Proceedings of Symposium on Ultrasonic Electronics, Vol. 30 (2009) pp. 25-26
18-20 November, 2009

C-Mode Observation of Nonlinearity Parameter *B*/*A* by Automatic Measurement
自動測定による非線形パラメータ *B*/*A* の C モード観察

Shigemi Saito[1†] and Jung-Ho Kim[2] ([1]School of Marine Science and Technology, Tokai University; [2]GW Corporation)
斎藤繁実 [1†]，金正鎬 [2]（[1] 東海大・海洋; [2] ジーダブリュー）

1. Introduction

A method to automatically measure the nonlinearity parameter *B*/*A* of a small volume sample set in the focal region of focused Gaussian beam was previously developed.[1] In this paper, by shifting the focus on a thin sliced biological tissue, the measurement is repeatedly conducted many times. Using this result, the C-mode image to show nonuniform distribution of *B*/*A* is generated.

2. System and Automatic Measurement

In **Fig.1**, the LN transducer with an inverted polarization layer generates and detects the burst wave of fundamental (f=18.6 MHz) and second harmonic (2f=37.2 MHz). Through a solid acoustic lens with a 5 mm aperture radius, a focused Gaussian beam of 10.65 mm focal length is emanated. The 1/e beam width is 0.22 mm at the focus. Intermediating a 1-mm thick ring spacer, a tungsten rod and a 1-mm thick polystyrene-plate acoustic window provide a sample layer. To keep the sample temperature at 20°C, cooling water is circulated around the water couplant, and all the acoustic system of Fig.1 is placed in a fixed temperature chamber.

When the layer is empty, the reflected wave amplitude P_{B0} from the rear surface of the window is measured. This rod position to set the surface on the focal plane is defined as z_S=0. After filling the layer with distilled water, the layer thickness is obtained from the time interval τ_W of two bursts reflected from the rod and the rear surface of the window as $L=c_W\tau_W/2$. When the rod is set at $z_S=-L$ so that the end is located on the focal plane, the FFT is executed for the reflected wave to obtain the nonlinear second harmonic amplitude P_{NW}. Further, when dual frequency bursts of f and 2f are radiated, the amplitudes P_{W1} and P_{W2} and the relative phase delay Φ_W of the 2f component in the wave reflected from the rod are also measured.

After filling the layer with a sample, at z_S=0, we measure the time interval τ_S of the bursts reflected from the rear surface of the window and the rod as well as the amplitude P_B of the wave reflected from the rear surface. Then the sound speed is determined as $c=2L/\tau_S$, and the density ρ is derived from P_B/P_{B0}.[2] Moving the rod to $z_S=-cL/c_W$, the amplitudes P_{S1} and P_{S2} and phase delay Φ_S in the wave reflected from the rod are similarly obtained for the dual frequency sound. The attenuation coefficients α_1 at f and α_2 at 2f are obtained from the insertion loss P_{W1}/P_{S1} and P_{W2}/P_{S2}. The magnitude of velocity dispersion $\Delta k=(\Phi_W-\Phi_S)/2L$ is also obtained. Measuring the nonlinear second harmonic P_{NS} in the wave reflected from the rod, *B*/*A* is finally determined.[3] These processes are sequentially run with LabVIEW program.

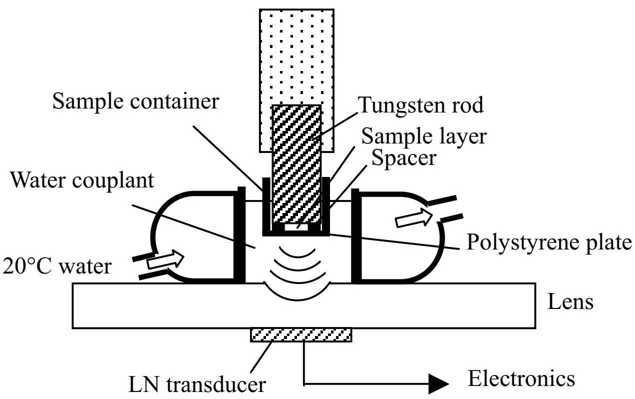


Fig.1. Cross sectional view of acoustic system.

3. Multipoint Measurement for Liquids

The result of the above *B*/*A* measurement repeated 256 times on a point of the layer filling water or ethylene glycol is shown in **Fig.2**. *B*/*A* was

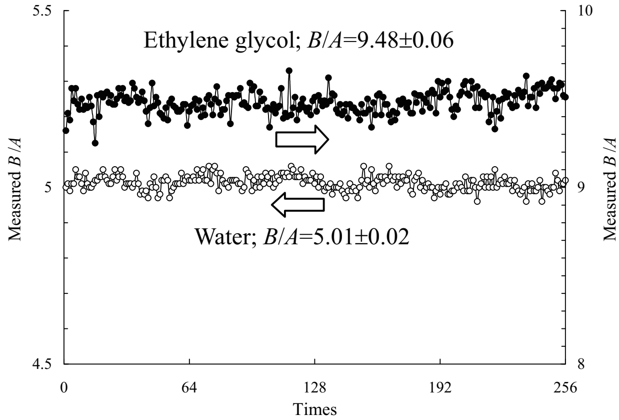


Fig.2. Repeated measurement result for liquids.

ssaito@scc.u-tokai.ac.jp

measured with the standard deviation smaller than 1%. Each measurement takes 5 s, so that 22 minutes are taken for 256 time measurements.

