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DE HAAS–VAN ALPHEN EFFECT IN POTASSIUM*

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A study of the alkali metals is of particular interest for an understanding of the electronic structure of metals since these metals should conform most closely to an idealized metallic model of free conduction electrons. Previous measurements of transport properties[1] and specific heats[2] of the alkali metals are in fair accord with this model. In the free-electron picture, a spherical Fermi surface in $\vec{k}$ space gives rise to de Haas–van Alphen oscillations whose period is given simply by $P=(2e/\hbar c)(3\pi^2N)^{-2/3}$, where e, $\hbar$, c have their usual meanings and N is the number of valence electrons per unit volume. The period of the oscillations is related to the extremal cross-sectional area A of the Fermi surface perpendicular to the magnetic field by $P=2\pi e/c\hbar A$. For the case of potassium with 1.32×10^{22} electrons per cm^3 (at room temperature), one would expect a period of 5.69×10^{-9} $gauss^{-1}$ corresponding to an extremal area of 1.68×10^{16} cm^{-2}. Such a short period is of the same order of magnitude as those found in the noble metals,[3] and one would expect to observe such an effect utilizing the high-field pulse technique.[4]

In this paper we report on the observation of de Haas–van Alphen oscillations in a single crystal of potassium in pulsed magnetic fields up to 160 kilogauss. Figures 1 and 2 show the observed oscillations as taken directly from the

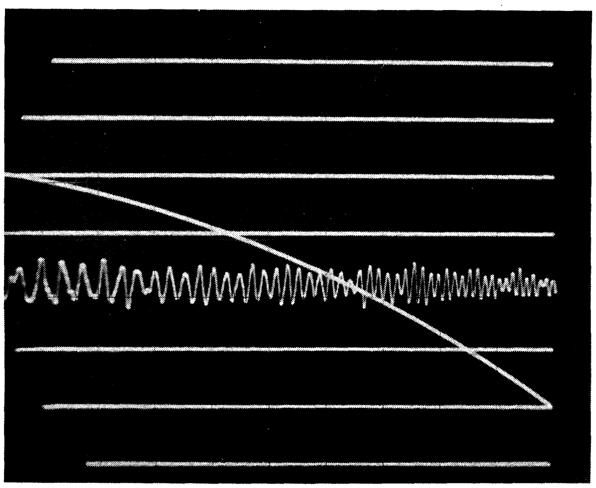

FIG. 1. de Haas–van Alphen effect in potassium at 1.77°K. The oscillating trace (≈ 0.1-mv amplitude) shows the output from a pickup coil containing the sample. The curved trace shows the field increasing from 151.7 to 158.5 kilogauss during a sweep time of about 1.0 millisecond (time increasing from right to left). The change in interval occupied by each successive period is due to the decrease of the time derivative of the magnetic field.

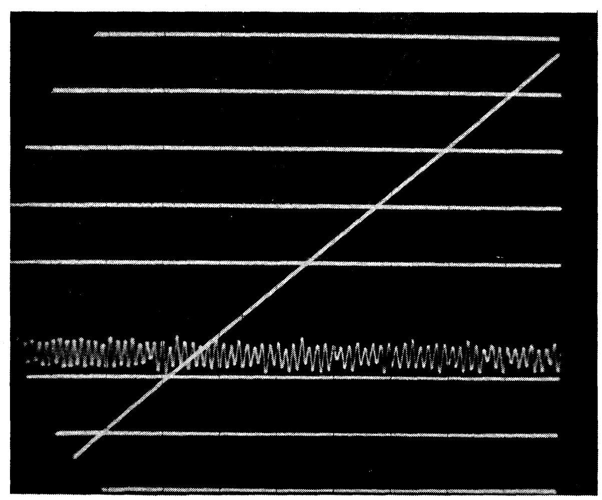

FIG. 2. de Haas–van Alphen effect in potassium at 1.07°K. The diagonal trace shows the field decreasing (from right to left) from 132.8 to 126.9 kilogauss during a sweep time of about 0.9 millisecond.

oscilloscope. The measurements yield a period of $5.75\times10^{-9}\pm1\%$ gauss^{-1}, indicating a cross-sectional area of the Fermi surface of 1.66×10^{16} cm^{-2}, in good agreement with that predicted from the free-electron model. It might be pointed out that the theoretical value is only valid to approximately 2% since no correction for thermal contraction was made. Furthermore, because the measurements were carried out for only one orientation nothing can be said as yet regarding deviations of the Fermi surface from sphericity. A plot of $\ln(a/T)$ versus T, where a is the amplitude of the oscillations and T is the absolute temperature, gives a straight line with slope $-2\pi^2k/\beta H$, where H = magnetic field and $\beta=e\hbar/m^*c$, from which we deduce the effective mass of the electrons as $(0.90\pm10\%)m_0$ (m_0 = free-electron mass). The specific heat data of Douglass et al.[2] give $m^*=1.3\,m_0$.

