(It will be noted that there is a slight dip in the experimental points near $T/T_c=0.7$. This is not felt to be a real effect; it is, however, being investigated further.)

It seems, therefore, that this preliminary comparison gives good support to the new theory of superconductivity. It would also appear as if one of the most direct ways of measuring the superconducting energy gap as a function of temperature is by means of ultrasonic attenuation.

Presumably one could also deduce similar information from measurements for the region $kl<1$. The theory here, however, is essentially more complicated because the electron mean free path enters, and this will also depend upon the energy gap. One would expect that the electron mean free path would increase as the gap increases with decreasing temperature until eventually kl became greater than unity, and the attenuation would become independent of electron mean free path. Experimentally one gains support for this picture since for $kl<1$, the attenuation near the transition temperature varies as the square of the frequency but becomes dependent on the first power of the frequency sufficiently far below the transition temperature.

The authors would like to thank Professor Bardeen for pointing out the exact connection between his theory and our measurements and for sending a table of values for the energy gap. They would also like to thank Mr. David Gavenda for his invaluable assistance in making the measurements.

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New V-Center Spin Resonance in LiF

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In previous work[1,2] it was shown that by x-irradiation of LiF crystals at or below liquid nitrogen temperature an electron deficiency center is created which can be described as an F_2^- molecule-ion and which probably is not associated with vacancies or other imperfections. The original F_2^- centers disappear irreversibly and two new kinds of center appear if the LiF crystal is subsequently warmed up to about 130°K. One of these is also an F_2^- molecule-ion but probably associated with a vacancy pair; the other center, to be discussed in this letter, consists of an Fe_3^{--} group presumably associated with a vacancy aggregate. The spin resonance of the F_3^{--}center is readily separable from the spin resonance of the F_2^- centers because of the much shorter relaxation time of the former.

We can deduce the atomic structure of the center directly from the gross features of the resonance spectrum. The over-all spread of the hyperfine spectrum for the new center is almost the same as for the F_2^- centers, indicating that the resonance is also due to a hole on fluoride ions. The basic pattern consists of 8 hyperfine lines of equal intensity, implying that the hole interacts with *three* fluorine nuclei. For special orientations of the dc magnetic field the eight-line pattern degenerates into a six-line pattern with the intensity ratio 1:2:1:1:2:1, indicating that two of the three nuclei are equivalent, i.e., the nuclear configuration is an isosceles triangle. Two to six basic patterns are observed simultaneously, depending upon the orientation of the crystal in the dc magnetic field. The analysis of this observation leads to the conclusion that the base of the triangle is a [110] axis and its plane a (001) plane. All six [110] axes are equally populated. The triangle is flat, i.e., the nuclei are not far from collinearity. The simplest vacancy configuration that makes the center uncharged and complies with the observed symmetry is the one proposed by Seitz[3] for the V_4 center (Fig. 1).

For most orientations the basic eight-line pattern contains four independent line separations, which can be consistently described by three parameters, each parameter giving the contribution to the hyperfine interaction of one nucleus α ($\alpha=1, 2, 3$). Thus, first-order perturbation theory is a good approximation for

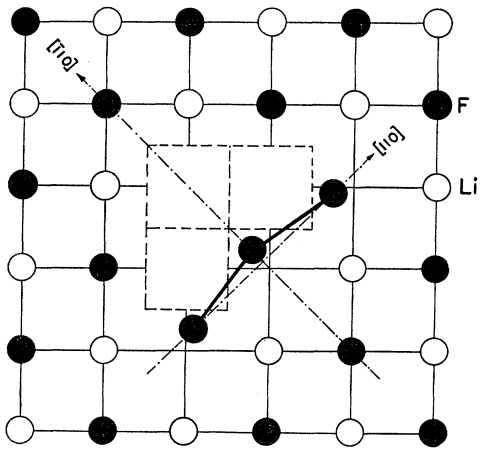

Fig. 1. Symmetry and orientation of the triatomic V center as deduced from the spin resonance spectra. The vacancy configuration and the exact positions of the nuclei cannot be derived rigorously from the spectra, but the model proposed here is consistent with our observations.

those orientations. The observed anisotropy of the hyperfine interaction is consistent with the form $g_0\beta\mathbf{S}\cdot\sum_{\alpha=1}^{3}\mathbf{T}^{(\alpha)}\cdot\mathbf{I}^{(\alpha)}$. The three tensors $\mathbf{T}^{(\alpha)}$ can be simplified by symmetry arguments. The principal axes x_2, y_2, and z_2 of the tensor $\mathbf{T}^{(2)}$ correspond to the axes $[\bar{1}10]$, $[110]$ and $[00\bar{1}]$ of the crystal; whereas the principal axes of $\mathbf{T}^{(1)}$ and $\mathbf{T}^{(3)}$ turn out to be tilted by $\theta=17°$ as shown in Fig. 2. The magnitudes of the principal components listed in Table I enable us to draw important conclusions as to the nature of the wave function of the ground state:

The traces of these tensors are comparable in magnitude to the components themselves, whatever signs we choose for their components. Consequently, the wave function does not have nodes at the nuclei, and an appreciable s admixture must be assumed. This in turn shows that the ground state of this triatomic center is not derivable from a molecular $p\sigma$ state because the wave function of any $p\sigma$ state must have a node at the center nucleus 2 for symmetry reasons. Nevertheless, the splitting from nucleus 2 is largest for $\mathbf{H}$ parallel to one of the six $[110]$ axes. Therefore, the axis of the p function at nucleus 2 lies along the height of the triangle and not parallel to the base.

