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# Photoacoustic tuning characteristics and imaging using a spheroidal acoustic resonance cell with leakage

漏洩のある回転楕円体共鳴セルを用いた光音響信号の同調特性とイメージング

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## 1. Introduction

The resonant photoacoustic (R-PA) imaging was proposed, and its ability for the PA imaging of the specimen set external to the PA cell was demonstrated by author's group [1-4].

Traditionally, the effect of a small leakage in an acoustic resonator can be treated by a boundary-perturbation (BP) theory. However, for an open acoustic resonator with a large leakage used in a photoacoustic (PA) detection with a spheroidal resonator, the BP theory tends to be violated.

In the present paper, the equivalent acoustic circuit analysis was performed using cell size and the tuning characteristic for the closed resonator. The circuit parameters for the RLC acoustic resonant circuit were determined. The tuning characteristics was investigated experimentally and compared with the theoretical calculation.

This scheme was also applied to PA imaging setting the specimen 1mm apart from the PA cell without any sealing. The amplitude and phase PA imaging of a layered specimen showed the advantage of the present scheme (freedom from sealing) for the applications to the spectroscopic measurement or nondestructive evaluation.

## 2. Tuning characteristics --experimental and theretical--

Experimental setup for resonance is the same as the one described in [2]. A PA cell with a spheroidal acoustic cavity with axial length (2a=81 mm) and diameter (2b=27mm) was used for an acoustic resonator. The leakage was introduced by drilling a hole (0.2 - 10 mm diameter) to a 15 $\phi$ stop plug. Dependence of the resonance frequency shift on the hole diameter was measured.

On the other hand, tuning characteristics were calculated by an equivalent acoustic circuit model [1,4,5]. The experimental and theoretical tuning characteristics were shown in dotted and solid lines in Fig. 1, respectively.

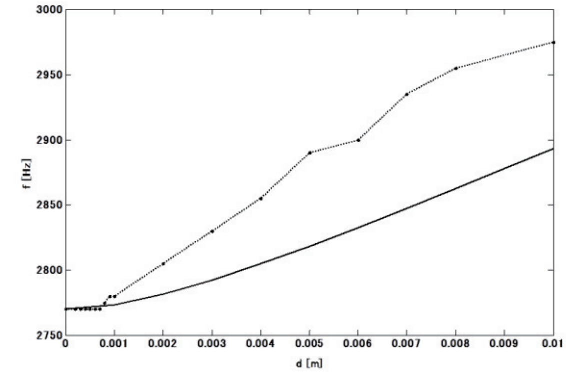


Fig. 1 Experimental (dotted) and theoretical (solid) resonant frequency shift dependence on hole diameter.

These results agreed qualitatively within a factor of two.

## 3. Imaging experiment

In order to demonstrate the phase-imaging ability, the same R-PA cell (a/b=3) was .used to image a transparent plate specimen (OHP sheet) colored at front and rear surfaces separately(Fig. 2).

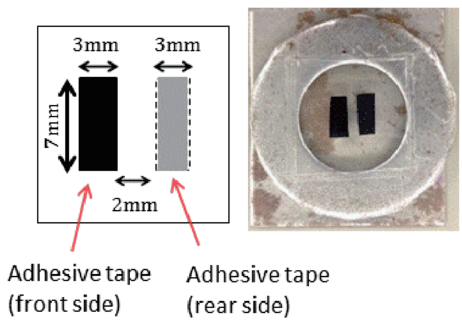


Fig. 2 Specimen used in PA phase-imaging

The obtained PA phase images corresponding to those generated at front and rear surfaces respectively, shows a remarkable phase difference (115 degree) as shown in Fig. 3.

