1P2-6

Basic study on intraocular pressure measurement using acoustic radiation pressure

音響放射圧を用いた眼圧測定の基礎検討

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1. Introduction

Since the increase in intraocular pressure is a major cause of the onset of glaucoma, intraocular pressure inspection is effective for the prediction of glaucoma. As the inspection of intraocular pressure, the method blowing compressed air on the eyeball to measure its distortion is generally used. However, the voices such as "I am not used to" or "are not good at" are often heard from the person who got this inspection.

As other intraocular pressure measurement, the Goldmann tonometer or the Schiøtz tonometer etc. is also generally employed. But these methods need to touch the eyeball directly, and the burden on the patient is considerable.

Therefore, we are attempting to develop another method of measuring intraocular pressure in order to reduce the burden on patients. So we are focusing on the acoustic radiation pressure of ultrasound, and studying whether that is applicable to the intraocular pressure measurement.

2. Acoustic Radiation Pressure

The acoustic radiation pressure is known as a stationary pressure derived from the nonlinearity of ultrasound. And in the case of aerial ultrasound, if let the density of air be ρ (kg/m^3), the speed of sound be c (m/s), and the sound pressure at the surface of the object be p [Pa], the acoustic radiation pressure [Pa] acting on the object is given by

$$P = \alpha \frac{p^2}{\rho c^2} \tag{1}$$

where α is a coefficient, and α = 2 when the reflection of the sound wave is total reflection[1).]

Indeed the pressure is generally very weak, but we are expecting that it is possible to measure intraocular pressure by pressing the surface of the eyeball using this acoustic radiation pressure, as well as the case of using compressed air.

In order to confirm it, we made an apparatus using ultrasonic sound source of 40kHz (made by Tristate inc.), which is used for parametric speaker shown in Fig. 1. And, in order to irradiate small objects such as eye ball with strong ultrasound, 100 parametric sound sources were arranged on the inside of the spherical surface so that the center becomes the focal point.

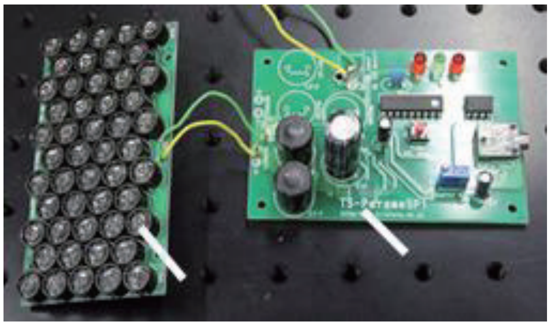

Fig. 1 Parametric speaker.

3. Method

In order to place the ultrasonic sound source on a spherical surface, an acrylic hemisphere with a diameter of about 20 cm was used this time.

Incidentally, as an arrangement of elements, the hexagonal close-packed structure is often used. However, this arrangement may cause side lobes due to six-fold symmetry. Therefore, in this study, we decided to use the Fibonacci angle Φ, which is famous for the arrangement of sunflower seeds, in order not to produce side lobes so much. The Fibonacci angle, also called the golden angle, is an inferior angle when 360 ° is divided into a golden ratio of 1 : (1 + $\sqrt{5}$)/2 and is approximately given as Φ = 137.5°.

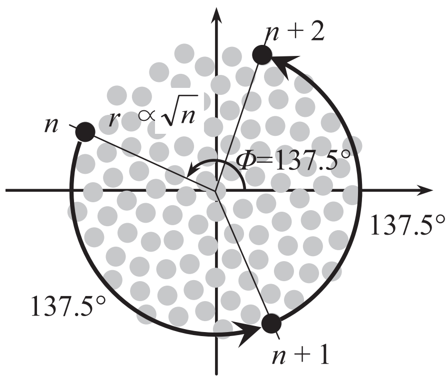

Fig. 2 Fibonacci angle.

