agreement with what one would find from Eq. (1) using Leighton's results for $g(\omega)$, and also from a one-dimensional approximation.

In summary, the inelastic cold neutron scattering experiment on the low-concentration nickel-palladium alloys has confirmed the existence of defect modes of vibration predicted by theory.

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NOISE TEMPERATURE OF HOT ELECTRONS IN GERMANIUM

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The random fluctuations in velocity of free electrons in a semiconductor give rise to electrical noise which, in analogy with Nyquist's formula for a passive resistor, can be characterized by a noise temperature T_n, where kT_n is the available noise power per unit bandwidth. For electrons heated by an applied electric field E, the noise temperature measured transverse to E is given under suitable conditions by

$$T_n = e\langle v_t^2\tau\rangle/\mu_t', \tag{1}$$

where v is an electron's velocity, and τ its mean free time. The brackets indicate an average over $f(\epsilon)$, the distribution function in energy of the electrons, and the subscript t refers to the transverse direction. The transverse differential mobility μ_t' is the derivative of $\langle v_t\rangle$ with respect to a transverse electric field. The related quantity $T_n' = T_n\mu_t'/\bar{\mu}_l$ gives a moment of the distribution function not available from previous measurements. Here $\bar{\mu}_l$ is the longitudinal dc mobility; the measured ratio $\mu_t'/\bar{\mu}_l$ differs from unity only as a result of the anisotropic mobility of hot electrons. If f is a Boltzmann function, $\propto \exp(-\epsilon/kT_\epsilon)$, then $T_n' = T_\epsilon = 2\langle\epsilon\rangle/3k$. For other forms of $f(\epsilon)$ proposed for hot electrons, T_n' is not very different from $2\langle\epsilon\rangle/3k$.[1]

Furthermore, if f can be written in the form $f(\epsilon/\epsilon_0)$ which depends on E only through a normalizing factor and the parameter ϵ_0, and if the relaxation of momentum is by the emission and absorption of acoustic phonons, then the quantity $\theta = T_n'(\bar{\mu}_l)^2$ is constant with E. Conversely, any region in which there is a variation of θ with E implies that f is changing its shape in that region.

This Letter gives, for the first time, results of measurements of T_n' for hot electrons in a solid. Oriented specimens of 8 ohm-cm n-type single-crystal germanium $1\times1\times5$ mm^3 were cut and etched in CP-4, and noninjecting contacts covering the small faces were attached by alloying with 0.6% Sb-Au wire. The electrons were heated by 7-μsec pulses applied to these contacts through appropriate rf filters, and the transverse noise voltage at 420 Mc/sec was coupled capacitatively to a receiver where it was continuously compared with a standard. The lattice was held at room temperature by adjustment of a flow of cooled nitrogen. Differences in noise temperature could be measured to within ±10°K ± 10%, including an allowance for systematic errors. A pulse bridge was used to measure $\bar{\mu}_l$ at the same time.

Measurements of T_n' were made as a function of E. Results identical within experimental error were obtained for the four combinations of directions shown in Table I; typical data are shown in Fig. 1. The result that T_n' is independent of current direction was not expected; this fact is dis-

Table I. Orientations used for noise measurements.

Case	Direction of electric field	Direction of noise measurement
a	[110]	[$\bar{1}$10]
b	[100]	[011]
c	[110]	[001]
d	[100]	[001]

cussed below. The changes in T_n' are, as would be expected, quadratic in E at low fields, but become more nearly linear at fields of the order of 900 v/cm. Under the conditions of this experiment, the conversion from T_n to $T_n' = T_n\mu_t'/\bar{\mu}_l$ caused a change of at most 1% and served mainly to increase the scatter of the experimental points. In Fig. 2 we plot θ/θ_0 vs $(\bar{\mu}_l/\mu_0)^2$ for two samples with the combinations of directions given as cases (b) and (d) in Table I. Note that θ/θ_0 is not constant in any region of this graph, and varies from unity at zero field to about 0.87 at 1700 v/cm.

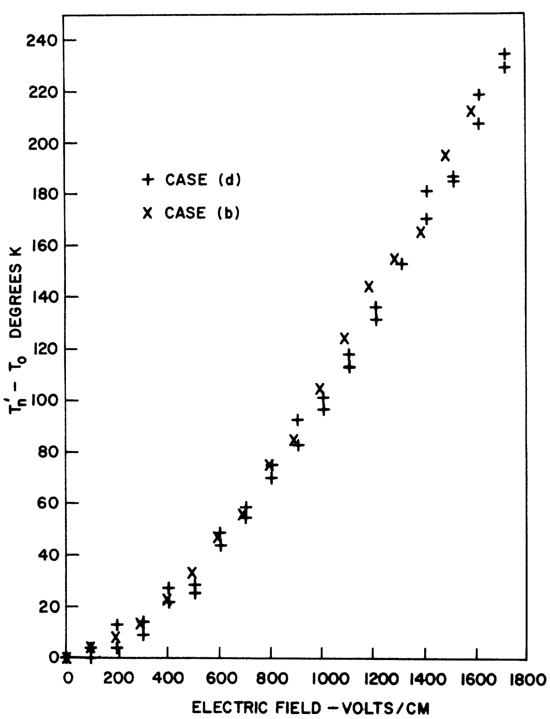

FIG. 1. Differences of corrected noise temperature T_n' and lattice temperature T_0 plotted as a function of electric field. For both cases plotted, the current is in the [100] direction; the direction in which the noise is measured is [011] (b) or [001] (d).

From this last result, and the previous argument, we conclude that, with the lattice at room temperature, the shape of $f(\epsilon)$ must be changing with E. In particular, since f is known to be Boltzmannian when $E = 0$, it follows that it is not for hot electrons. This is in agreement with the calculations of Morgan,[2] and the optical measurements of Brown and Paige[3] for hot holes under similar conditions.

