pendent of the detailed form of the energy surfaces is needed. These measurements are being continued on other substances.

I wish to thank Professor P. Grassmann, the Director of this Institute, and Dr. J. L. Olsen for their kind encouragement and support. This work was supported financially by a Arbeitsbeschaffungskredit des Bundes.

[1]de Launay, Dolecek, and Webber, J. Phys. Chem. Solids (to be published).

[2]J. L. Olsen, Helv. Phys. Acta 26, 798 (1953).

[3]The measurements with longer pulse length were carried out using apparatus kindly lent by Mr. P. Cotti.

[4]Lifshits, Azbel', and Kaganov, J. Exptl. Theoret. Phys. U.S.S.R. 31, 63 (1956) [translation: Soviet Phys. JETP 4, 41 (1957)].

[5]J. M. Ziman, Phil. Mag. 3, 1117 (1958).

STIMULATED EMISSION OF RADIATION BY RELATIVISTIC ELECTRONS IN A MAGNETIC FIELD*

Jürgen Schneider
Department of Physics, Duke University, Durham, North Carolina
(Received April 27, 1959)

The Schrödinger equation of an electron, moving perpendicularly to a magnetic field H, can be reduced to the equation of the harmonic oscillator.[1] The kinetic energy W_i of an electron in the state i is therefore given by $W_i = (i+\frac{1}{2})\hbar\omega_0$, where $\omega_0 = eH/m_0c$ is the cyclotron frequency, associated with all transitions between the states i and $i+1$. Using the relativistic Schrödinger equation and neglecting the spin, the kinetic energy levels of the electron are found to be[2]

$$W_i = m_0c^2[1+2(i+\tfrac{1}{2})\hbar\omega_0/m_0c^2]^{\frac{1}{2}} - m_0c^2. \quad (1)$$

Transitions between states $i+1$ and i now result in a whole spectrum of frequencies $\omega_{i+1,i}$:

$$\omega_{i,i+1} = \omega_0(1 - i\hbar\omega_0/m_0c^2). \quad (2)$$

Second order terms in $\hbar\omega_0/m_0c^2$ have been neglected. Consider N_i electrons in the energy state i. Under the influence of an alternating electric field they will undergo absorption and induced emission at the frequencies $\omega_{i,i+1}$ and $\omega_{i,i-1}$. The net transfer of power is

$$P_i = N_i\hbar(\omega_{i,i+1}w_{i,i+1} - \omega_{i,i-1}w_{i,i-1}). \quad (3)$$

The transition probability $w_{i,i+1} = w_{i+1,i}$ is given by

$$w_{i,i+1} = \hbar^{-2}E^2(\mu_{i,i+1})^2 g(\omega). \quad (4)$$

The quantity

$$\mu_{i,i+1} = e[(i+1)\hbar/2m_0\omega_0]^{\frac{1}{2}} \quad (5)$$

is the matrix element of the harmonic oscillator for the transition between the state i and $i+1$; E is the amplitude and ω the frequency of the external electric field. For sufficiently sharp lines, i.e., for a small collision frequency $1/\tau$, the response curve $g(\omega)$ can be assumed to be Lorentzian:

$$g(\omega) = \tau/[1+(\omega_{i,i+1} - \omega)^2\tau^2]. \quad (6)$$

Introducing Eqs. (2), (4), (5), and (6) into Eq. (3), one obtains

$$P_i = N_i(e^2\tau/m_0)(E^2/2)\varphi,$$

$$\varphi = \frac{(1-i\alpha)(i+1)}{1+(\omega_{i,i+1} - \omega)^2\tau^2} - \frac{[1-(i-1)\alpha]i}{1+(\omega_{i,i-1} - \omega)^2\tau^2}, \quad (7)$$

where $\alpha = \hbar\omega_0/m_0c^2$. Neglecting again second order terms in α, the function φ can be written

$$\varphi(x) = \frac{1}{1+x^2} + 2Q\frac{W}{m_0c^2}\frac{x}{(1+x^2)^2}, \quad (8)$$