Kinetic energy considerations lead to the relative signs of the p functions shown in Fig. 2. Confirmation for this assignment comes from overlap considerations: The inequality of $|T_y^{(2)}|$ and $|T_z^{(2)}|$ may be attributed to overlap. For no overlap and no s admixture, we would have $T_y^{(\alpha)}=T_z^{(\alpha)}=-\frac{1}{2}T_x^{(\alpha)}$. The s contribution to $T_x^{(\alpha)}$, $T_y^{(\alpha)}$ and $T_z^{(\alpha)}$ is always of the same sign as the p contribution to $T_x^{(\alpha)}$. These two theorems lead us to the relative signs for $T_{x,y,z}^{(\alpha)}$ and the decomposition of $\mathbf{T}^{(\alpha)}$ into its s and p parts, $\mathbf{T}^{(\alpha)}(s)$ and $\mathbf{T}^{(\alpha)}(p)$, proposed in Table I. The fact that $|T_y^{(2)}(p)|<|T_z^{(2)}(p)|$ suggests that overlap reduces the magnitude of the wave function between the atoms, the effect being maximal in the xy plane, thus confirming the sign of the p functions. This is consistent with the reduction of $|T_y^{(1)}(p)|$ relative to $|T_z^{(1)}(p)|$. The tilt of the p functions for $\alpha=1$ and 3 similarly diminishes $|T_x^{(\alpha)}(p)|$ from $|2T_z^{(\alpha)}(p)|$ through overlap. Another consequence of the overlap is that this inward tilt is probably greater than θ.

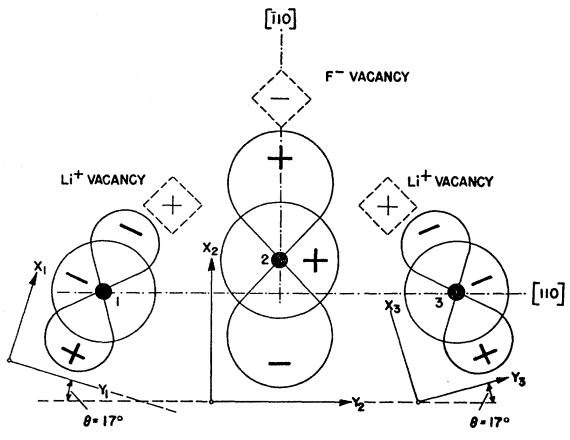

FIG. 2. Schematic representation of the ground state wave functions and their symmetry. The axes x_α, y_α, and z_α ($\alpha=1, 2, 3$) are the principal axes of the tensors $\mathbf{T}^{(\alpha)}$.

TABLE I. Principal components of the tensors $\mathbf{T}^{(\alpha)}$. The measurements give only the absolute values of the total components. The relative signs as well as the decomposition into s and p parts were obtained from a proposed interpretation of these data.

	$T_x^{(\alpha)}$ (gauss)			$T_y^{(\alpha)}$ (gauss)			$T_z^{(\alpha)}$ (gauss)		
α	total	p part	s part	total	p part	s part	total	p part	s part
2	+1122	+908	+214	−212	−426	+214	−268	−482	+214
1, 3	+378	+178	+200	+142	−58	+200	+80	−120	+200

The relative signs of the s-admixtures given in Fig. 2 are suggested by crystalline field considerations based on the vacancy configuration of Fig. 1.

A discussion of the spectroscopic splitting factor involves higher order analysis of the hyperfine structure and will be given in a forthcoming detailed paper.

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Dorfman's Proposal Regarding Cyclotron Resonance in Ferromagnetic Substances*

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DORFMAN[1] has recently made the interesting suggestion that the spin-orbit interaction in ferromagnetic and ferrimagnetic substances provides an effective magnetic field (of the order of 10^6 oersteds) acting on the orbital motion of electron and hole charge carriers in these substances. He suggests that cyclotron (diamagnetic) resonance might therefore be detected at appropriate frequencies (of the order of 10^{12} cps) in the absence of an applied external magnetic field.

However, in a perfect crystal the spin-orbit interaction is invariant under the translation group of the crystal, just as the Coulomb potential is invariant, and the electron eigenfunctions will be rigorously of the Bloch form $e^{i\mathbf{k}\cdot\mathbf{r}}u_\mathbf{k}(\mathbf{r})$, where $u_\mathbf{k}$ contains spatial and spin coordinates. Such states do not have the characteristics of the Landau states of free particles in a uniform magnetic field. Indeed, it is well-known[2] that the usual relation $\mathbf{v}=\mathrm{grad}_\mathbf{k}\epsilon$ for the group velocity v as determined from the energy ϵ is valid regardless of the nature of the periodic potential. The galvanomagnetic[3] and magneto-optical effects[4] in ferromagnetic