Table I. Summary of results in terms of J_I, the induced superconducting current density, and H_{fp}, the magnetic field at which fluxoids first penetrate into the superconductor.

Material	H_{fp} (Oe)	J_I at $H_a = 2000$ Oe (A/cm^2)
Diffusion process Nb_3Sn	400 ± 100	10×10^4
Arc-cast Nb_3Sn	350 ± 75	1×10^4
Arc-cast Nb_3Al	375 ± 75	2×10^4
Arc-cast V_3Ga	400 ± 100	8×10^4
Arc-cast V_3Si	550 ± 75	2×10^4

the intrinsic magnetization could originate from loops of extended flaws,[11] if these flaws interact with the fluxoids in such a way as to support a change in the density of fluxoids. Such a density gradient is equivalent to the postulated loop currents.

The powder specimens measured were obtained from a parent ingot by crushing, sizing, and then blending (to about 40 volume %) with Fisher Nonac stopcock grease which electrically insulated the particles from one another. The slurry was packed into a paper straw or glass tube ($\sim\frac{1}{8}$ in. diameter, $\sim\frac{1}{2}$ in. long) and cooled to 4.2°K. The magnetic measurements were made by the method described in reference 3.

Table I summarizes the results for the four intermetallics in terms of two parameters H_{fp} and J_I.

I wish to thank C. P. Bean for a number of valuable conversations and I. S. Jacobs, P. E. Lawrence, D. S. Rodbell, and C. H. Rosner for lending me their experimental apparatus.

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OSCILLATORY QUANTUM EFFECTS IN THE ULTRASONIC VELOCITY IN BISMUTH

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We have observed oscillatory changes in the velocity of sound in bismuth at 4°K as a function of magnetic field. The classical quadratic variation of the velocity of sound with magnetic field has been previously observed[1] in the metals Sn, Al, and Mg at room temperature. It has been suggested[2] that quantum effects, analogous to the de Haas–van Alphen effect, in the velocity of sound should also occur. The conditions for the observation of quantum effects in the sound dispersion are the same as those required to observe such effects in other transport phenomena, i.e., the magnetoresistance and thermal conductivity. These conditions are (1) that $\hbar\omega_c > kT$ and (2) that $\omega_c\tau > 1$, where ω_c is the cyclotron frequency ($=eH/m^*c$). Physically these conditions are required so that the broadening of the Landau levels due to electron scattering, either because of thermal vibrations or impurities, will not be great enough to smear out the oscillations.

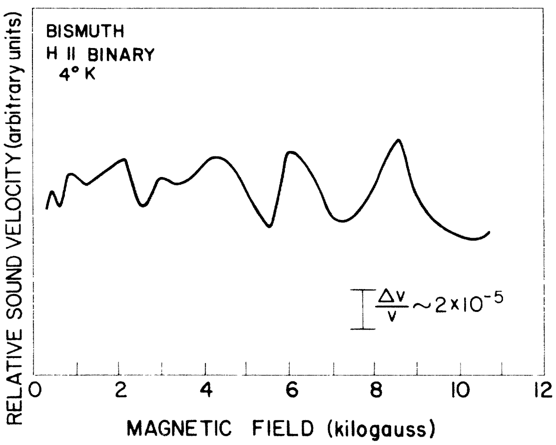

FIG. 1. Variation of ultrasonic velocity with magnetic-field intensity in bismuth at 4°K and 20 Mc/sec with H parallel to a binary axis and perpendicular to the direction of propagation. The minima observed at 33 Mc/sec appeared at the same value of magnetic field intensity as those shown here.

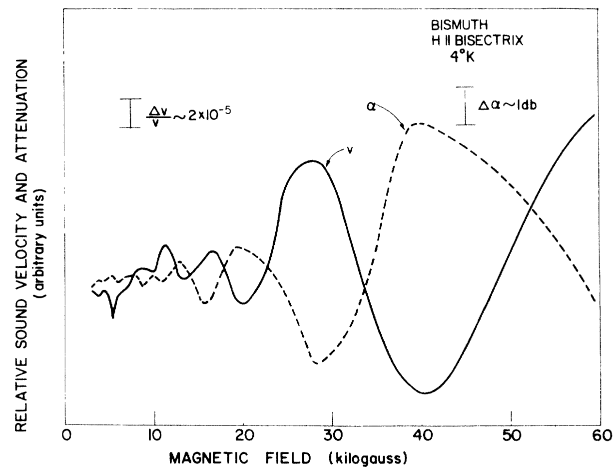

FIG. 2. Variation of ultrasonic velocity, v, and attenuation, α, with magnetic field in bismuth at 4°K and 20 Mc/sec with H parallel both to a bisectrix axis and to the direction of propagation.

