duce any stimulated emission at 56°K when the crystal was misorientated by more than a degree from the "push-pull" condition.

The results quoted below were obtained by an experiment using liquid oxygen pumped to a pressure of about 2 mm of mercury, which indicated a temperature near to 56°K. The cavity Q was in the region of 20 000. The pump power available was limited, our source being a war surplus 2K33 klystron whose power output was measured to be 50 milliwatts at the frequency of interest. It was apparent that the power entering the cavity was not sufficient to saturate the pump transitions completely. With the cavity undercoupled at the signal frequency, oscillations were observed, the power output being 50 microwatts at a frequency of 9518 Mc/sec. By using increased penetration of the coupling loop, the cavity could be overcoupled at the signal frequency and stable gain was achieved up to 30 db. The product $B\sqrt{G}$ was measured to be 3.8 Mc/sec. This figure was constant for signal levels in the range 10^{-12} to 10^{-7} watts.

The successful operation of a maser at these comparatively high temperatures has both theoretical interest, indicating that the relaxation processes are not so temperature dependent as was at one time envisaged, and also practical importance, as freedom from the use of liquid helium will simplify considerably the operation of maser equipment in the field. In conclusion, we would emphasize that our results are preliminary only, being obtained with restricted pump power, a cavity designed for experiments with another material at helium temperatures, and using an active sample whose size and shape were determined for us by chance. Thus we hope to see better performance data as a result of further development.

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FERROMAGNETIC SUPERCONDUCTORS

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Studies previously reported,[1] particularly on lanthanum-gadolinium solutions, have raised the possibility that the phenomena of superconductivity and ferromagnetism might overlap, resulting in a ferromagnetic superconductor. An interesting case where this occurs is found in the solid solutions between $CeRu_2$ (superconducting at about 5.1°K) and $PrRu_2$ or $GdRu_2$ (respectively, ferromagnetic at 40° and above 70°K).

The first system, $(Ce,Pr)Ru_2$, is shown in Fig. 1 and the region at which superconductivity and ferromagnetism might overlap is at temperatures below 1°K, not conveniently accessible with our apparatus.

The second system, $(Ce,Gd)Ru_2$, however, gave a temperature region a good deal above 1°K for the simultaneous occurrence of superconductivity and ferromagnetism in the same sample though perhaps not in the same volume element. This is shown in Fig. 2. For a composition of $Ce_{0.94}Gd_{0.06}Ru_2$, Curie point (Cpt) and superconducting transition temperature (T_c) coincide, provided the measuring field is below 10 gauss. With larger fields T_c can be lowered and so be more separated from the corresponding Cpt. For compositions with much higher T_c than Cpt the measurements require the destruction of superconductivity by a magnetic field before ferromagnetism can be detected. The inverse case in which the Cpt is higher than T_c is a much

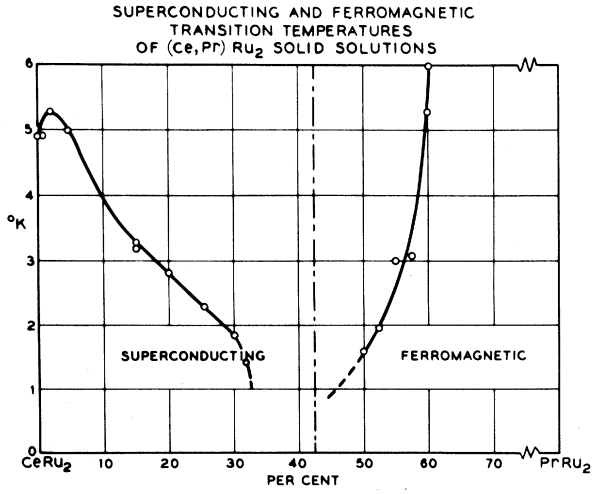

FIG. 1. Superconducting and ferromagnetic transition temperatures of $(Ce, Pr)Ru_2$ solid solutions.