A brief description of the pulsed-field apparatus used in the present experiment is given elsewhere.[5] The pickup coils used to detect the oscillations in magnetization of the specimen were wound on a 0.79-cm long form using No. 52 copper wire. They consisted of 3050 turns wound series-opposed on top of 4800 turns, so that the effective sensitivity was proportional to the difference in the number of turns. The pure metal was supplied by M. S. A. Research Corporation and had a ratio of room-temperature resistivity to helium-temperature resistivity of approximately 1300. The crystal (0.019 cm diam by 0.81 cm long) was grown by zone-melting techniques in an open-ended Pyrex capillary and was protected from oxidation by a film of mineral oil. Attempts to determine the crystal orientation with x rays were unsuccessful due to the small size of the specimen and the small atomic scattering factor of potassium.

The authors wish to acknowledge the suggestion of D. Shoenberg regarding the use of coaxial pickup coils and valuable discussions with J. Trivisonno, Charles S. Smith, R. Bowers, and A. F. Kip concerning techniques for handling alkali metals.

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OPTICAL SATURATION OF F-CENTER SPIN RESONANCE*

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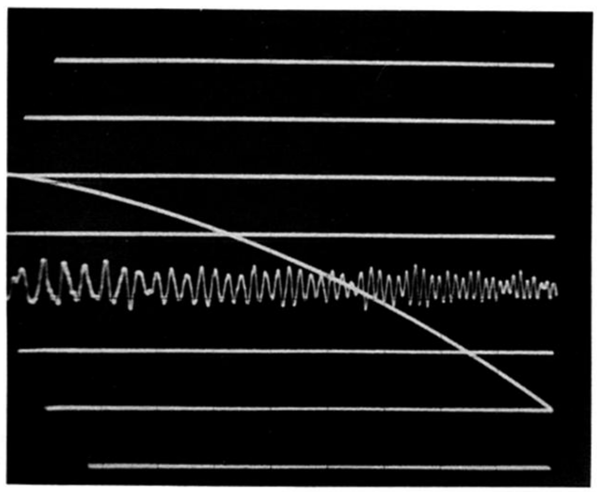
The influence of external light on the spin resonance of F centers in KCl has recently been observed,[1,2] with somewhat ambiguous results. This note reports results of preliminary experiments at 9.0 kMc/sec on very pure samples of KCl in which both the steady-state population difference and the spin relaxation time were measured during exposure to light. Irradiation by light in the F band was found to influence the populations of the ground-state sublevels as expected by excitation to a bound state; lattice heating was found to be negligible.

The ground state of F centers in KCl has been described in some detail by Gourary and Adrian.[3] Relaxation[4] of the populations of the two levels of the ground state to the lattice temperature is accomplished by phonons. Absorption of light in the F band equally from both levels and the subsequent random return should drive the populations toward equality and decrease the apparent relaxation time, τ. The rate equations for n electrons in levels 1 and 2 may be written as

$$dn_1/dt=-[2(w_{12}+w_{21})+2W+2\mathcal{W}+AN]n_1 + (w_{21}+W+\mathcal{W}+AN_1)n=-dn_2/dt, \qquad (1)$$

where[5,6] $n=n_1+n_2$ with no storage in the optically excited states, w_{12} is the probability of transition



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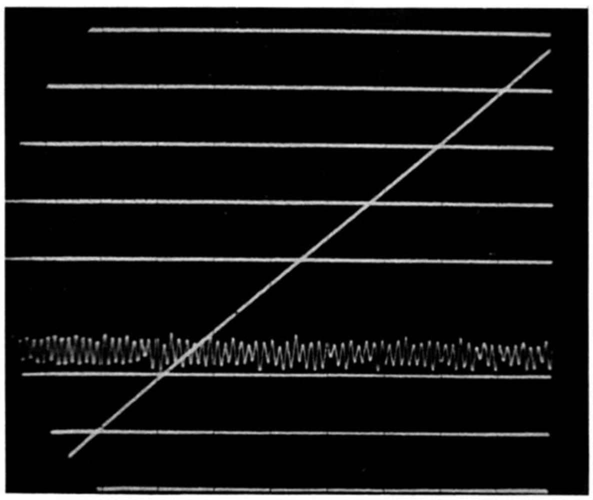

FIG. 2. de Haas—van Alphen effect in potassium at 1.07°K. The diagonal trace shows the field decreasing (from right to left) from 132.8 to 126.9 kilogauss during a sweep time of about 0.9 millisecond.