Since these conditions are most easily achieved in semimetals with small effective masses at low temperatures, we have examined the variation of the velocity of sound in bismuth as a function of magnetic-field intensity at 4°K using both 20-Mc/sec and 33-Mc/sec longitudinal ultrasonic waves. Figure 1 shows our results for the magnetic field parallel to the binary axis and perpendicular to the direction of sound propagation where oscillations in the sound velocity of the order of 10^{-5} are observed. For this configuration oscillations are expected due to one mass only; in this case the magnitude is[3] $m^* = 0.010\,m_0$. Using a value[4] for the Fermi level $\mathcal{E}_F = 0.025$ eV, we find that for the spin splitting equal to the Landau splitting,[5] the $n = 1$ minimum should occur at 21.5 kG, $n = 2$ at 10.7 kG, $n = 3$ at 7.1 kG, etc. For this configuration the maximum field available was 11 kG; therefore we were not able to observe the first minimum. The minima for higher quantum numbers are observed, however. For the other configuration with H parallel to the bisectrix direction one would expect to see two sets of oscillations corresponding to masses[3] $m^* = 0.009\,m_0$ and $m^* = 0.018\times m_0$. For the latter mass the last minimum ($n = 1$) should occur at $H = 40$ kG, $n = 2$ minimum at $H = 20$ kG, $n = 3$ minimum at $H = 13.3$ kG, and so on. The last minimum for the smaller mass should occur at $H = 20$ kG. The experimental results are given in Fig. 2 with the magnetic field and the propagation along the bisectrix axis. The results are in reasonable agreement with the predicted positions of minima. Simultaneously with the velocity observations, attenuaticn observations were also taken. These are included in Fig. 2. Oscillations of the de Haas–van Alphen type are also observed in the attenuation.[6] As one would expect, the maxima in the absorption coincide with the minima in velocity.

These measurements were taken using the conventional pulse-echo technique. With this system it was possible to measure velocity changes $\Delta v/v \sim 2\times10^{-5}$ by measuring the time difference between corresponding points on two rf waves, one within the pulse envelope of the first echo and its mate within the envelope of the tenth echo. This system was adequate for measuring the main features of the phenomenon. In order to study the fine structure, which should occur in addition to the H^2 dependence of the sound velocity, we are now in the process of constructing a more sensitive system.

We have made estimates of the amplitude of the oscillations using the theoretical results of Quinn and Rodriguez[2] by inserting a phenomenological relaxation time into their Eq. (7) under the condition that $\omega_c\tau > 1$. These estimates give results for the velocity change which are much larger than those observed experimentally. This indicates that this model does not hold in our case. Nevertheless, although the effect is small, i.e., a maximum $\Delta v/v \sim 10^{-4}$, this is still large in terms of the sensitivity available for this type of measurement. Actually, when the techniques are improved, permitting measurement of $\Delta v/v \sim 10^{-7}$, this method should prove superior to the ultrasonic attenuation, to the de Haas–van Alphen, or to the oscillatory magnetoresistance measurements.

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OPTICAL DOUBLE-PHOTON ABSORPTION IN CESIUM VAPOR*

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This Letter reports the observation of optical double-photon absorption[1] in an atomic system: excitation of the $6S_{1/2}$ - $9D_{3/2}$ transition in Cs by intense light from a ruby maser. For a double-photon transition to occur, the energy of the excited level must be twice that of a single incident photon, and the initial and final states must have the same parity. The $9D_{5/2,3/2}$ levels in Cs, which have term[2] values 28 836.06 and 28 828.90 cm^{-1}, are conveniently at twice the frequency of the 14 400-cm^{-1} (~6940Å) light from a ruby optical maser. Furthermore, they allow a two electric-dipole transition since $\Delta l = 2$, $\Delta J = 1, 2$. The Doppler width of the transition is 0.04 cm^{-1}, and although the actual width may be somewhat greater due to collisions, the necessity for obtaining a coincidence between this sharp absorption and the maser emission frequency imposes a stringent experimental requirement on thermal tuning[3] of the ruby maser. The absorption was detected by observing the fluorescent decay of the $9D_{3/2}$ state to $6P_{3/2}$, yielding quanta at 5847 Å.

An atomic resonant double-quantum transition allows a more straightforward application of theory than have other somewhat similar cases. Two-photon excitation of impurity levels in a crystal has been considered by Kleinman[4] and observed in $CaF_2:Eu^{++}$ by Kaiser and Garrett.[5] In this material the intermediate states are believed to be charge transfer bands of large oscillator strength. Single-quantum absorption is observed over a band as wide as about 5000 cm^{-1}, and the observed forbidden transition may occur because of crystalline field, phonon interaction, or magnetic dipole effects. Single-quantum forbidden transitions have also been observed between levels in alkali metals[6,7] and attributed to quadrupole absorption.[8]

For Cs vapor, the expected transition probability and signal were calculated from second-order electric-dipole matrix elements using the Bates-Damgaard[9] method, and summed over those states with large contributions, i.e., small energy denominators. Our maser produces about 3×10^{18} photons (~1 joule) in 0.5 msec in a beam of 0.25 degree half-angle. If this is focused by a 2.0-cm lens into cesium vapor at 0.1 Torr pressure, we expect to excite about 5×10^{12} atoms into the $9D_{3/2}$ state, assuming that the maser line is about 0.04 cm^{-1} wide. Under these conditions and neglecting possible collision effects, we expect that 5×10^{11} photons will be emitted in the 5847 line. Cesium-cesium collisions and possible maser-line broadening will reduce this number.

Experimentally, the output of a pulsed ruby source, filtered to remove background light, was focused onto a heated glass cell where cesium vapor could be introduced from a reservoir tube. Provisions were made for periodically pumping out accumulated gases due to heating; the residual pressure in the cell with cesium cold was kept below 10^{-6} Torr. The emission from the cell, observed at right angles to the ruby beam, was filtered through a $CuSO_4$ solution to remove scat-