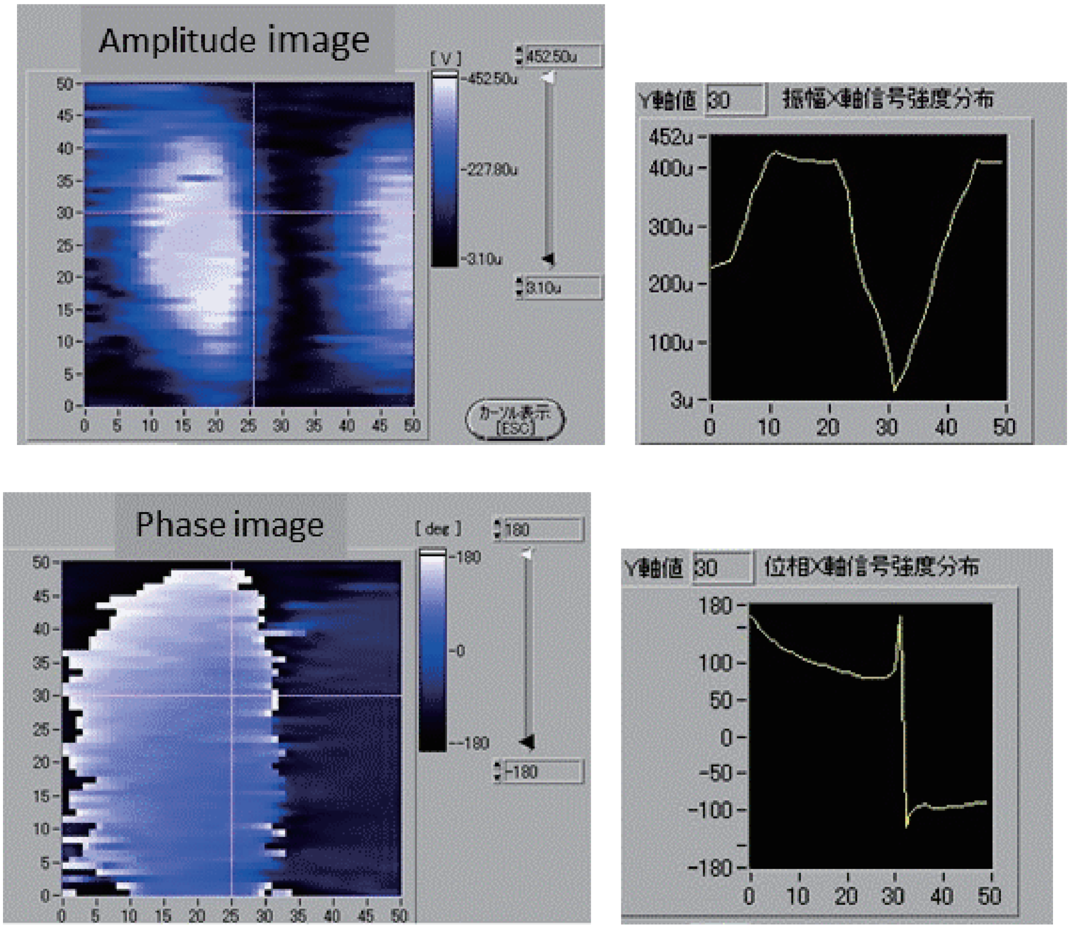


Fig. 3 The obtained PA amplitude (upper) and phase (lower) images.

The PA phase signal generated in left side (front surface) in the figure advances compared with that in right side (rear surface) as expected. The experimental conditions are as follows: laser power 32 mW, modulation frequency 3.1 kHz, scanning range $500\mu m \times 500\mu m$, spatial resolution 50 x 50 pixels. To reduce noise, band-pass filter with a gain of 20dB and Q-factor of 10 was used.

**4. Discussion and conclusions**

In this paper, tuning characteristics of a spheroidal acoustic resonance cell with a large leakage were investigated both theoretically and experimentally. Two results agreed well within a factor of two. Furthermore, the PA cell was used for the phase imaging experiment. The phase imaging was successfully performed.

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