anomalously large χ_d is due to some correlation or exciton effect, which would be expected to be proportional to a quadratic form in Δn, Δp, n_0, and p_0.

There exists the rather remote possibility that the light affects the large paramagnetic component of the lattice susceptibility directly. However, all processes which do not in some way relate to correlation or to another breakdown in the usual theory may almost certainly be ruled out by the magnitude of the observed χ_d. Further experiments, using extrinsic samples, together with measurements at lower temperatures, are expected to yield the answers to many of these questions.

We wish to acknowledge the help of B. Tompkins in the construction of the apparatus, as well as several very helpful conversations with M. A. Lampert, J. Loferski, and A. Rose.

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PIEZOELECTRIC PRODUCTION OF MICROWAVE PHONONS

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Recently Baranskii,[1] and Bömmel and Dransfeld[2] have reported the production and propagation of ultrasonic waves in crystalline quartz, excited by electromagnetic fields, in the frequency range of 10^8 to 2.5×10^9 cps.

We have been able to extend the frequency, at which ultrasonic wave propagation is detectable, to the vicinity of 10 000 Mc/sec. Specifically, we have successfully propagated longitudinal elastic waves at low temperatures in quartz bars, with optically flat ends and of various dimensions, placed between two re-entrant microwave cavities tuned to the transmitter frequency.

Figure 1 shows an oscilloscope trace of the following experiment carried out in a liquid helium bath. A pulse of microwave energy at 9370 Mc/sec is fed to one cavity, whereupon it is piezoelectrically converted to an elastic wave of the same frequency which travels along the quartz rod at the characteristic sonic velocity. Upon arrival of the wave at the receiver cavity, a part of its energy is reconverted to a radio-frequency signal and is detected and displayed on the oscilloscope, appearing as the first echo pulse. The remaining sound wave energy is reflected at the receiving end of the rod, traveling back to the transmitting end whereupon it is again reflected to the receiver cavity to produce another echo pulse, and so on, until the ultrasonic wave train dies out. It will be observed that, whereas the first echo pulse is detected at a time τ after the direct transmitter pulse, the second and all subsequent pulses are separated by a transit time of 2τ since these have made a

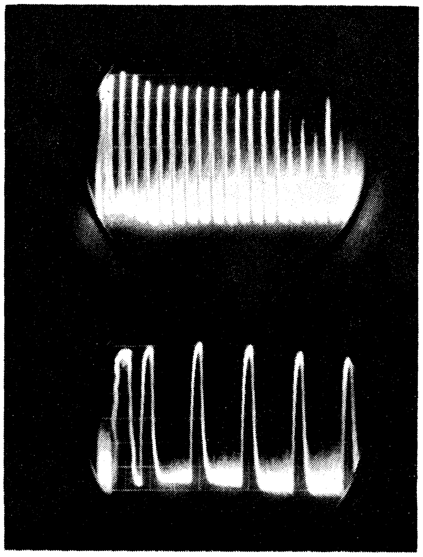

FIG. 1. Oscilloscope trace of the receiver output registering pulses of microwave power (9370 Mc/sec) acoustically delayed by a quartz rod 3 cm in length and submerged in liquid helium at 4.2°K. The lower trace is identical with the one above except for an expanded time base. Time increases from left to right. Note that the first echo appears at a time τ after the direct transmitter pulse (first pulse on photograph) whereas all subsequent echoes are spaced at intervals of 2τ (see text).

complete round trip. This feature is seen more clearly in the lower trace of Fig. 1, which exhibits the pulses on an expanded time base.

The dimensions of the quartz rod used in this experiment were 3 cm (length) by 0.3 cm (diameter), with the x axis along the length of the rod. The characteristic time (2τ) between pulses was about 11 microseconds, and the pulse duration, two microseconds. The peak rf power incident upon the transmitter cavity was 25 watts, derived from a 4J50 magnetron.

In Fig. 1, the first dozen or so pulses appear to have nearly the same amplitude due to saturation of the receiver. After correction for this effect, the amplitude of each successive pulse is as shown in Fig. 2, where the third echo pulse is normalized to 100. The pulse decay envelope is seen to be more complicated in detail than the expected simple exponential drop-off. The details of the decay curve appear to be a function of the microwave electric field configuration at the point of coupling in the transmitting cavity and of the particular quartz rod employed. Thus the irregular decay may be caused by partial coupling to other elastic modes of the rod in such a way that energy is alternately exchanged between them. This detail is under further investigation.