Scanning the beam on the sample layer by two-dimensionally moving the *x-y* stage installing the lens and LN transducer with a 0.2 mm step in the extent of 3×3 mm^2, *B*/*A* was measured for water at 16×16=256 points. The result is shown in **Fig.3** in gray scale. Due to the setting error of z_S, it can result in $\Delta k \neq 0$ even for non-dispersive liquids. To keep $2L|\Delta k|$ less than 0.01 rad, the rod surface must be parallel to the *x*-y plane with error less than 0.1°. Due to this difficulty, the measured *B*/*A* values are scattered as shown in Fig.3(a). Assuming Δk=0 in water, the scatter becomes small as in Fig.3(b).

4. Application to Biological Samples

Using two microtome blades set parallel with a 1.3 mm spacing, biological samples were sliced and set in the layer with saline or distilled water. The lateral size was set smaller than the inner diameter of the spacer. The measured *B*/*A* for an area of 3×3 mm^2 scanned by the beam is shown in **Fig.4**. The standard deviation of 10%, which is larger than in liquids, in the results for pig liver(a) and chicken liver(b) suggests non-uniformity of *B*/*A*. In the sample of squid mantle(c), *B*/*A* is observed to gradually change with the location.

(a) *B*/*A*=4.93±0.08

(b) Neglecting Δk, *B*/*A*=4.96±0.04

Fig.3. Scanning measurement for water.

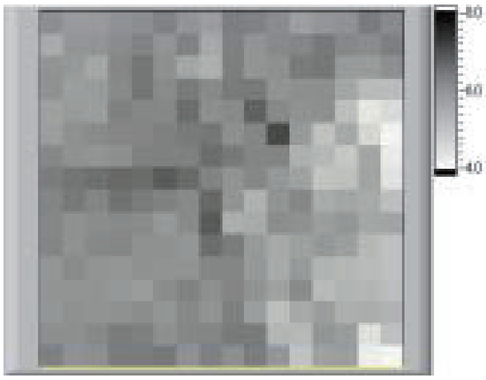
5. Conclusion

Thin biological samples were observed with C mode display of automatically measured *B*/*A*. It was suggested that *B*/*A* is not uniform in the small area. The enhancement of the measurement speed and accuracy will be investigated hereafter.

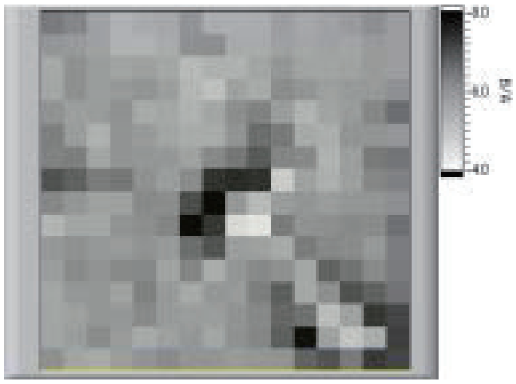
This work was supported by a Grant-in-Aid for Scientific Research (C) 19560429. Prof. Yasuhiro Senga is thanked for invaluable discussion.

References

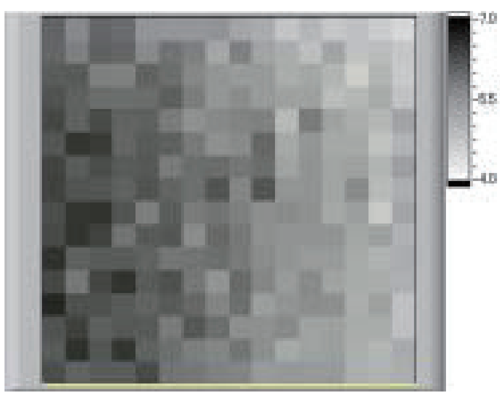
1. S. Saito and J.-H. Kim: Proc. 29th USE (2008) 63.
2. S. Saito and T. Watanabe: IEICE Tech. Rep. US2007-104 (2008).
3. S. Saito and T. Watanabe: IEICE Tech. Rep. US2008-5 (2008).



(a) Pig liver; *B*/*A*=5.92±0.51



(b) Chicken liver; *B*/*A*=5.98±0.51



(c) Squid mantle; *B*/*A*=5.65±0.49

Fig.4. C-mode *B*/*A* image for biological sample.