first two peaks\(^9\) which he was unable to identify. By using monochromatic excitation he showed that the 1.07 \(m_0\) peak was that due to the spin orbit split-off valence band. Hence from the 0.7 \(m_0\) light hole it was possible to estimate the heavy hole to be 2.2 \(m_0\). At 70 kMc this required fields of the order of 60 kgauss. Hence the experiments were repeated with higher fields to obtain all three masses as shown.

**CONCLUSIONS**

In order to carry out the experiments to date, we have had to work on a two-shift basis and are already starting on a three-shift operation in order to accommodate additional experiments that are being planned for the existing magnet laboratory. It is expected that in about one and a half years the new laboratory will be in operation and will permit many more researchers from other organizations as well as graduate students and visiting scientists to participate and perform experiments with high fields. Since the sponsorship comes from the Solid State Sciences Division of the Air Force Office of Scientific Research, it is expected that the bulk of the program will be in solid state. However, the new facilities will be made available to research workers of other fields as well, with the object of making this a truly international Laboratory and with an international flavor as well.

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**Modification of Spin Screw Structure due to Anisotropy Energy and Applied Magnetic Field**

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Recent development in the theory of screw structure of spins and its modification due to anisotropy energy and applied magnetic field is reviewed, with reference to neutron diffraction work on rare-earth metals and \(\text{MnAu}_2\).

**1. INTRODUCTION**

The screw structure of spins, first predicted by Yoshimori\(^1\) and later by Villain\(^2\) and Kaplan\(^3\), has found its application in a number of examples. Rare-earth metals with more than half-filled \(4f\) shells, ranging from \(\text{Tb}\) to \(\text{Tm}\) (\(\text{Tb, Dy, Ho, Er, Tm}\)), present intricate but interesting examples. For these metals magnetic measurements have been done by the people at Ames\(^4\) and neutron diffraction measurements by the people at Oak Ridge.\(^5\) They all show ferromagnetism at low temperatures, not always a simple ferromagnetism intricate but interesting examples. For these metals anisotropy energy is expected that in about one and a half years the new laboratory will be in operation. In order to carry out the experiments to date, we have had to work on a two-shift basis and are already starting on a three-shift operation in order to accommodate additional experiments that are being planned for the existing magnet laboratory. It is expected that in about one and a half years the new laboratory will be in operation and will permit many more researchers from other organizations as well as graduate students and visiting scientists to participate and perform experiments with high fields. Since the sponsorship comes from the Solid State Sciences Division of the Air Force Office of Scientific Research, it is expected that the bulk of the program will be in solid state. However, the new facilities will be made available to research workers of other fields as well, with the object of making this a truly international Laboratory and with an international flavor as well.

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by Herpin and Mériel\textsuperscript{9} with MnAu\textsubscript{2} by neutron diffraction measurements. Rare-earth metals are also being investigated at Oak Ridge by Koehler.\textsuperscript{10} The corresponding theory, applicable to simplest cases only at the present moment, has been developed by Herpin and Mériel,\textsuperscript{9} Enz,\textsuperscript{11} and the present writer.\textsuperscript{12}

It is the purpose of this memorandum to briefly review the information at present available and to outline the theories mentioned above.

2. OUTLINE OF THE THEORY OF SCREW STRUCTURE

Before going over to the main part of the present article, it might be helpful to briefly outline the theory of screw structure. Consider a set of layers of atoms whose spins are coupled ferromagnetically within each layer with an exchange constant $J_i$, between adjacent layers with $J_e$, between next-nearest-neighboring layers with $J_{e}$, and so on. Let the spins in the same layer be parallel and their direction be specified by an angle $\theta_n$, measured in one plane from a certain specified direction, where $n$ is the number of the layer under consideration. Then the interaction energy can be written

$$E = -N\sum_1^n \left[ J_i \cos(\theta_{n+1} - \theta_n) + 2J_e \cos(\theta_{n+2} - \theta_n) + \cdots \right]$$

where, for the sake of simplicity, the number of pairs interacting in the same way are supposed to be included in the exchange constants. If we put $\theta_n = nq + \text{const}$, we have

$$E = -N\sum_1^n \left[ J_i \cos(q_{n+1} - q_n) + 2J_e \cos(q_{n+2} - q_n) + \cdots \right]$$

$N$ being the number of layers. Thus, the minimum of the energy corresponds to the maximum of $J(q)$, and if $J(q)$ is the largest at $q = 0$ or $\pi$ the system will show ferromagnetism or antiferromagnetism, respectively. If, however, $J(q)$ is the largest at $q_0$ different from 0 and $\pi$, the system will have a screw structure, in which the spin vectors rotate uniformly with an angle $q_0$ as one goes from layer to layer. Yoshimori has proved rigorously that for crystals consisting of equivalent magnetic atoms—equivalent in the sense that the environment of every atom, as regards the magnetically interacting neighbors, is the same apart from translation—the screw structure represents the stable solution of the problem of minimum energy if $J(q)$ is the largest at $q_0$. The example he took was MnO\textsubscript{2}, for which he explained beautifully the neutron diffraction lines observed by

\textsuperscript{9} A. Herpin and P. Mériel, C. R. Acad. Sci. 250, 1450 (1960); preprint from Service de Physique du Solide et de Résonance Magnétique, Centre d’Etudes Nucléaires de Saclay.


\textsuperscript{13} R. A. Erickson, unpublished work.
