mutes with the unvaried quantities, is an admissible variation. The commuting part produces no effect in Fermi systems, and the anticommuting part produces no effect in Bose systems. The full extent of the class of admissible variations is not yet known.

[1] N. M. Hugenholtz, Phys. Rev. **96**, 1158 (1954).
[2] J. Schwinger, Phys. Rev. **91**, 713 (1953).

Possibility of a Nuclear Radiation Detector by Means of Electroluminescent Phosphors

W. Low
Department of Physics, The Hebrew University, Jerusalem, Israel
(Received February 24, 1955)

EVER since Rutherford used scintillations of phosphorescent screens to count alpha particles, the scintillation counter has been used with great advantage as a nuclear radiation detector. Recently, in particular,[1,2] the combination of a photomultiplier with a phosphor like activated sodium iodide has served as a very efficient detector of α, β, and γ rays.

This note is to point out that the light output of scintillation counters using electroluminescent phosphors could possibly be increased by subjecting the phosphor to strong electric fields. (Strong electric fields have been used successfully with crystal counters like CdS and diamond.[3]) The application of dc or ac voltages of the order of 10^5 v/cm on certain powdered phosphors increases the luminescent brightness of ultraviolet-excited phosphors.[4–6] The increase of the brightness is a function of the applied voltage. Furthermore, the sudden application of an electric field or of light excitation (when the phosphor is subjected to the field) results in strong light flashes; this is called the Gudden-Pohl effect.[7] The electrons in the conduction band of a phosphor subject to high local fields are probably accelerated to energies which may cause further ionization, thus resulting in electron multiplication with perhaps local avalanche formation.[8,9] This process probably occurs only near the cathode[9] and is analogous to the processes found in glow gas discharges.

If an ionizing particle enters a phosphor which is subjected to very strong electric fields close to electrical breakdown, it will create local ionization and perhaps local avalanches along its path. These electrons on recombination will emit light flashes which can be amplified and recorded with a photomultiplier arrangement. Such a counter could possibly be made proportional by biasing the phosphor with different voltages.

We would like to suggest another possibility for the use of proper electroluminescent phosphors. Such phosphors show a threshold voltage above which light is emitted even without any external excitation. When the applied voltage increases, the light output also increases. The threshold voltage is considerably changed by irradiation with ultraviolet light, i.e., by the promotion of electrons into the conduction band. In such a case a momentary flash is observed. An ionizing particle may also give rise to a pulse of light from an electroluminescent phosphor.

[1] H. Kallmann, Natur. u. Tech. (July, 1947).
[2] R. Hofstadter, Phys. Rev. **75**, 796 (1949).
[3] R. Hofstadter, Proc. Inst. Radio Engrs. **38**, 726 (1950).
[4] Low, Steinberger, and Braun, J. Opt. Soc. Am. **44**, 504 (1954).
[5] G. Destriau, Electrochemical Society Meeting, May, 1954 (unpublished).
[6] Alexander, Low, and Steinberger (to be published). Observations have been made on ultraviolet-excited phosphors subjected to strong electric fields.
[7] B. Gudden and R. Pohl, Z. Physik **17**, 334 (1923).
[8] D. Curie, J. phys. radium **13**, 317 (1953).
[9] W. W. Piper and F. E. Williams, Phys. Rev. **81**, 151 (1952).

Cyclotron and Spin Resonance in Indium Antimonide

G. Dresselhaus, A. F. Kip, C. Kittel, and G. Wagoner
Department of Physics, University of California, Berkeley, California
(Received February 7, 1955)

CYCLOTRON resonance has been observed in a single crystal of indium antimonide at a frequency near 24 000 Mc/sec, using a light modulation technique with injected carriers, as described in our earlier publications.[1] One resonance line observed at low field strengths corresponds to an effective mass $m^* = (0.013 \pm 0.001)m$, and the resonance appears to be isotropic under rotation in a (100) plane, to within the experimental error. A recorder tracing of a typical run is shown in Fig. 1. We infer from the isotropic mass that the resonance is associated with conduction electrons. Pearson and Tanenbaum[2] have made magnetoresistance

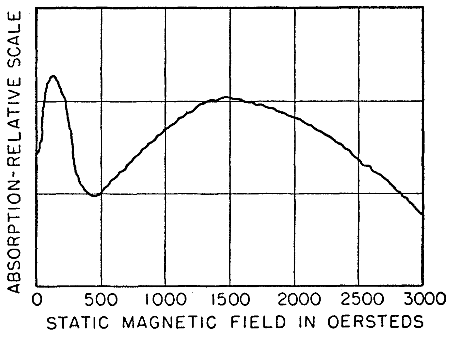

FIG. 1. Power absorption (relative scale) *vs* static magnetic field intensity, at a frequency of 23 975 Mc/sec. The origin for the vertical axis is somewhat uncertain. The low-field peak is associated with electrons, while the higher-field peak is probably associated with holes. The electronic effective mass was obtained from the average of the peak positions of a number of runs. No correction has been made for the effect of the width of the low-field line on the resonance condition, but an estimate suggests that the true effective mass may be about 3 percent higher than the apparent value; this is within the experimental error.

measurements on n-InSb which suggest strongly that the conduction band edge is spherical, while the work of Hatton and Rollin[3] suggests that the valence band is more complicated. Mobility and degeneracy studies by various workers had suggested a light effective mass for electrons in InSb, but not quite as light as we find at the band edge. The specimen giving the line shown in the figure is p-type with acceptor concentration estimated to be less than 5×10^{14} cm^{-3}. At 4°K the resonance can barely be resolved, but at 2.2°K the line is clearly resolved, with a relaxation time of approximately 1×10^{-11} sec. An n-type specimen with $N_d\sim10^{15}$ cm^{-3}, $N_a\sim10^{13}$–10^{14} cm^{-3}, gave at 2.2°K a relaxation time of about 0.7×10^{-11} sec.