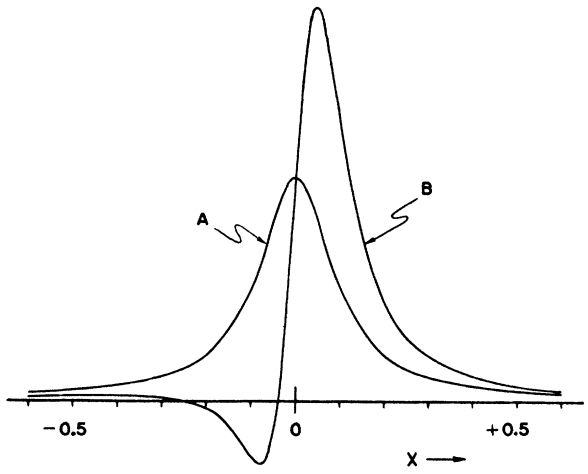

FIG. 1. Cyclotron resonance absorption of a nonrelativistic (A) and a relativistic (B) electron.

where $x=(\omega_{i,i+1}-\omega)\tau$, W is the kinetic energy of the electron, and $Q=\omega_0\tau$. In the nonrelativistic limit, i.e., for $W/m_0c^2=0$, the cyclotron resonance line is Lorentzian. However, for $QW/m_0c^2>1$, the function φ may become negative, corresponding to a net stimulated emission instead of absorption. This effect is shown in Fig. 1 where we have taken $QW/m_0c^2=1.5$, e.g., $Q=10\,000$ and $W=76$ ev.

If the electrons are not monochromatic, but have rather a distribution of energies, one obtains essentially the same effect, if there is an overpopulation of the upper states.[2] The above formulas (7) and (8) have also been derived[2] by means of the Boltzmann transfer equation, taking into account the dependence of the electron mass on the kinetic energy.

It does not appear unlikely that this effect could be used for a new type of maser, which would require no microwave "pump" and no low-temperature operation.[2]

The author wishes to thank Dr. Walter Gordy for his interest in this work.

*This research was supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.

[1]L. Landau, Z. Physik 64, 629 (1930).

[2]J. Schneider (to be published).

STRENGTHS OF HIGH-ENERGY CAPTURE GAMMA RAYS IN W^{184}

D. J. Hughes, M. K. Brussel, J. D. Fox, and R. L. Zimmerman
Brookhaven National Laboratory, Upton, New York
(Received May 27, 1959)

During the past few years the Brookhaven fast chopper[1] has been devoted to an extensive study of the parameters of energy levels in heavy nuclides excited by the capture of slow neutrons. The results, obtained primarily from total cross sections alone, have given information on the distribution laws of radiation widths, neutron widths, and spacings of these energy levels.[2] However, little is known of the spins, J, of the levels, aside from the limitation to two values, $I\pm\frac{1}{2}$, with I the target nucleus spin. In a few favorable cases, for which Γ_n is larger than Γ_γ, the total cross section suffices for J determination, but in general, partial cross sections, scattering or capture, must be measured as well.

Another possible method for spin measurement is based on the capture gamma rays emitted from the individual levels. The most direct use of capture gamma rays for determination of J applies when the ground-state transition is allowed for one of the spins only.[3] An example[4] is the compound nucleus W^{184}, in which the electric dipole ground-state transition, of energy[5] 7.42 Mev, is allowed for the $J=1$ but forbidden for the $J=0$ levels. In this ground-state technique of spin identification the question of the variation in transition probability from level to level is important, for it might be possible that a $J=1$ level would exhibit no observable ground-state gamma because of an extremely weak transition probability. Because of this application to spin determination, and the intrinsic interest in transition probabilities as well, it is desirable to gain information on the high-energy capture gamma rays in heavy nuclides.

Essentially no information exists concerning the relative transition probabilities involved in the present situation, that is, the emission of gamma rays from neighboring levels a few ev apart to the same final state, some 6 or 7 Mev distant. The typical neutron capture gamma-ray measurements do not supply the necessary information, for they are limited to excitation by one energy only, usually thermal neutrons. Electric dipole transitions in the hundred-kev range[6] show wide variations in transition probability and are usually hindered by large amounts relative to the high-energy capture gamma rays; the latter are in reasonable agreement with estimates[6] based on Weisskopf's single-particle model, although exhibiting variations of the order of a factor of ten from nuclide to nuclide.

Earlier capture gamma measurements with the Brookhaven fast chopper showed[4] strong ground-state transitions[7] for several of the known resonances in the target nucleus W^{183}, indicating that $J=1$ for these resonances. In that work gamma-ray energies were measured in sodium iodide crystals located near the capturing sample, and neutron energies simultaneously by time of flight to the sample. The same equipment has now been installed at the NRU reactor, Chalk River, Can-