infinity. The image was found to consist of the anticipated Fraunhofer diffraction pattern for a rectangular aperture illuminated by wavefronts approximately plane and approximately coherent. This pattern disappeared when the excitation was reduced below threshold. The choice of the small dimension of the aperture was such as to lead to an angular spacing of the diffraction fringe of the order of the angular divergence of the stimulated emission light.

We believe that the approximate parallelism of the light and the existence of the Fraunhofer fringes are clear evidence for coherence over a distance across the end surface of the order of 100 wavelengths.

Some further experiments were carried out with the crystal immersed in liquid nitrogen. Under these conditions it was found (1) that the threshold for the appearance of the stimulated emission phenomenon was ~30% lower than at room temperature, (2) that the R_1 line was narrowed by a further factor of 2 or more (but note that the unnarrowed line is itself a factor of 5 or so sharper than at room temperature), and (3) that the degree of parallelism was not significantly changed.

The degree of perfection of the crystals was investigated by x-ray techniques. The orientation of the c axis was found to vary down the length of the rod by as much as ± 1°; this may correspond to local variations in refractive index of the order of several parts per million. In addition the investigation revealed the presence of strain. Therefore, even though the ends are flat and parallel to one minute or so, the optical path lengths from end to end must vary by at least five wavelengths. Thus it seems unlikely that there is coherent excitation of a single decay mode of the crystal etalon. Rather it is probable that there is a coherent excitation of a large number of modes at once, although a small fraction of the total modes.

The energy emitted through the silvered ends and within the cone during a single pulse, as has been shown, was highly monochromatic and consisted of $\sim 10^{-2}$ joule. For such a light source this corresponds to an effective temperature of $\sim 10^{10}$ °K.

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NUCLEAR SPIN-LATTICE RELAXATION IN VANADIUM METAL

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From a comparison of the measured values of the Knight shift, $\Delta H/H$, and the spin-lattice relaxation time, T_1, of the nuclear magnetic resonance in a metal, information can be derived about the state of the electrons in the metal. For, as Korringa showed,[1] if the electrons responsible for the shift and the relaxation behave as uncorrelated electrons of largely s character, the following simple relation exists between T_1 and $\Delta H/H$:

$$T_1(\Delta H/H)^2 = (\hbar/\pi kT)(\beta I/\mu)^2, \tag{1}$$

where T is the absolute temperature, and β and μ are the magnetic moments of an electron and nucleus, respectively, while the other symbols have their conventional meanings. Conversely, departure from the Korringa relation indicates departure of the electrons from such simple behavior.

This note reports the results of measurements of T_1 in vanadium metal, and some inferences drawn from them. The results are of some interest because they are the first reported accurate measurements of T_1 in a transition metal, where the unfilled shell of d electrons might be expected to influence strongly the nuclear magnetic resonance. As a probable consequence of these electrons, the results show much the largest departure from the Korringa relation observed so far.

The sample was initially prepared electrolytically by the U. S. Bureau of Mines Electrometallurgical Section, and was found by analysis to have a purity of 99.7%, the principal impurity being 0.09% by weight of dissolved iron.

The measurements of relaxation were made at temperatures of 20.4°K, 77.3°K, and 292°K, and at a frequency of 11.000 Mc/sec by an improved, pulsed radio-frequency method incorporating coherent detection and post-detection integration. The pulse sequence used consisted of an initial $\pi/2$ pulse followed after a variable period by a further $\pi/2$ pulse.

The value of T_1 was found to vary inversely as the absolute temperature, T, from 292°K down to 20.4°K, with T_1T equal to $(0.788 \pm 1\%)$ sec °K, indicating that, over this temperature range, the dominant mechanism of spin-lattice relaxation is the interaction between the nuclear spins and the spins of the conduction electrons.

If we assume that the electrons producing the spin-lattice relaxation are behaving as uncorrelated electrons of mainly s character and use the measured value of T_1T in Eq. (1) we can calculate the value of Knight shift such electrons would produce. By this means we derive a value of $\Delta H/H$ of 0.219%. Measured values, however, are some 2.5 times this, ranging from 0.55%[2] to 0.58%.[3]

Such a discrepancy is in the wrong direction to be explained by invoking electron states of other than s character, for such states would merely contribute to the relaxation without affecting the shift. Furthermore, because of their low spin density at the nucleus, their effect on relaxation would be small.

Consequently, we assume that T_1 is largely determined by the effective density of s states at the Fermi surface. As this density appears, from the temperature-independence of T_1T, to be constant, and because of the lack of a plausible mechanism for prolonging T_1, we conclude that $\Delta H/H$ and, hence, the spin paramagnetism of the s states are enhanced by a factor of about 2.5.

However, further information about the relation of the effective density of states of the conduction electrons to their spin paramagnetism, χ_p, can be derived from measurements of the coefficient of electronic specific heat, γ_e, and the magnetic susceptibility of the metal.[4]

The measured value of γ_e in vanadium[5] is 8.8×10^{-3} joule/gram atom deg^2. If we again assume that the electrons are uncorrelated, we obtain a value for the spin susceptibility of these electrons of 122×10^{-6} emu/gram atom. Childs et al.[6] have measured the total susceptibility of vanadium and after making small corrections for diamagnetism have arrived at a value for the spin susceptibility of 308×10^{-6} emu/gram atom. Thus, the spin susceptibility of the mainly d-type electrons at the Fermi surface is greater than that expected from their effective density of states by the same factor, 2.5, as for the s electrons.

In the present state of theory the explanation of this surprising coincidence must be to some extent speculation, but in the absence of any better theory, it is suggested that the enhancement of the susceptibility is a result of exchange interactions between the conduction electrons, while one interpretation of the fact that the susceptibility of the s electrons is enhanced to the same high degree as that of the d electrons is that there is such thorough admixture of s states and d states at the Fermi surface, that they are equally affected by exchange effects.

From the measured values of T_1 and γ_e, we can deduce approximately the proportion, ξ, of the electrons at the Fermi surface having s character, by means of Korringa's formula,

$$T^{-1} = 2\pi k T \hbar^{-1} \xi^2 n^2(E_0) a^2(s), \tag{2}$$

where $n(E_0)$ is the total density of states at the Fermi surface, obtained from γ_e, and $a(s)$ is the hyperfine coupling constant for an s electron. Using the value of $a(s)$ calculated by Knight[7] in Eq. (2) leads to a value for ξ of 0.17. The fact that such a reasonable value for ξ can be obtained from T_1 alone tends to substantiate the view that the departure from the Korringa relation is mainly due to enhancement of the Knight shift.

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