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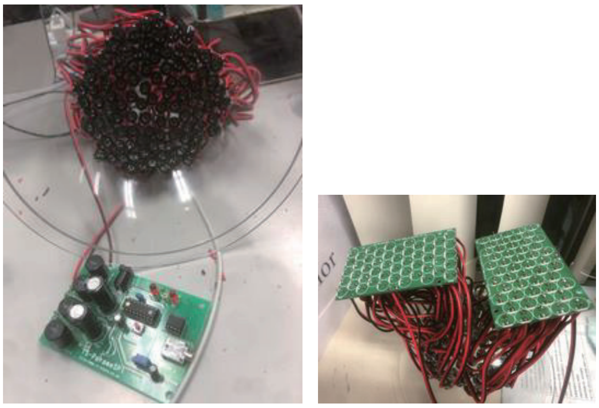
An arrangement like sunflower seeds can be obtained by putting the nth seed to the point of radius $c\sqrt{n}$ and angle $n\Phi$ as shown in Fig. 2, where c is a constant[2].

The finished product is shown in Fig. 3.



(a) Front view (b) Top view

Fig. 3 Finished product.

4. Result

First, the actual acoustic radiation force was measured with an electronic balance directly. As a result, it was found to be 1.20 gw (about 11.8 mN) as shown in Fig. 4.

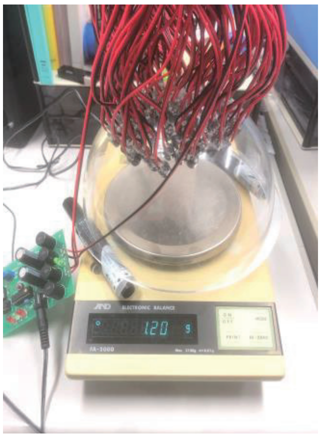


Fig. 4 Measurement of acoustic radiation force.

Next, in order to confirm the convergence of acoustic radiation pressure in this experiment, we prepared a container with water, and placed an apparatus on it to emit ultrasound.

As a result, when the center (focal point) of the sphere was adjusted to the surface of water, the surface of water shook violently, and fine bubbles were formed by the ultrasound (Fig. 5).

In addition, the same observation with the focal point about 6 cm above the water surface was performed, and then the ripples without bubbles were confirmed on the water surface (Fig. 6).

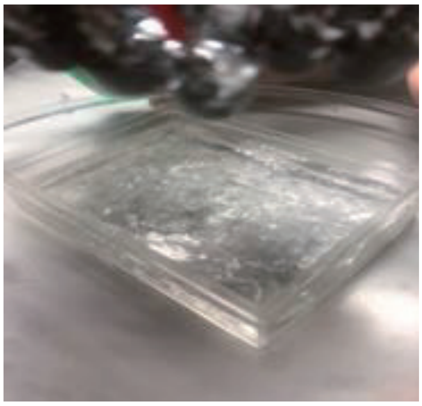


Fig. 5 Fine bubbles seen on the water surface.

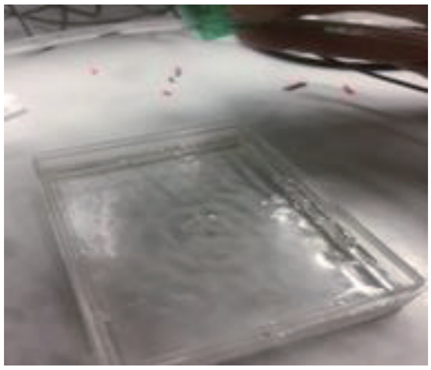


Fig. 6 Ripples seen on the water.

5. Conclusion

From this experiment, it was confirmed that the acoustic radiation pressure was so strong that the water surface bubbled at the focal point. That is, it was suggested that sufficient acoustic radiation pressure can be obtained for intraocular pressure measurement.

As a future subject, we would like to confirm whether agar-like substances or balloons with water can be similarly deformed, other than a free water surface.

In addition, we plan to study measurement methods such as distortion and natural frequency to evaluate the elasticity of the object.

Acknowledgment

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References

1. J.Saneyoshi, Y. Kikuchi and O. Kumamoto: *Cho-ompa Gijutsu Binran* (*Handbook of Unltasonic Technologies*) (Nikkan Kogyo Shimbun, Tokyo, 1978) Revised edition, p. 419, 432, 434 (in Japanese).
2. Przemyslaw Prusinkiewicz & Aristid Lindenmayer : *The Algorithmic Beauty of Plants*, (Springer-Verlag, 1990) p. 100.