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Multiple-wavelength Resonant Photoacoustic Imaging System

多波長共鳴光音響イメージングシステムの試作

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1. Introduction

Resonatnt photoacoustic (R-PA) imaging method is a scheme to utilize an acoustic resonant phenomenon for both spectroscopic measurement and imanging [1]. This scheme has an advantage of high-sensitivity even the environment with a leaky or open PA cell configuration. Therefore, this scheme can be used spectral measurement for wide spectral range. In the present paper, R-PA imaging system using a optical parametric oscillator (OPO) and diode pumped solid-state laser (DPSSL) with R/G/B colors as optical sources was fabricated and the basic characteristics were measured.

2. Experimental Apparatus

Basic experimental arrangement of the present study is shown in Fig. 1, which is similar to that described in ref. 1. For red, green and blue color lasers, DPSSLs with wavelength and power of 671nm (500 mW), 532 nm (1000 mW) and 457 nm (200 mW) were used respectively. Furthermore, a combination of a high-repetition rate (ranging from 2.5 kHz- 100 kHz) frequency-doubled YAG laser (Baltic 355-FS laser) and a hand-made PPM (periodically polarization modulated)-type OPO was used. The oscillation wavelength of signal (visible) and idler (infrared) waves were ranging 595-640 nm and 3.15-5.024 μm for a domain period of a SHG crystal Λ = 11.5 – 13μm. The OPO oscillation wavelength can be manually tuned. The size of a spheroidal acoustic resonator used for both DPSSL and OPO is designed to be length 2a=81 mm x diameter 2b=27 mm (long and short axes ratio a/b=3) such that the resonant frequency of the cavity f_0 is 2860 Hz. The laser and OPO modulation frequency was changed from 2.5 kHz to 4 kHz to cover the whole acoustic resonance. Modulation of the laser and PA signal data acquisition were both controlled with software LabVIEW. The tuning characteristics of the acoustic resonance of the PA cell (a/b=3) was measured and shown in Fig. 2. The obtained resonance frequency (closed cell) was 2940 Hz, which agreed with the theoretical value within the accuracy of 3%. In addition, the other R-PA cell used for DPSSL with the long and short axes ratio value of a/b=9 was designed and fabricated. The resonant frequency f_0=1350 Hz in this case.

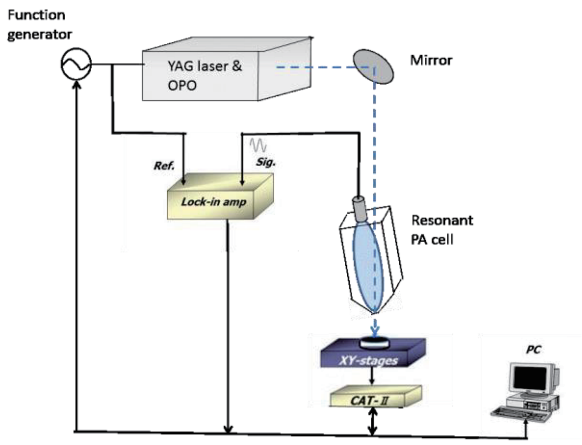

Fig. 1 Basic experimental setup

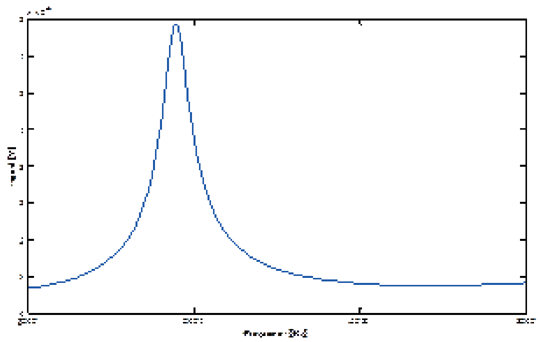

Fig. 2 Tuning characteristic (a/b=3).

3. Specimen and experimental results

At first for the imaging to detect the spectral difference, an aluminum plate with a size of 40 mm x 40 mm was painted with four colors (upper from left: blue, red and lower from left: black, green). The painted specimen was set about 3mm close at the outside of an acoustic resonator. The light source was a green color (wavelength 532 nm) DPSSL. The modulation frequency was 1490 Hz, which was about 10% higher than the resonance frequency f0 of the resonator (a/b=9) 1350 Hz.

