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EMITTING OF PHASE CONJUGATE ULTRASOUND WAVE INTO LIQUID BY PARAMETRICALLY EXCITED FERRITE

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Abstract - Phase conjugate sound waves at 6 MHz generated by polycrystalline ferrite sample at conditions of parametric magnetic field pumping over the threshold of absolute instability were studied in liquid. Conforming images of phase fronts for incident and conjugate waves were obtained. An angular anisotropy of effectivity connected with sample geometry was discovered and a method for it smoothing out is proposed. Maximum gain of acoustic wave in water was 43 dB (60 dB in ferrite).

Methods of ultrasonic wave phase conjugation (WPC) with amplification by using parametric echo in piezoelectrics /1/ have been proposed by several authors /2,3/. A practical application of WPC effect in acoustic imaging system was recently reported /4/. A parametric echo in magnets /5/ and perspective of magnetic dielectrics with strong magnetoelastic interaction as active media for WPC has also been described /6,7/. A giant amplification of conjugate wave at 30 MHz in regenerative regime has been discovered in ferrite /7/. In order to verify conjugate wave properties, experiments on stroboscopic visualization of acoustic fields in solid were carried out for waves with wide spatial spectra /8/. The impulse WPC process in magnets with pumping field amplitude over a threshold of absolute parametric instability has been studied by authors /8,9/.

In this paper experimental observation results of phase conjugate ultrasonic waves, emitted by ferrite sample in water in the regime of overthreshold parametric pump by magnetic field are reported.

The experimental setup is shown in Fig. 1(a). A polycrystalline Ni-ferrite sample 28 mm in diameter with pump coil on it was slightly immersed in a water which has been poured in a transparent basin. A direct magnetic field ($H = 400$ Oe) was applied along the sample axis. A plane ultrasonic transducer 18 mm in diameter was placed at the underwater end of an angle meter lever which axis O lied in the plane of the sample surface. This arrangement permitted irradiation of the sample surface with plane ultrasonic waves from various directions. The accuracy of angular measuring was 15° .

At the instant when incident ultrasonic pulse (6 MHz, $30 \mu s$ duration) from the transducer reached the active zone with coil the pumping rf pulse (12 MHz, $40 \div 100 \mu s$ duration) was switched on. A pumping field strength amplitude $h = 60$ Oe was approximately twice as large as absolute instability threshold value. A generated pulse of conjugate wave was received by the same transducer. Pump

source power in experiments was about 1.2 kW. Maximum intensity and gain of conjugate wave in water was 4 W/cm² and 43 dB (60 dB in ferrite) respectively.

The angular dependence of a normalized output signal amplitude for a 150 mm length sample is shown in Fig. 1 (b) by curve 1. Curve 2 shows the amplitude of signal, reflected from the sample surface and it was used to indicate the normal direction. Velocities of longitudinal and transverse waves in the sample were $v_l = 7.13$ km/s, $v_t = 3.34$ km/s and critic angles for water-ferrite interface - $\varphi_l^c = 12^\circ 6'$, $\varphi_t^c = 26^\circ 42'$. Angular positions of maxima in experiments ($\varphi_m = 4^\circ 30'$) didn't depend on H, h, and pump duration. Fig. 1 (c) shows the same experiment but with a sample of 100 mm length. In that case maxima were observed at angles $\varphi_m \approx 14^\circ$ which exceeded φ_t^c . The mentioned anisotropy is likely due to the sample geometry in conditions of a complicated parametrical interaction in a multi-mode waveguide structure.

Fig. 1. - Experimental setup (a) and normalized output voltages (b), (c) in angular effectivity measuring. (b) - 150 mm sample, (c) - 100 mm sample. 1 - conjugate wave, 2 - reflection from the sample front surface, 3 - conjugate wave in the presence of random plate.

In order to smooth out the angular dependencies a special plate which caused random-like phase distortions in wave fronts was placed close to the sample surface. Curve 3 in Fig.1 (b),(c) indicates that with this phase plate the angular dependencies became more smooth.

To be sure that wave phases are really conjugate one should compare images of radiated and received wave fronts. This experiment was carried out using shlieren method. A laser light beam propagated parallel to axis O . Stroboscopic regime permitted time separation of incident and conjugate waves. Images of wave fronts for two angular positions of the transducer are presented in Fig.2 and look like straight black and white strips. A good mutual

(a)

(b)

(c)

(d)

Fig 2. - Images of wave fronts. (a), (b) - incident waves at $\varphi = -15^\circ$ and $+15^\circ$ respectively; (c), (d) - conjugate waves. A black horizontal line is an angular position basis. Arrows show waves directions.

correspondence can be noticed. The angular difference of incident and reradiated wave fronts was less than 1° .

In experiment which setup is shown in Fig.3 (a) an incident wave from transducer has been focused in a point F by cylindric reflector and then it came to the sample. Conjugate wave propagated from the sample back to the focus.

Figure 3. Experimental setup (a) and images of fronts of incident (b) and conjugate (c) waves in experiments with focused wave. Arrows show a direction of wave propagation. F - focal area.

Fig. 3 (b), (c) shows wave front images of incident and conjugate waves near the focal point as black and white concentric arcs. A satisfactory conformity can be seen in that case also. In both optical experiments the sample of 100 mm length was used.

In conclusion we wish to note that the above experiments on direct observation of wave fronts in liquid as well as anisotropy investigations have demonstrated the applicability of parametric interaction in ferrite to sound wave phase conjugation with amplification.

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