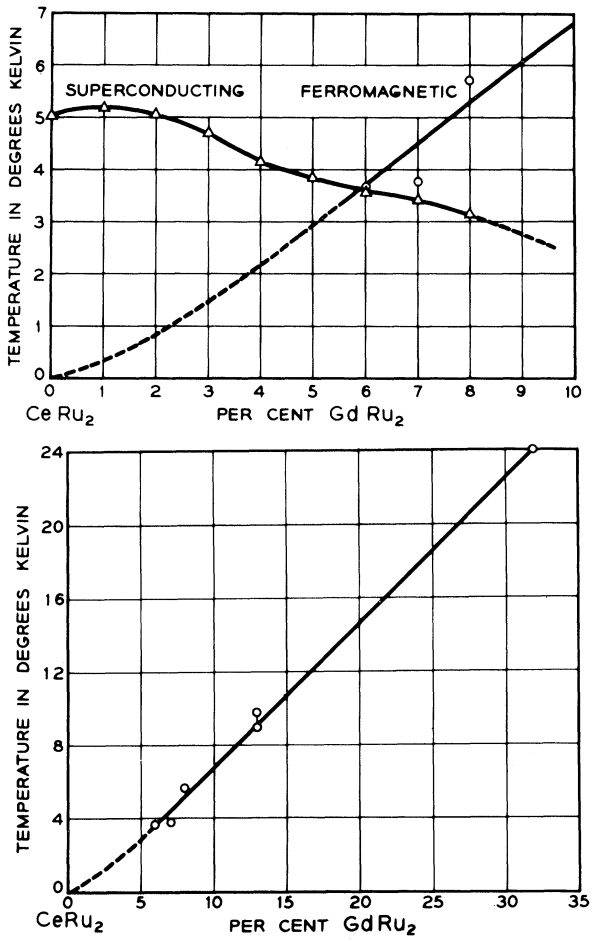

FIG. 2. Superconducting and ferromagnetic transition temperatures of (Ce, Gd)Ru_2 solid solutions. (a) 0 to 10% $GdRu_2$. (b) Ferromagnetic Curie point from 5% to 32% $GdRu_2$.

easier one in which to show the occurrence of both. By lowering the temperature of a sample with 8% gadolinium, first the onset of ferromagnetism at the Cpt is observed and then at lower temperatures yet the crystal becomes superconducting. However, at these low temperatures the spontaneous ferromagnetic polarization is more than an order of magnitude larger than any frozen-in flux would be for a typical nonmagnetic superconductor.

The fact that so much flux escapes the sample even though it is superconducting would suggest that the sample never leaves the intermediate state. If, as seems likely, a typical conduction electron in the sample is acted on by the total flux, the London equation curl $\vec{j} = (1/\lambda c)\vec{B}$ and Maxwell's equations demand that $B \to 0$ in the interior of a massive specimen, and only the flux in a shell of order of the penetration depth can escape, giving a negligible total moment. This is, of course, not the case if there is a pattern of superconducting domains whose sizes adjust themselves to yield the observed flux.

We want to thank Dr. A. M. Clogston for many stimulating discussions, and Mrs. V. B. Compton for all the structural work.

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MOBILE AND IMMOBILE EFFECTIVE-MASS-PARTICLE COMPLEXES IN NONMETALLIC SOLIDS

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Quite recently the study of excitons has taken a front-rank position among the techniques for the study of nonmetallic solids.[1] It is the purpose of this note to outline a natural extension of the concept of the exciton, namely to consider bound aggregates of two or more charged particles in a nonmetallic solid, at least two of which are effective-mass particles, i.e., electrons in a conduction band or holes in a valence band. We refer to such aggregates as "effective-mass-particle complexes."[2] The exciton itself is, of course, the simplest such complex. The choice of nomenclature reflects the restriction of our discussion to those weakly bound complexes for which the well-known effective-mass approximation gives a good description of the "envelope" motion of the electrons and holes. Therefore our conclusions are particularly relevant to those solids (e.g., Ge, GaAs, CdS) for which the only possible excitons are shallow ones. A complex which has as a constituent member an ion fixed in the lattice is localized about the ion and hence is called an immobile complex. On the other hand, a complex consisting entirely of effective-mass particles is obviously a mobile complex.[3]

We have listed some five types of complexes in Table I, which also contains explanations of the notation. For the sake of simplicity we assume spherical constant-energy surfaces for electrons and holes. In enumerating complexes