When the temperature is varied from 1.8°K to 20°K, it is found that the average attenuation increases somewhat more rapidly than linearly with temperature. At 77°K no ultrasonic wave propagation was observable. It is expected that umklapp processes will become effective in attenuating the wave in the temperature range between 20°K and 77°K.

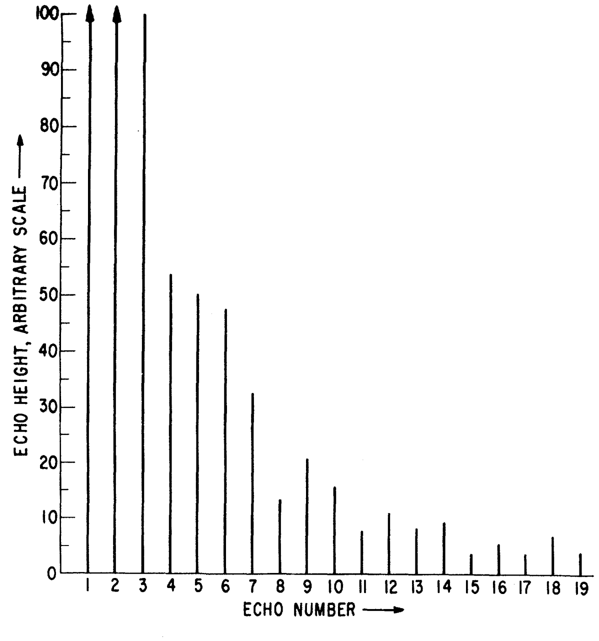

FIG. 2. Graph of relative echo amplitudes after correction for receiver saturation. Third echo pulse is normalized to 100.

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MAGNETIC OSCILLATIONS OF ULTRASONIC ATTENUATION IN A COPPER CRYSTAL AT LOW TEMPERATURES*

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In an earlier communication[1] we reported an apparently oscillatory dependence of ultrasonic attenuation in a polycrystalline sample of copper, this occurring at helium temperatures where the electron mean free path (l) was comparable to the ultrasonic wavelength (λ). The results were explained in terms of resonant conditions between the electron orbit diameter and the spatially periodic fields carried by the wave. It was shown that the average Fermi momentum calculated from such a picture was consistent with a value for copper of one free electron per atom. These measurements, however, were deficient in several obvious respects. Only one or two maxima and minima were discernible, and a polycrystal was used because at that time a single crystal of sufficiently long mean free path was not available. Furthermore, a subsequent theoretical analysis by Rodriguez[2] has suggested that such an oscillatory effect would not be expected (at least from a classical Boltzmann equation analysis), and so it was proposed that the observed effect was perhaps a consequence of the polycrystalline nature of the sample.

Here we report some more recent measurements made in a very pure copper single crystal which verify that a pronounced oscillatory effect is indeed found. Moreover, this effect is significantly anisotropic, suggesting that ultrasonic methods should be useful in obtaining information

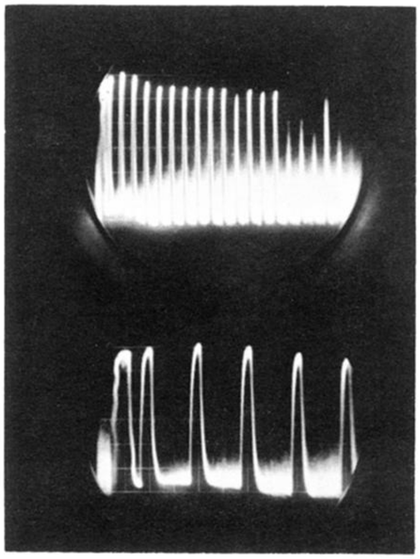

FIG. 1. Oscilloscope trace of the receiver output registering pulses of microwave power (9370 Mc/sec) acoustically delayed by a quartz rod 3 cm in length and submerged in liquid helium at 4.2°K. The lower trace is identical with the one above except for an expanded time base. Time increases from left to right. Note that the first echo appears at a time τ after the direct transmitter pulse (first pulse on photograph) whereas all subsequent echoes are spaced at intervals of 2τ (see text).