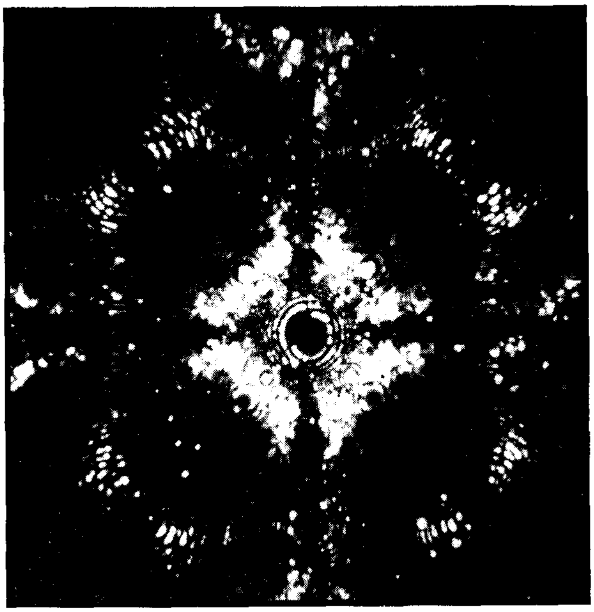

FIG. 1. Iron whisker with two screw dislocations intersecting central 001 plane.

in the form of a horse shoe (Fig. 1) rather than the closed ring which is common for field evaporation in the absence of a dislocation.[11] Figure 2 shows the same Fe whisker as Fig. 1 after the two dislocations were anihilated by climb at 21°K under the radial stress of 10^{11} d/cm^2 exerted by the field during continued field evaporation. The central region of the 011 oriented crystals was too faint to reveal with certainty the presence of dislocations, while the net planes of the two sidewards lying cube planes collapsed in a regular manner with closed rings. From the horse shoe shape one can conclude that the 001 oriented iron whiskers contained a pair of dislocations fairly close together (100 A) and near the axis with screw components of the Burgers vectors in the 001 axis and of opposite sign. If these were, as they seemed

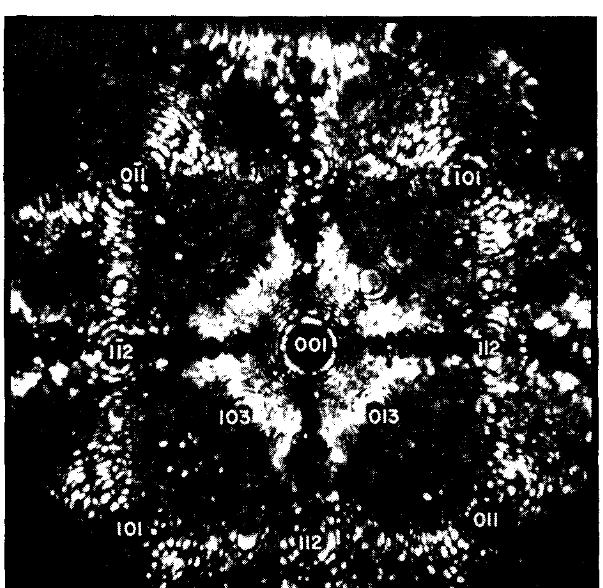

FIG. 2. Same iron whisker after field evaporation of 20 more surface layers and anihilation of dislocations.

to be, the only dislocations in the entire whisker cross section (most of it was etched away to shape the tip and the areas outside the 001–103 regions could not be observed well enough) then there would be no net twist in agreement with the x-ray investigations of the previous observers. The experiments are being continued in order to find out whether the occurrence of paired axial screw dislocations is a general phenomenon in whiskers without Eshelby twist.

The author is indebted to Dr. N. Cabrera and Dr. W. W. Webb for stimulating discussions.

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Operation of a Zero-Field *X*-Band Maser*

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(Received July 10, 1959)

A MASER using iron doped Al_2O_3 has been operated successfully as an amplifier at 12.3 kMc using only very small magnetic fields for tuning. In this case the crystalline electric field splits and mixes the spin states in a manner suitable for three level maser action without a magnetic field present. With other presently used materials, one has to use a large dc magnetic field to obtain a similar situation.

