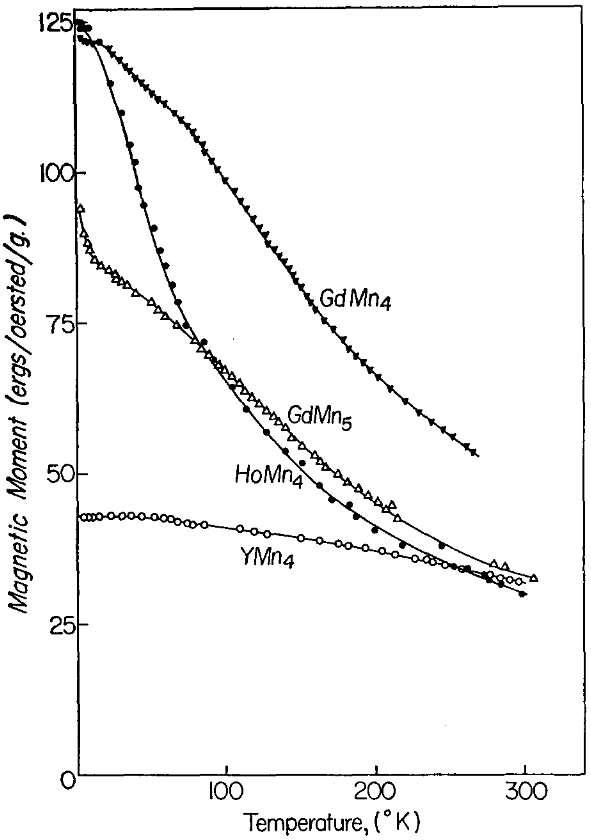

FIG. 1. Thermomagnetic behavior of AMn_4 alloys and $GdMn_5$ at 7240 oe.

thermomagnetic curves for the three AMn_4 alloys and GdMn are$_5$ shown[3] in Fig. 1. The AMn_5 and A_2Mn_9 curves, where A is Ho or Y, resemble the corresponding AMn_4 curves, except that the moment per gram decreases as the Mn content increases. In the Gd alloys, the data for Gd_2Mn_9 fall very close to the $GdMn_5$ curve. The significance of the difference in behavior between $GdMn_4$ and the other two alloys below 10°K is not at present clear.)

The fact that the saturation moment is maximal for alloys of composition AMn_4 lends support to the indication derived from the x-ray studies that this rather than AMn_5 is the basic stoichiometry. However, results obtained to date are not sufficiently extensive and conclusive to exclude the possibility that $GdMn_5$ (or some other phases with Mn content in excess of 80%) exists. Resolution of this question must await additional work, probably necessitating the development of a technique for obtaining single crystals.

* This work was supported by the Directorate of Chemical Sciences, Air Force Office of Scientific Research.

[1] L. V. Cherry and W. E. Wallace, J. Appl. Phys. 32, 340S (1961).

[2] L. V. Cherry and W. E. Wallace, unpublished work.

[3] W. M. Hubbard, E. Adams, and J. V. Gilfrich [J. Appl. Phys. 31, 368S (1960)] in their study of alloys of Gd with the transition metals of the First Long Period report a few magnetic measurements for Gd-Mn alloys. Their observations are in general agreement with the results reported here and in reference 1.

Trigonal Sites and 2.24-Micron Coherent Emission of U^{3+} in CaF_2

S. P. S. PORTO AND A. YARIV
Bell Telephone Laboratories, Inc., Murray Hill, New Jersey
(Received January 2, 1962)

IN CaF_2, U^{3+} displaces a Ca^{++} ion. The extra positive charge can be neutralized in a number of ways: Bleaney[1] has found, by paramagnetic resonance methods, a compensation mechanism whereby an extra F^- ion occupies the nearest interstitial site, a situation giving rise to a tetragonal symmetry about the ⟨100⟩ direction and one which resolves the tenfold degeneracy of the $^4I_{9/2}$ ground state of the U^{3+} free ion into Kramers doublets.

Low[2] has shown that a very small fraction of the U^{3+} ions retain the original cubic symmetry of the site, in which case the residual degeneracy is made up of two quartets (Γ_8) and one doublet (Γ_6).

We have found, in addition to the two sites described above, a U^{3+} with a trigonal S_6 symmetry about the ⟨111⟩ direction. The tenfold degeneracy is split into five Kramers doublets and paramagnetic resonance is observed when the lowest doublet is split in a magnetic field.

The observed paramagnetic resonance spectrum, when the external magnetic field was rotated in the (110) plane, is shown in Fig. 1. There are four trigonal sites two of which have their trigonal axes in the (110) plane containing the magnetic field. These sites give rise to the C and F spectra of Fig. 1 where the minima are separated by 70.5°. The two sites with trigonal axes along the body diagonals which are not contained in the (110) plane give rise to a single spectrum which is shown as D. In our case D was actually split slightly due to a small crystal misorientation. The spectra were obtained at 24 kMc.