The last result is not invalidated by the neglect of the optical-mode contribution to momentum relaxation, which is estimated to amount to about 2% at the highest fields used. Nor can the departure from constancy be charged to additional noise mechanisms not considered in the derivation of Eq. (1), for a decrease of θ is inconsistent with the increased contribution expected from such mechanisms. Furthermore, these mechanisms (such as the energy relaxation[4] and intervalley[5] noises of Price, etc.) can interfere only if at least one of the reciprocal mass tensors has an off-diagonal element connecting the field and measuring directions. For combination (a) of Table I, none of the mass tensors has such an element; the fact that the noise is the same for this as for the other combinations suggests that such noise mechanisms are negligible, and also that the valleys are in equilibrium among themselves.

The linear dependence of T_n' on E observed at the higher fields is consistent with the Pisarenko

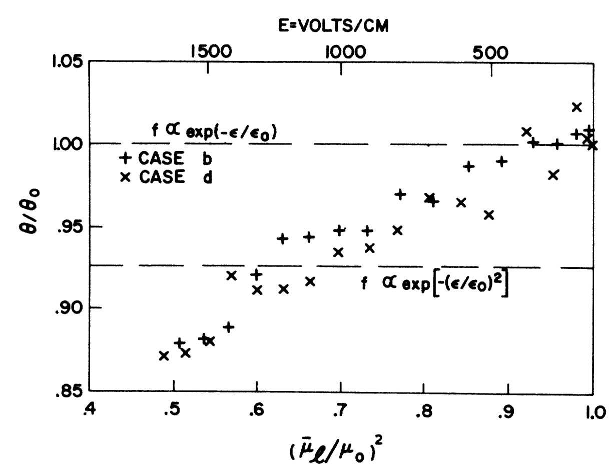

FIG. 2. The variation of $\theta = T_n'\bar{\mu}_l^2$ plotted against $\bar{\mu}_l^2$, with electric field as a parameter. Ordinate and abscissa are normalized with respect to zero-field values, and the values of θ appropriate to two possible distribution functions are shown. Approximate values of electric field are also indicated.

distribution,

$$f(\epsilon) \propto \exp[-(\epsilon/\epsilon_0)^2], \qquad (2)$$

which would result if scattering by acoustical phonons dominated both energy and momentum relaxation.[6] Apart from the fact that such an $f(\epsilon)$ predicts $\bar{\mu}_l \propto E^{-1/2}$, which is not observed, it also implies a constant value of θ/θ_0 equal to 0.925. The fact that the observed θ/θ_0 decreases smoothly to values lower than 0.925 shows that the change in $f(\epsilon)$ is not simply a transition from a Boltzmann to a Pisarenko distribution.

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PION-PION RESONANCES IN A PURE $T=1$ STATE*

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Proton-proton interactions, in which a deuteron is formed leaving the created pions in a pure $T=1$ isospin state, have been studied in pictures taken in the BNL 20-inch hydrogen bubble chamber exposed to a 2.05-Bev proton beam at the Cosmotron.[1]

The deuterons were identified by momentum-bubble density measurements.[2] Each event in which a deuteron was identified was measured with a digitized microscope. The events were analyzed using reconstruction programs TRED I and TRED II, and were kinematically fitted to particular reactions with the program GUTS. In this way, 149 events corresponding to the reaction,

$$p+p \rightarrow d+\pi^+ + \pi^0, \qquad (1)$$

and 75 events corresponding to the reaction,

$$p+p \rightarrow d+\pi^+ + \pi^+ + \pi^-, \qquad (2)$$

have been observed out of 53 000 p-p interactions.[3]

Reactions (1) and (2) are particularly suited to the study of π-π interactions as the effect of nucleon isobars is strongly suppressed,[4] and as the pions are in a pure isospin state. Possible π-π interactions have been studied by determining the Q values, i.e., the kinetic energy in the rest system of the two and three pions produced in these reactions.

In Fig. 1 the frequency distribution of Q values for the $\pi^+\pi^0$ mesons of reaction (1) plotted in 25-Mev intervals is presented. In order to eliminate fortuitous fluctuation due to the choice of the particular Q-value interval used in constructing the histogram, an ideogram normalized to the same area was plotted, and it is indicated by a dashed line. The long dashed curve represents the Q-value distribution determined from a three-body phase-space calculation[5] normalized to the total number of events. The disagreement between this phase-space curve and the experimental data is apparent. A very narrow peak is observed at $Q \cong 285$ Mev, and within the experimental errors of ±15 Mev, its width is consistent with zero width. Barloutaud et al.,[6] Erwin et al.,[7] and Peck et al.[8] reported the presence of a peak at about the same position, and attribute it to a "dipion" called ζ of $T=1$. Another broader peak can be observed at about 450 Mev, but given the effect of a rapid decrease in available phase space beyond 475 Mev, it is difficult to determine the exact position of the peak or to establish its width. It is certainly in good agreement with the ρ particle having a Q value of 420 Mev, reported by many authors,[9] and with the reported full width of ~120 Mev.

In Fig. 2 the experimental Q-value distributions for the $\pi^+\pi^+\pi^-$ mesons of reaction (2) are presented in a plot similar to that of Fig. 1. The long dashed curve represents the Q value according to covariant four-body phase space as calculated by Hoang and Yung[10] and is normalized to the total number of events. No striking deviation from the phase-space curve is seen, but there is an indication of a narrow accumulation of events at a Q value of ~235 Mev. Due to poor statistics and to the lack of an exact four-body phase-space cal-