The paramagnetic resonance spectrum of the Fe^{+++} ion in Al_2O_3 has been studied in several laboratories,[1–4] and its energy level diagram for small magnetic fields and $\theta = 0°$ (i.e., the c axis aligned with the dc magnetic field) is shown in Fig. 1. A total of six levels is involved as the spin of the Fe^{+++} ion is 5/2. Note that each of the levels is designated as a mixture of spin states. This mixing is a result of interactions with the cubic crystalline electric field and occurs only for ions with a spin of 2 or larger. As a result of this mixing, transitions from the lower two states to the upper two states are allowed even with $\theta = 0°$. When θ is varied, the rate of splitting with magnetic field of the pairs of spin states changes.

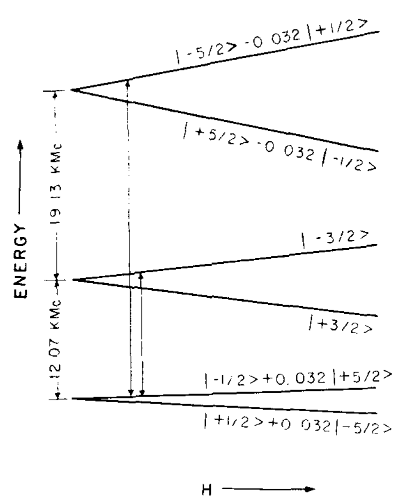

FIG. 1. Energy level diagram for Fe^{+++} ion in Al_2O_3 for small magnetic fields and $\theta = 0$.

A small silver-plated rectangular parallelepiped of 0.1% nominal iron-doped Al_2O_3 prepared by Linde was used as a reflection cavity.[5] Cavity modes with excellent loss Q's were obtained at 12.3 and 31.8 kMc. With $\theta = 20°$ and $H = 120$ gauss the frequencies of the transitions indicated on the energy level diagram matched these cavity resonances.

A QK290 klystron was used to provide 10 mw of pump power at 31.8 kMc. We were able to saturate the 31.8-kMc transition at 4.2° even though the paramagnetic absorption appeared to be very weak. A voltage gain band width product of 15 Mc/sec was obtained at this temperature with a signal frequency of 12.3 kMc.

* This research was supported by Project Michigan (administered by the U. S. Army Signal Corps).
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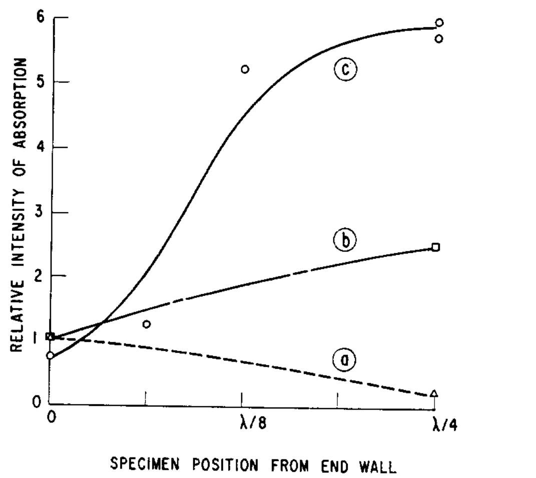

FIG. 1. The relative intensity of the magnetic resonance absorption by a sample of $MnFe_2O_4$ powder as it depends upon position of the sample in a rectangular $TE_{10(16)}$ microwave reflection cavity. The frequency is 9.1 kMc/sec, the incident power is 50×10^{-3} w. The specimen is moved along the central E plane from the end wall to a quarter of a guide wavelength above the end wall. Curve (a) corresponds to a powder sample cemented to the outside of a quartz capillary tube that is 3 mm in length and of 0.25-mm o.d. The capillary is oriented along the microwave electric field direction; a dc magnetic field also acts along this direction. In curve (b) a 0.025-mm-diam copper wire 3 mm long is introduced into the capillary of (a). In (c) the sample examined in (a) and (b) has been replaced by another that consists of approximately the same amount of $MnFe_2O_4$ powder that is now cemented *directly* to the surface of a copper wire of the same dimensions as in (b). The curves (a), (b), and (c) are drawn to collect the data points. The relative intensity of absorption is determined in relation to (a) at the end wall position.