Since, as was demonstrated by Sorokin and Stevenson,[3] the trivalent uranium in CaF_2 (U^{3+}:CaF_2) can be made to emit coherent 2.5-micron radiation under sufficiently strong excitation, it was of interest to determine which crystal site is responsible for this radiation. Our investigations disclose that in crystals in which the tetragonal site concentration is comparable to that of the trigonal site, the coherent radiation is near 2.5 microns. In a crystal in which the trigonal sites outnumbered the tetragonal sites by 10:1, the 2.5-micron radiation could not be detected. Instead, a new 2.24-micron coherent emission was found which we thus associate with the trigonal site. The spectral profile of the 2.24-micron emission is shown in Fig. 2.

A more complete account of the paramagnetic resonance analysis and the results of a current investigation into the site selection mechanisms will be published elsewhere.

The authors are indebted to Dr. P. A. Forrester and Dr. C. F. Hempstead who had investigated Tb^{3+} in tetragonal and trigonal sites[4] and thus greatly facilitated the present work. The crystals used were obtained from W. Hargraves of Optovac and from

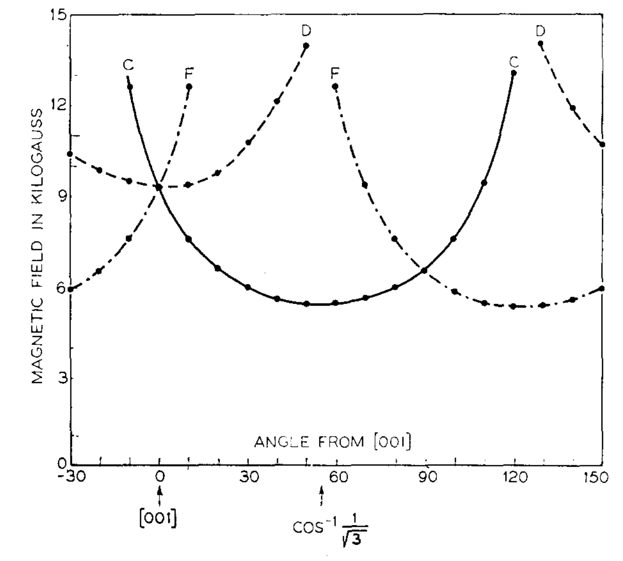

FIG. 1. Paramagnetic resonance spectra of the four trigonal sites of U^{3+} in CaF_2. The resonance magnetic field is plotted vs its deviation angle from the [0,0,1] direction.

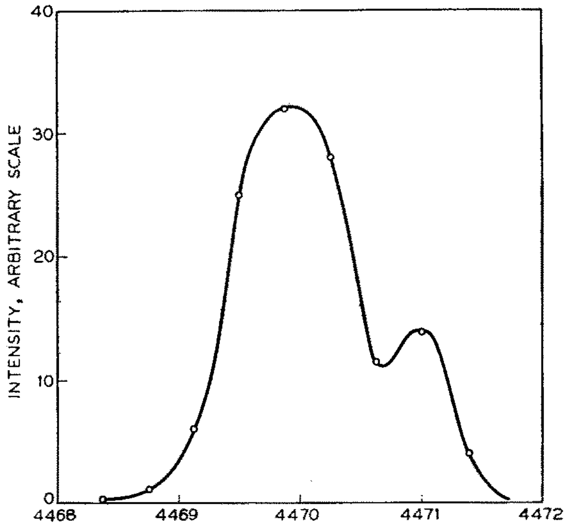

FIG. 2. The spectral profile of the coherent emission associated with the trigonal site.

R. W. Johnson of Harshaw Chemicals Company. L. E. Cheesman and D. H. Olson assisted ably in the experimental work.

[1] B. Bleaney, P. M. Llewellyn, and D. A. Jones, Proc. Roy. Soc. (London) **B69**, 858 (1956).
[2] G. Vincow and W. Low, Phys. Rev. **122**, 1390 (1961).
[3] P. P. Sorokin and M. J. Stevenson, Phys. Rev. Letters **5**, 557 (1960).
[4] P. A. Forrester and C. F. Hempstead (to be published).

