

## Interferometric method of ultrasound absorption measurement in liquids

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### 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

$$\alpha l + \varepsilon = \operatorname{arcsinh}(\sin \Delta k l), \quad (1)$$

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

$$\Delta k l = 2\pi \Delta l / \lambda = \pi \Delta l / 0.5 \lambda, \quad (2)$$

where  $\Delta l$  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  $\varepsilon$  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,  $\varepsilon$  may be considered constant. To eliminate  $\varepsilon$ , measurements must be carried out at least at two different  $l$  values:

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

where  $\Delta l_1$  and  $\Delta l_2$  are the measured values.

The values of  $l$  and  $\Delta l$  are measured by a laser interferometer by means of distance marks. For the measurement of ultrasound velocity  $\Lambda/8 \approx 0.08 \mu\text{m}$  value marks are usually used, where  $\Lambda$  is the wavelength of the optical wave. To provide sufficient  $\Delta l$  measurement accuracy it is necessary to obtain at least 0.01  $\mu\text{m}$  order marks because the value  $\Delta l$  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  $\Delta l$  are measured in turn and a number of values  $\operatorname{arcsinh}(\sin \pi \Delta l / 0.5 \lambda)$  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  $\lambda$ , we calculate  $\alpha$ . When measuring  $\alpha \lambda$ , we use the relationship  $\Delta l / 0.5 \lambda = \tau / T$ , where  $\tau$  and  $T$  are the time in which the moving transducer travels the distances  $\Delta l$  and  $0.5 \lambda$  respectively. These values are defined when filling up both intervals to be measured with time marks. The values  $\operatorname{arcsinh}(\sin \pi \tau / T)$  corresponding to each acoustic resonance are calculated and stored in a memory of a computer.

There are some hundreds of  $\operatorname{arcsinh}(\sin \pi \Delta l / 0.5 \lambda)$  or  $\operatorname{arcsinh}(\sin \pi \tau / T)$  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:

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

where  $n$  is the quantity of halfwaves in the moving interval,  $\tau_1$ ,  $\tau_2$  are the values of  $\tau$ , 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

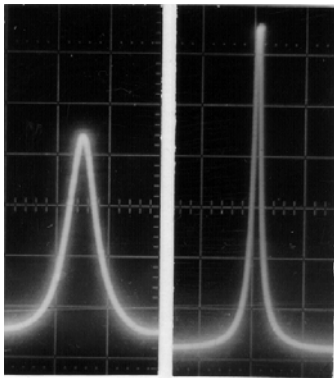


Fig.1 Resonant peak from variation with distance between transducers (8.7mm) must show a normal distribution.

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  $\operatorname{arcsinh}(\sin \pi\tau / T)$  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  $\alpha\lambda = 0.75 \cdot 10^{-3}$ . The theoretical value for water at this frequency and temperature is  $\alpha\lambda = 0.52 \cdot 10^{-3}$ . The difference  $0.23 \cdot 10^{-3}$  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.

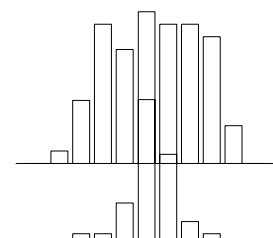
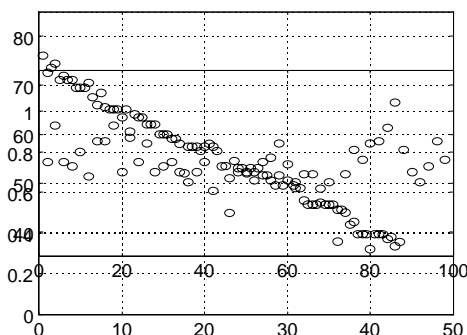
**References**

1. A.Voleiðis, B.Voleiðienė. Ultrasound velocity dispersion in aqueous solutions of some rare earth nitrates and sulphates.13<sup>th</sup> Congr.Acoust., Belgrade, vol.4. pp.331-334. 1989.
2. A.Voleiðis, B.Voleiðienė, 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.