We have made preliminary observations on two resonance lines with heavier masses, $m^*\sim0.18m$ and $m^*>1.2m$; the lines are somewhat anisotropic, and we suggest tentatively that they may be associated with holes. The study of these lines is continuing.

An electron spin resonance line has also been observed in both crystals at a g value of 2.11 ± 0.03.

We are particularly indebted to H. J. Hrostowski of the Bell Telephone Laboratories for the provision of the InSb crystals. The high purity of these crystals made possible the work reported here. We are indebted also to R. C. Fletcher and C. Herring for assistance and information. This work has been supported in part by the Office of Naval Research and the U. S. Signal Corps.

[1] A. F. Kip, Physica (to be published); Dresselhaus, Kip, and Kittel, Phys. Rev. **98**, 368 (1955).

[2] G. L. Pearson and M. Tanenbaum, Phys. Rev. **90**, 153 (1953).

[3] J. Hatton and B. V. Rollin, Proc. Phys. Soc. (London) **A67**, 385 (1954).

PHYSICAL REVIEW VOLUME 98, NUMBER 2 APRIL 15, 1955

Proceedings of the American Physical Society

MINUTES OF THE SEVENTH ANNUAL GASEOUS ELECTRONICS CONFERENCE (HELD UNDER THE JOINT SPONSORSHIP OF THE DIVISION OF ELECTRON PHYSICS, AMERICAN PHYSICAL SOCIETY, AND THE COLLEGE OF ENGINEERING, NEW YORK UNIVERSITY) AT NEW YORK, NEW YORK, ON OCTOBER 14–16, 1954

THE Seventh Annual Conference on Gaseous Electronics was held in Vanderbilt Hall on the Washington Square Campus of New York University on October 14, 15, and 16, 1954. There were 244 registrants. A symposium of three invited papers consisted of "Mechanism of Uniform Field Breakdown," by F. Llewellyn Jones, University Collete of Swansea; "Formative Time Lags of Uniform Field Breakdown," by L. H. Fisher, New York University; and "Secondary Processes and the Mechanisms of Spark Breakdown," by L. B. Loeb, University of California, Berkeley. A fourth invited paper, "Effect of Electrons on Spectral Lines Emitted in a Discharge," was by H. Margenau of Yale University. Abstracts of some of the contributed papers are printed hereunder.

The banquet of the Conference was held on Friday evening, October 15. T. E. Allibone (Associated Electrical Industries of Great Britain) and W. Finkelnburg (Siemens-Schuckert Werke, Erlangen, Germany) were the after-dinner speakers, and the theme of each was the state of Gaseous Electronics research in his country.

The Conference Committee for the coming year consists of W. P. Allis (*Chairman*), J. D. Cobine, L. H. Fisher, H. Margenau, A. V. Phelps, and D. J. Rose.

LEON H. FISHER For the Conference Committee

A1. Negative Ion Formation Using Monoenergetic Electrons. W. M. HICKAM AND R. E. FOX. *Westinghouse Research Laboratories.*—Ion formation involving electron attachment at low energies was investigated with monoenergetic electrons as obtained by the retarding potential difference (RPD) method.[1] Initial studies with this method reveal that electron attachment in some cases may occur only over an extremely narrow energy range. For such cases it becomes increasingly important that monoenergetic electrons be used in order to obtain the true excitation curve. For example, in the case of the formation of SF_6^-, the large cross section is found to occur only for electrons whose energy is less than 0.1 ev. The dissociative attachment process which yields SF_5^- also has a maximum cross section for electron energies of less than 0.1 ev. In this case, however, the negative ion formation as a function of electron energy decreases more slowly, going to zero at about 2 ev. The use of monoenergetic electrons can account for the wide differences between these results and those previously obtained[2] for SF_6. It will be demonstrated how the extremely narrow capture process can yield information concerning the behavior of the electron beam at these low energies.

[1] Fox, Hickam, Kjeldaas, and Grove, Phys. Rev. **84**, 859 (1951).

[2] A. G. Ahearn and N. B. Hannay, J. Chem. Phys. **21**, 119 (1953).

A2. Rotational Excitation by Slow Electrons.* E. GERJUOY AND S. STEIN, *University of Pittsburgh and Westinghouse Research Laboratories.*—Theoretical cross sections have been developed for the rotational excitation of homonuclear molecules by slow electrons,[1] and the results applied to calculation of the fractional energy loss per collision λ. In N_2, at energies below the vibrational threshold, theoretical losses are approximately twice experimental[2] but many times larger than $2m/M$. In H_2 the theoretical losses are not more than 2.5 $(2m/M)$, and, except at the lowest energies studied (ν 0.1 ev), are significantly smaller than observed.[2] It would be desirable to have more direct experimental evidence of rotational excitation. For this reason we have calculated λ at 77°K in pure para-hydrogen and in the equilibrium mixture of ortho- and para-hydrogen. At electron energies $\sim$0.075 ev,