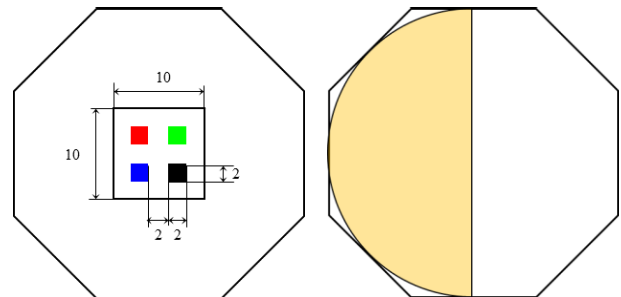


Fig.2 A 4-colored OHP sheet specimen (sample #1). And a yellow color dye powder was set on an aluminum foil specimen (sample #2).

An arrangement of the 4-colored OHP sheet specimen (sample #1) is shown in Fig. 2. The 2 mm square-shaped four color painted regions were arranged (color: upper from left, red and green; lower from left, blue and black). A yellow color dye powder was set on an aluminum foil shown in Fig. 2 was used as a specimen (sample #2). The dye powder put on the right half of the specimen was wiped out with wet cotton with ethanol. Imaging was performed through the window with a 30 mm diameter.

Scanning regions for sample #1 and #2 were 15 mm x 15mm and 30 mm x 30mm, respectively.

[†]e-mail: tpth@tjcc.tohoku-gakuin.ac.jp

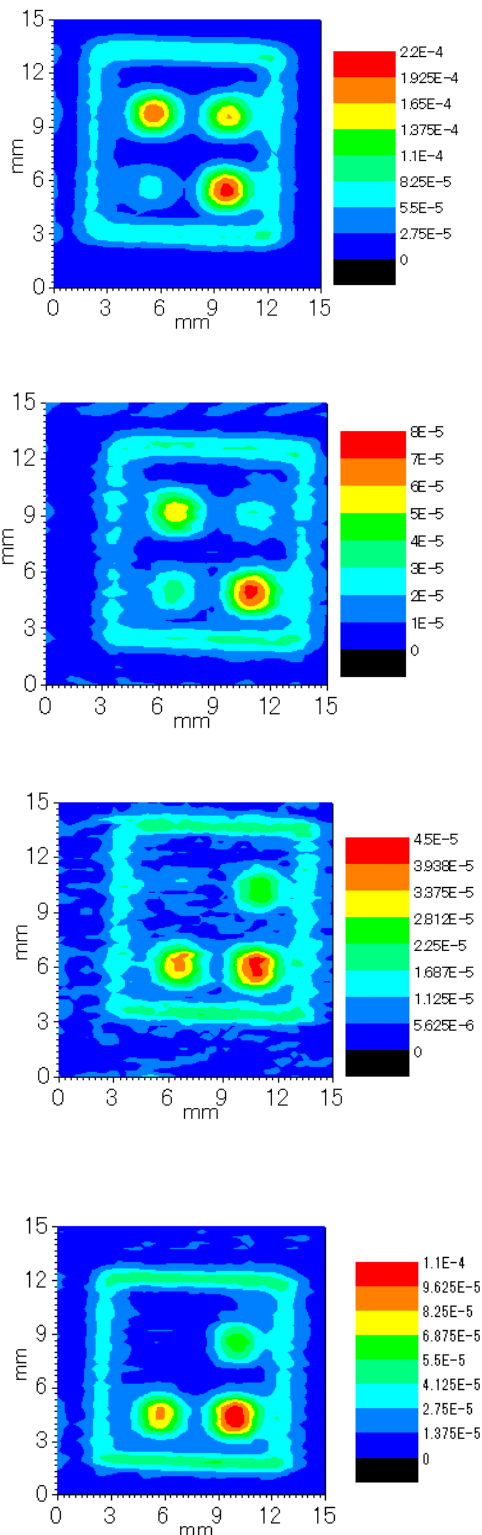


Fig. 3 PAM image of the sample #1. Excitation wavelengths were (a) 455 nm, (b) 505 nm, (c) 617 nm, and (d) 660 nm (from top to bottom).

The resolution was 50 x 50 pixels. A modulation frequency of 45 Hz was used.

3. Experimental results

The PA images of the sample #1 obtained with blue, green, orange and red LEDs were shown respectively in Figures 3 (a), (b), (c) and (d). The PA signal amplitudes reflect the differences of the absorption coefficients of the specimen for the corresponding excitation light wavelengths correctly.

In Fig.4, the PA image of the powdered yellow color dye excited by 455 nm LED was shown. The PA image of the very slight amount of color dye powder could be detected.

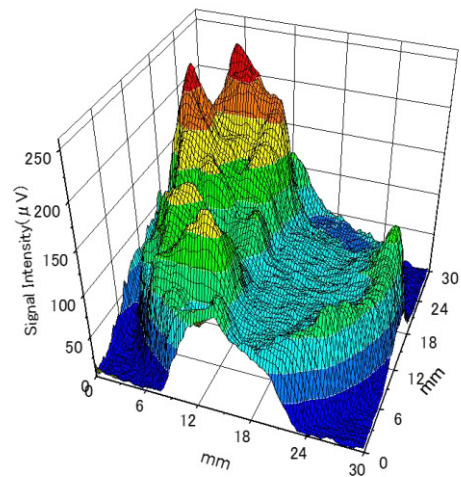


Fig. 4 PAM image of the yellow powder dye (sample #2). Excitation wavelength was 455 nm.

4. Discussions and conclusion

To perform the micro-spectroscopic quantitative analysis using PAM, further improvement of spatial resolution and the development of nearly-continuous spectral LED sources are strongly required. We would like to increase LEDs with various wavelengths and improve spatial resolution of the PAM by reducing the spot size of LED images.

References

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2. T. Hoshimiya: Proceedings of USE2010, 143 (2010).
3. H. Endoh, N. Ohtaki and T. Hoshimiya: Jpn.J. Appl. Phys. **45** (2006) 4609.