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**Ultragarso absorbcijos matavimo skysėiuose interferometrinis metodas**

Reziumė



Pasiūlytas naujas ultragarso absorbcijos skysčiuose matavimo būdas bei informacijos apdorojimo metodika, kai lazeriniu interferometru yra matuojamas ultragarsinio interferometro kiekvieno rezonansinio piko plotis 0,707 lygyje. Pateikiami absorbcijos matavimų rezultatai distiliuotame vandenyje. Ultragarso absorbcijos matavimai yra atliekami vienu metu su ultragarso greičio matavimais. Autorių turima informacija tai yra naujovė eksperimentinėje praktikoje.

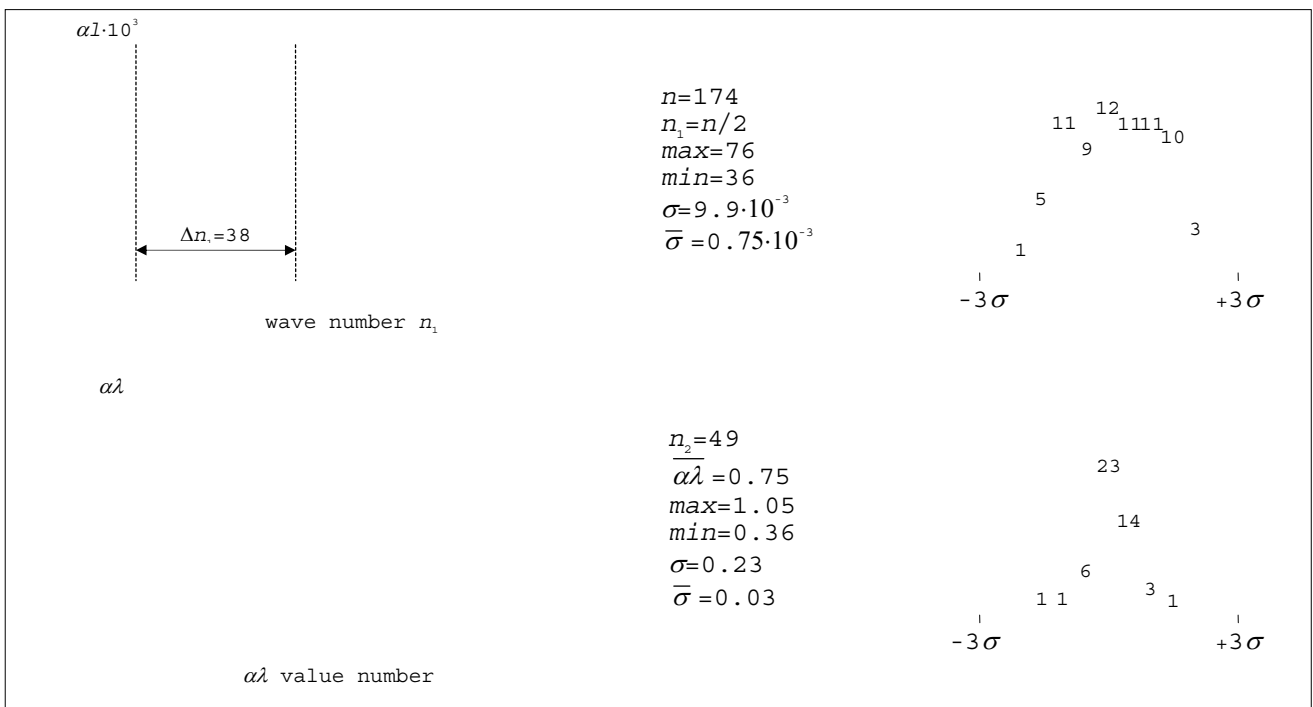


Fig.2. Ultrasound absorption