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Interferometric method of ultrasound absorption measurement in liquids

V. Sukackas[*], A. Voleiðis, B. Voleiðienë

Prof.K.Barðauskas Ultrasound Research Center,
[*]Department of Physics,
Kaunas University of Technology

Introduction

The measurements of ultrasound absorption are provided simultaneously with ultrasound velocity measurements. A computer based measuring system operates on the principle of a variable path two crystal ultrasonic interferometer. The peculiarity of the system is the measurement of each standing ultrasonic halfwave length and each resonance peak width by the *He-Ne* laser interferometer. The laser beam reflects from a polished surface of a moving piezotransducer. The system operates in a wide frequency range, it may be used for gases as well. Methods of ultrasound velocity measurement with accuracy up to 0.001%, information processing and representation, experimental results in the areas of molecular acoustics, medicine and metrology were discussed in [1-3].

Method

Ultrasound absorption measurements are based on a relationship

$$al + \varepsilon = \text{arcsinh}(\sin \Delta kl), \qquad (1)$$

where α is the absorption coefficient, l is the distance between transducers, ε is the quantity evaluating energy losses in transducers, etc., $k=2\pi/\lambda$ is the wave number. In its turn the value Δkl may be expressed in the following way:

$$\Delta kl = 2\pi\Delta l / \lambda = \pi\Delta l / 0.5\lambda, \qquad (2)$$

where Δl is the length difference between its resonance value and the value corresponding to the decrease of output signal 3 *dB* in respect to the resonance.

It was shown in our and other authors investigations that the quantity ε depends on the ultrasound frequency and resonance frequency of the crystals, electrical loading of the crystals, mechanical loading of their other side, mounting losses and on acoustical impedance of the liquid under test. However, at the given frequency and liquid, ε may be considered constant. To eliminate ε, measurements must be carried out at least at two different l values:

$$\alpha = \frac{1}{l_1 - l_2}[\text{arcsinh}(\sin \pi\Delta l_1 / 0.5\lambda) - \text{arcsinh}(\sin \pi\Delta l_2 / 0.5\lambda)], \qquad (3)$$

where Δl_1 and Δl_2 are the measured values.

The values of l and Δl are measured by a laser interferometer by means of distance marks. For the measurement of ultrasound velocity $\Lambda/8\approx0.08$ μm value marks are usually used, where Λ is the wavelength of the optical wave. To provide sufficient Δl measurement accuracy it is necessary to obtain at least 0.01 μm order marks because the value Δl itself is of order of microns or its parts depending on a frequency and absorption. The distance marks of such an order are obtained from an output signal of the laser interferometer. All halfwaves and corresponding Δl are measured in turn and a number of values arcsinh$(\sin\pi\Delta l/0.5\lambda)$ are calculated.

When the speed of a moving piezotransducer is constant, absorption coefficient may be also measured by using time marks, not the distance ones. It may be defined by two steps: first, we may find attenuation per wavelength $\alpha\lambda$ and later, having the known wavelength λ, we calculate α. When measuring $\alpha\lambda$, we use the relationship $\Delta l/0.5\ \lambda = \tau/T$, where τ and T are the time in which the moving transducer travels the distances $\Delta\ l$ and 0.5 λ respectively. These values are defined when filling up both intervals to be measured with time marks. The values arcsinh$(\sin\pi\tau/T)$ corresponding to each acoustic resonance are calculated and stored in a memory of a computer.