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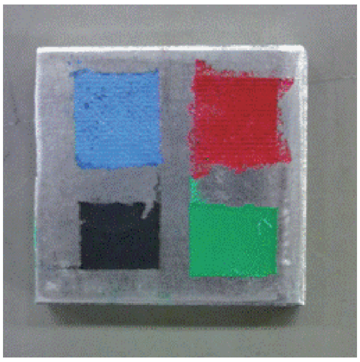
The photograph of the specimen and the obtained PA amplitude image were shown in Figures 3 (a) and (b), respectively. The scanned area was 23 mm x 23 mm. Those showed PA signal is higher at the regions colored with black (lower left) and red (upper right) regions, where the absorption of green light is higher than the other regions.



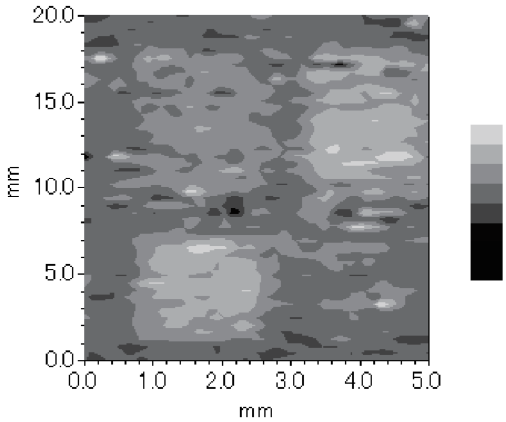


Fig. 3 (a) Aluminum colored specimen (upper)

(b) PA amplitude image (lower)

Next, to demonstrate the ability of OPO PA imaging, a circular brass plate with the diameter and thickness of 25 mm and 4 mm, respectively, painted with a black paint was used for a specimen. The resonant frequency for the open or leaky cavity (a/b=3) was about 3120 Hz, in which the specimen was set about 10 mm apart from the open aperture with a diameter 9 mm ϕ .

The PA imaging with the 532 nm output of the pulse-mode OPO output was shown in Fig. 4. The output power was 244 mW. In this measurement, a band-pass filter (NF FV-651) was used to reduce the background noise. The central frequency and Q-factor was 3100 Hz and 5, respectively. The resolution of the image was 50 x 50 pixels. The obtained image clearly showed the specimen shape, which proved the lock-in detection simultaneously used with a nanosecond region laser pulse achieved the same grade image quality with that obtained with a sinusoidally modulated continuous-wave (cw) laser light. .

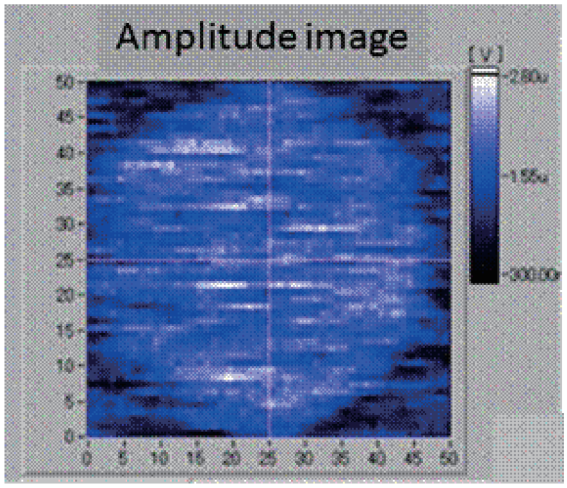


Fig. 4 PA amplitude image obtained with the R-PA scheme. The distance from the specimen and cavity was about 10 mm.

4. Discussions and conclusion

To summarize the present study, the imaging system using the R-PA scheme with various excitation wavelengths was designed and fabricated in for the first time. The present R-PA imaging scheme has the advantage that can be operated under the open or leaky environment for the acoustic sealing. That characteristic is advantageous for the applications: i) detection of a large size specimen under study (free from the restriction to include in a PA cell) and ii) wide-range frequency scanning (free from the window transmission restriction).

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References

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