Electron Current Pulsations in Multipacting Discharges*

AUGUST MILLER† AND H. BARTEL WILLIAMS
Physics Department, New Mexico State University, University Park, New Mexico
(Received December 6 ,1961)

RADIO-FREQUENCY discharges between plane parallel internal metallic electrodes at pressures below 10^{-3} torr (hereafter called "multipacting" discharges) generally have been thought of as being controlled almost entirely by the secondary electron resonance mechanism,[1,2] the influence of ions usually being regarded as relatively unimportant. Multipacting discharges usually exhibit very little visible glow, and the electron current has been assumed to have a steady-state value determined by the electron dynamics, the secondary emission characteristics of the electrode, and space-charge effects.

Recent observations of multipacting discharges subjected to axial magnetic fields of a few hundred gauss have indicated that very large periodic pulsations in the electron current may occur in an apparently steady-state discharge. Such pulsations occur with frequencies of the order of a few hundred kc and have been shown to be simultaneous with pulsations in the light intensity.

The experimental discharge chamber consisted of a 9.0-cm.-i.d. Pyrex cylinder sealed to brass end-plates with Picein 105 hard wax. Type "A"-nickel electrodes were mounted from the end-plates and had a diameter of 7.0 cm. The electrode separation was adjustable from 0 to 6.5 cm by means of a sliding O-ring seal. A pair of Helmholtz coils were used to provide an axial magnetic field in the discharge region. Pumping was accomplished with an oil diffusion pump with liquid N_2 or solid dry ice trapping. Radio-frequency power was supplied at 40 Mc from a 600-w transmitter and at 55 Mc from a 60-w transmitter. Electron currents were sampled through 0.025-cm-diam hole in the center of one of the electrodes and were observed by means of a Tektronix-type 585 oscilloscope. Pressure was monitored with a Veeco-type 75 ionization gauge.

Electron current pulsations were observed with rf excitation at both 40 and 55 Mc, but the frequency of pulsation was not noticeably sensitive to the excitation frequency. On the other hand, the pulsation frequency was found to be approximately inversely proportional to the axial magnetic field strength in the range 200–600 gauss and nearly proportional to the inverse square of the peak applied rf voltage. Pressure variations between 5×10^{-4} and 1×10^{-3} torr strongly affected the frequency of the current pulsations, but no useful data were obtained in this connection. In general, the frequency appeared to increase with increasing gas pressure.

Several types of gases were fed into the discharge chamber by a continuous bleeding process, but again the pulsation rate did not seem to change noticeably for different kinds of gases. Argon, hydrogen, helium (all of industrial grade), and air were used.

Extensive alterations were made in the external circuitry and arrangement in order to detect any external influences that might have been causing the pulsations. All such attempts failed to indicate external causes for the pulsations and it is firmly believed that the causes lie within the discharge itself.

It was found that the pulsations could be stopped in at least two different ways. First, if the rf power was increased above some critical value, a transition into the high-frequency plasmoid[3,4] mode occurred, and the pulsations ceased. Second, a dc bias of 20 to 50 v placed between the two electrodes also stopped the pulsations without an appreciable change in the visual appearance of the discharge, even with rf voltage up to 1 kv (peak) applied between the electrodes.

Although no extensive theory describing the pulsation process has been devised, it is proposed that periodic partial extinction of the discharge occurs as the result of detuning the multipacting electron phase angles by the space charge of ions trapped in the center of the discharge tube. This trapping is due to the fact that the electrons, in crossing the tube in resonance with the applied rf field, produce a potential well for positive ions.[5] As a substantial number of ions is collected in the tube, their space charge upsets the critical phase angle relationship between the electrons and the rf field. This causes partial, if not total, extinction of the discharge. In such a situation the ions remain for a period which is long compared to the period of the applied rf voltage. After their dissipation, the multipacting begins anew. The application of a small dc bias should serve as a steady ion "sink," prevent any substantial buildup, and thus eliminate the pulsations. This effect was observed experimentally.

Since this type of pulsation can occur in an apparently "normal" multipacting discharge, it is evident that special checks should be made to assure its absence in any experiments designed to study the "pure" multipacting discharge.

* This work was supported by the Army Research Office, Durham, North Carolina. It has been extracted from the doctoral thesis of A. Miller.
† Now at Goodyear Aircraft Corporation, Litchfield Park, Arizona.
[1] E. W. B. Gill and A. von Engel, Proc. Roy. Soc. (London) **A192**, 446 (1948).
[2] A. J. Hatch and H. B. Williams, J. Appl. Phys. **25**, 417 (1954).
[3] R. W. Wood, Phys. Rev. **35**, 673 (1930).
[4] A. J. Hatch, Bull. Am. Phys. Soc. **4**, 152 (1959).
[5] H. B. Williams, Phys. Rev. **107**, 1451 (1957).

Announcements

Call for Papers for the Fourth Joint Automatic Control Conference

The Fourth Joint Automatic Control Conference will be held at the University of Texas in Austin on June 19–21, 1963. Papers on control theory, applications, and components are now being