There are some hundreds of arcsinh$(\sin\pi\Delta l/0.5\ \lambda)$ or arcsinh$(\sin\pi\tau/T)$ values. This number corresponds to a number of observed resonance cases. Then this array is processed, maximal and minimal values are found, graph and histogram are drawn. One can find some characteristic error sources from the graph. For instance, if every second value is larger, it shows that there exists direct leakage of a high frequency signal to a receiver circuit, deviation from a straight line - changes of shapes of resonance peaks and so on. The histogram must show a uniform distribution. According to the graph an operator chooses the beginning and the end of the interval to be analysed and the moving measuring interval.Then $\alpha\lambda$ is found according to the formula:

$$\alpha\lambda = \frac{2}{n}\left[\operatorname{arcsinh}(\sin \pi\tau_1 / T) - \operatorname{arcsinh}(\sin \pi\tau_2 / T)\right], \quad (4)$$

where n is the quantity of halfwaves in the moving interval, τ_1, τ_2 are the values of τ, corresponding to the beginning and the end of the interval. Thus a digital filtration of $\alpha\lambda$ values is carried out. The obtained array of $\alpha\lambda$ values is statistically processed, graph and histogram are drawn up, their parameters are calculated. In the ideal case the graph must be a straight horizontal line and the histogram must show a normal distribution.

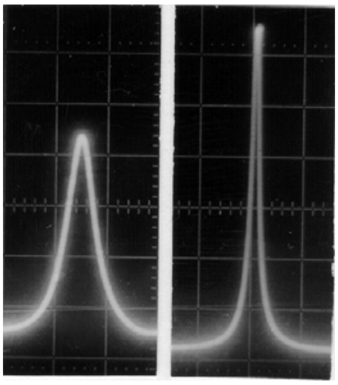


Fig.1 Resonant peak form variation with a distance between transducers (8.7mm →0mm)

Data corresponding to extreme positions of a moving transducer may be neglected if systematic errors are observed due to peak satellites, etc. Information of absorption measurements on a display is presented in analogy to that of ultrasound velocity.

Results

Measurements were performed in distilled water (low absorption liquid) at 14.12 MHz. The displacement of piezotransducer was 8.7 mm. Resonant peak amplitude and width variations with a distance between transducers is shown in Fig.1.

174 resonances were observed, and mean values for every two adjacent peaks were taken in Fig.2, in all 87 points. The graph of arcsinh*(sinπτ/T)* variation is a straight line with only random deviations and shows a good quality of the acoustic system. The moving measuring interval is chosen equal only to 38 waves, and 49 values of $\alpha\lambda$ are obtained. The histogram is normal with the mean value $\alpha\lambda$=0.75·10^{-3}. The theoretical value for water at this frequency and temperature is $\alpha\lambda$=0.52·10^{-3}. The difference 0.23·10^{-3} is evidently due to a diffraction, detector error, etc. and may be assumed as a systematic error.

The authors feel that such a simultaneous measurement of ultrasound velocity and absorption by an ultrasonic interferometer while storing and processing information from all observed resonance cases is the first in an experimental practice.

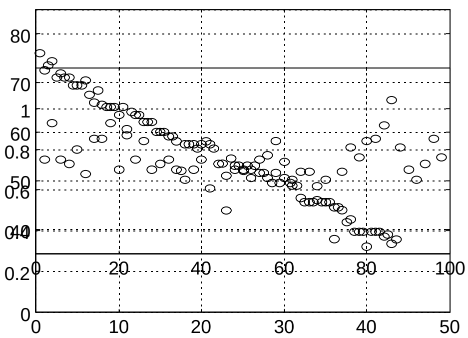
References

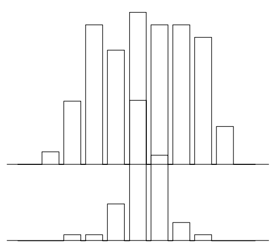
1. **A.Voleiðis, B.Voleiðienë**. Ultrasound velocity dispersion in aqueous solutions of some rare earth nitrates and sulphates.13th Congr.Acoust., Belgrade, vol.4. pp.331-334. 1989.
2. **A.Voleiðis, B.Voleiðienë, V.Sukackas**. Computer based ultrasonic interferometer and its application in scientific investigations. Abstract of UI-91 conf., Le Touquet, France, p.119, 1991.
3. **A.Voleiðis, V.Sukackas**. Microcomputer based ultrasonic laser interferometer. Scientific works of the higher schools of Lithuania ''Ultragarsas''(Ultrasonics). No.23. pp/185-189. 1991.