Microwave Magnetic Field near a Conducting Perturbation

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(Received June 15, 1959)

THE intensity of a magnetic resonance absorption has been used to examine the microwave magnetic field strength near a conductor that perturbs the microwave electric field of a resonant cavity. One interesting result is that the microwave magnetic field strength near the surface of a conducting rod may be easily made to exceed the maximum magnetic field strength existing in the unperturbed cavity at the same incident power level. This would appear to be a useful means of effectively coupling microwave energy into a magnetic specimen.

When a conductor is placed into a region of an electric field it is polarized. Time dependent electric fields give time dependent polarizations that have the periodicity of the external field and give rise to currents that, aside from geometric factors, have a magnitude proportional to both the electric field strength and the frequency.* The microwave magnetic field due to these currents is particularly large for rod-shaped specimens, and the experimental observations reported in the following relate to that geometry.

The first experiment to be described is the measurement of the relative intensity of the microwave magnetic resonance absorption of an $MnFe_2O_4$ powder specimen as it depends upon position within a rectangular (TE) microwave cavity at *ca* 9 kMc/sec. The powder specimen is cemented onto the outside surface of a quartz capillary tube that is 3 mm long and of 0.25-mm o.d. The capillary is attached to a quartz post so that it can be positioned along the central "E" plane of the cavity with the capillary axis along the microwave E field. A dc magnetic field is applied in the axial direction, and its magnitude is adjusted to establish the magnetic resonance of the powder. The total resonance absorption here is composed of contributions from many, essentially isolated, randomly oriented particles of the ferrite powder; the line width of the composite absorption is about 1000 oe. The resonance absorption is used here as an indication of the square of the microwave magnetic field strength averaged over the sample. In Fig. 1, curve (a) displays the observed decrease of the relative intensity of absorption as the sample is moved away from the cavity end wall. This is the variation expected for a magnetic resonance absorption that is driven by the usual microwave magnetic field strength for this cavity geometry. The experiment is now repeated after introducing into the capillary tube a bare copper wire that is 3 mm long and of 0.025-mm diam. In all the results described here the cavity coupling and incident microwave power are constants of the experiment. The small variation of the cavity Q with dc magnetic field is used as a measure of the magnetic resonance absorption in the standard way.† Curve (b) displays the fact that the relative intensity of absorption now increases (the line width and shape remaining as before) with position away from the end wall. This is in agreement with the prediction that the electric field "drives" the absorption; that is, the microwave electric field is locally perturbed and gives rise to a locally large magnetic field. Further confirmation is found in curve (c) of the figure which displays the result of an experiment in which a copper wire of the same size as in (b) is coated directly (no intervening quartz capillary) with approximately the same amount of the ferrite ($MnFe_2O_4$) powder. The increased absorption, here relative to (b), is interpreted to be the result of the larger microwave magnetic field that occurs closer to the perturbing conductor.

The next experiment describes the dependence of the microwave magnetic field at the surface of a conductor as it depends upon conductor length at fixed position in the microwave cavity. The conductor in this experiment is ferromagnetic and so supplies its own field probe; i.e., the resonance absorption is due to the magnetization within the surface "skin depth." The geometry of the experiment is shown in the sketch of Fig. 2 and is such that the magnetic resonance is equivalent to resonance in a wide, flat plate. The relative intensity of absorption is expected to be proportional to the square of the surface microwave magnetic field multiplied by the length of the conductor; the latter factor measures the effective magnetic sample volume for constant "skin depth." We further expect the magnitude of the surface microwave magnetic field to be proportional to the square of the rod length.‡ The over-all dependence of the relative intensity of absorption, for otherwise identical conditions, becomes proportional to the 5th power of the specimen length. Figure 2 indicates this expectation to be confirmed. When the rods become comparable in length to the width of the cavity, the data appear to be approaching length independence. This behavior may arise from the increasing importance of the capacity between the specimen ends and the cavity walls.