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.

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OPTICAL SATURATION OF F-CENTER SPIN RESONANCE*

B. R. McAvoy, D. W. Feldman, J. G. Castle, Jr., and R. W. Warren

Westinghouse Research Laboratories, Pittsburgh, Pennsylvania

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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

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

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

from 1 to 2 induced by the lattice, W is the probability of transition induced by the microwave radiation, $\mathscr{W}$ is the probability of transition from 1 to 2 induced by the optical radiation, and A is the probability of transition by cross-relaxation to one of N impurity spins, of which N_1 spins are capable of flipping in pairs with F electrons in level 1. Since the N impurity spins are more strongly relaxed to the lattice than the F-center spins, N_1 is independent of n_1 and the F-center population difference, $\Delta n(t)$, is given by

$$\Delta n(t) - \Delta n(\infty) = B \exp(-\lambda t), \qquad (2)$$

where $\lambda = 2(w_{12}+w_{21}) + 2W + 2\mathscr{W} + AN = 1/\tau$, $\Delta n(\infty) = [w_{21} - w_{12} + A(2N_1 - N)]/\lambda$, B is the initial perturbation, and $2(w_{12}+w_{21}) + AN = 1/\tau_0$, the reciprocal of the spin relaxation time observed with zero incident light. With low power input, we have found $2W \ll 1/\tau_0$. Therefore, for low temperatures the expected relations between observed quantities are

$$1/\tau = (1/\tau_0) + 2\mathscr{W}, \qquad (3)$$

$$\Delta n(\infty)/\Delta n(\infty)_0 = \tau/\tau_0, \qquad (4)$$

where $\Delta n(\infty)_0$ is the steady-state population difference without light.

The samples were prepared from single crystals of pure KCl which had been grown in a horizontal furnace under an atmosphere of HCl. The method of purification will be described elsewhere.[7] The resultant purity was found by ionic conductivity to be about thirty parts per billion. The crystals were colored to saturation by bremsstrahlung from 2-Mev electrons and kept in the dark until used.

In the experiment, light from an Osram *XBO* 2001 lamp is focused into a quartz prism monochromator. Light from the monochromator is directed through the multiple glass walls of a helium-nitrogen double Dewar into a microwave cavity of special design. Details of a similar cavity design are reported elsewhere.[8] The cavity is resonant in the TE_{103} mode with the sample mounted at one end of the cavity near a window. The transmission of the window to light is ~0.8, and to microwave is $\sim 10^{-4}$. Light transmission of the sample is monitored through a second window by a phototube. The power in the light beam incident on the Dewar is measured by a thermopile. The optical absorption spectrum of each sample is measured at 2.1°K. The absolute photon absorption rate is obtained from the measured absorbance of the sample with corrections for reflection losses at nine surfaces, transmission of the cavity window, and estimated scattering. The heat absorbed in the sample and cavity from the beam is found by the change in heater power required by the temperature regulator[6] to be in agreement with the thermopile values. The heat input (~20 microwatts into the sample) gives a negligible rise in temperature in the center of the sample whose outer surfaces are bathed in liquid helium II. A microwave signal power of 10^{-8} watt is employed together with a rapid field sweep of 100 μsec duration twice each second. Resulting average microwave power gives $2W$ much less than $1/\tau_0$. Resonance absorption signals without saturation are observed in this way. Spin relaxation times are measured by the inversion-recovery technique[6]; for no light conditions, room light is excluded from the sample.

Optical saturation is evident in Fig. 1 where the appearance of the resonance absorption signals on the oscilloscope is given for the conditions with and without F-band light. Since the resonance line shape remains constant under

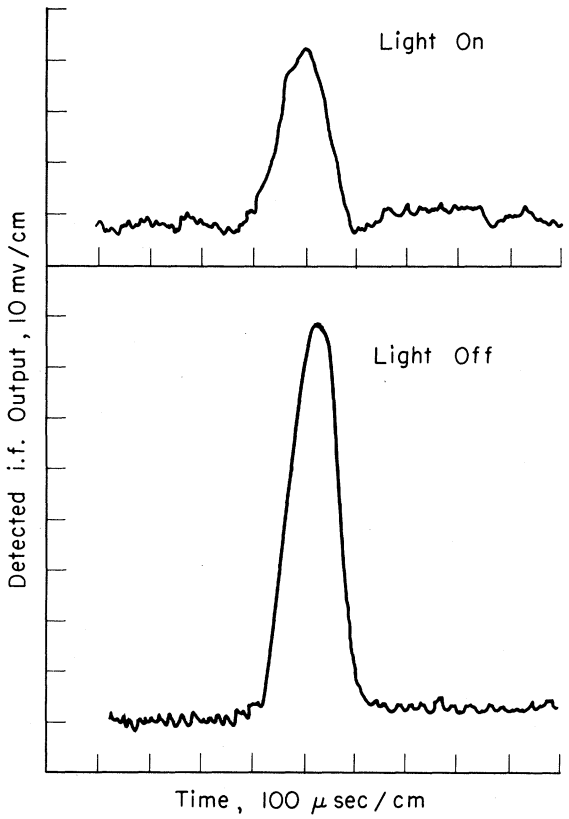

FIG. 1. Microwave resonance absorption by F centers in a crystal of KCl at 2.1°K and 3 kgauss with and without F-band light.

Table I. Effects of F light on ground-state properties of F centers in a γ-irradiated sample of pure KCl at 2.1°K.

Photon absorption rate (10^{14} sec^{-1})	Observed spin absorption signal (relative)	Observed spin relaxation time (sec)	Calculated absorption signal [Eq. (4)]
0	1.0	1350[a]	1.0
1	0.5	540	0.4
2	0.2	270	0.2

[a]This rather long time appears to be the characteristic spin-lattice relaxation time and is under further study by Feldman, Warren, Castle, and Gourary.

optical saturation, the signal height is sufficient for the comparison of Eq. (4).

The observed resonance signals and relaxation times are given in Table I for one sample irradiated to a total dose of 5×10^5 r and having 1×10^{16} F centers. Proportionality between the effective relaxation time and the steady-state population difference is found for two intensities of F light. This agreement confirms the model for optical saturation in which the excitation of isolated F centers occurs to these bound excited states and there is essentially no preferential pumping.

In addition the data allow a comparison of absolute rates. For 1×10^{14} photons absorbed per second and two photons absorbed for every optically induced spin flip, an effective relaxation time of 60 seconds is expected on the basis of Eq. (3) and 1×10^{16} F centers. The number of F centers measured by spin resonance absorption agrees with the number calculated from optical absorbance[9] within a factor of two. Uncertainties in the optical measurements probably account for the discrepancy from the observed τ of 270 seconds.

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EXTREMELY LOW LOSS ACOUSTIC RESONANCE IN SINGLE-CRYSTAL GARNET SPHERES

R. C. LeCraw, E. G. Spencer, and E. I. Gordon
Bell Telephone Laboratories, Murray Hill, New Jersey
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An acoustic resonance has been observed at room temperature and ~9.2 Mc/sec in single-crystal spheres of yttrium iron garnet (YIG) with losses nearly an order of magnitude lower than any other known material at the same temperature and frequency. Until now, quartz crystals vibrating in shear modes were recognized as having the lowest acoustic losses at this temperature and frequency.[1]

The above observation was first made on a YIG sphere using magnetoacoustic resonance (MAR). With this technique a microwave pump signal is used to excite parametrically into acoustic oscillation a small spherical sample of YIG biased with a dc magnetic field near ferromagnetic resonance.[2] At a critical rf mag-