V.Sukackas, A.Voleiðis, B.Voleiðienë

Ultragarso absorbcijos matavimo skysèiuose interferometrinis metodas

Reziumë





Pasiûlytas naujas ultragarso absorcijos skysèiuose matavimo bûdas bei informacijos apdorojimo metodika, kai lazeriniu interferometru yra matuojamas ultragarsinio interferometro kiekvieno rezonansinio piko plotis 0,707 lygyje. Pateikiami absorbcijos matavimø rezultatai distiliuotame vandenyje. Ultragarso absorbcijos matavimai yra atliekami vienu metu su ultragarso greièio matavimais. Autoriø turima informacija tai yra naujovë eksperimentinëje praktikoje.

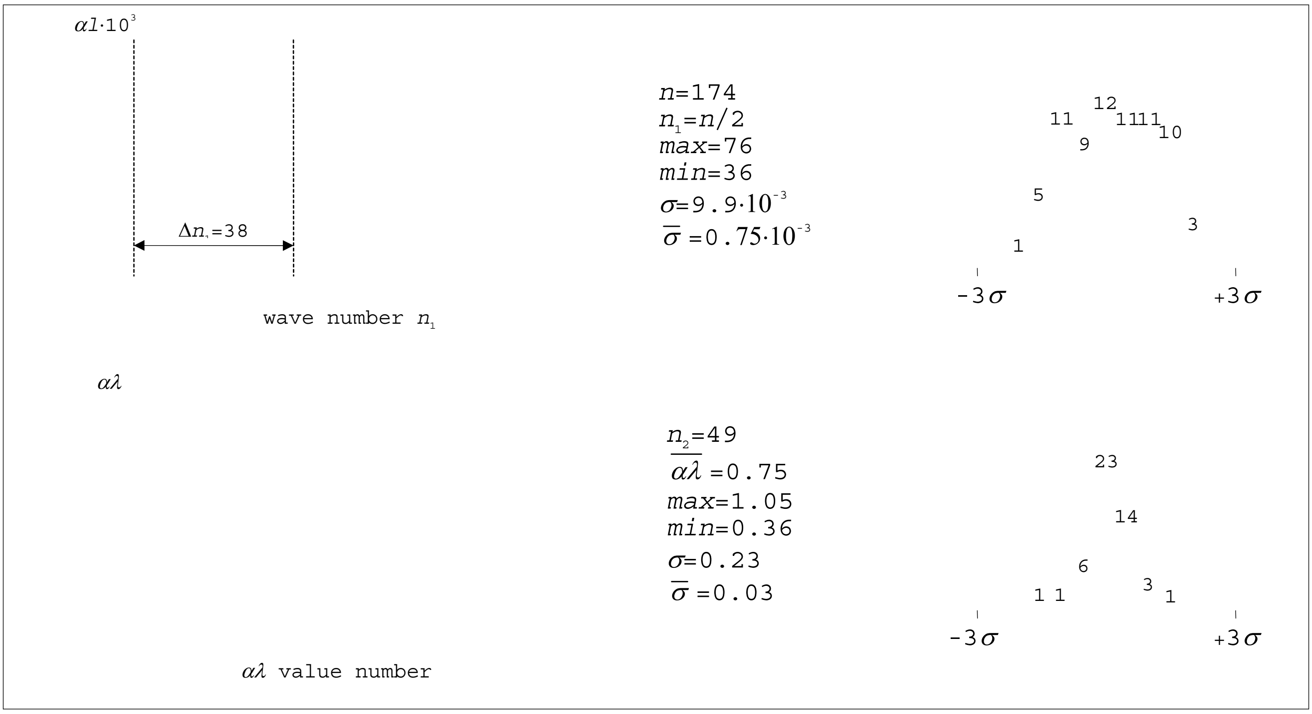


Fig.2. **Ultrasound absorption**

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