$J \geqslant 2$. The assignment $J=0, 2, 0$ to the three states concerned which is suggested by the shape of the curve could be accepted only if a reason could be found for the reduction of the coefficients by a factor of two. Obvious possibilities of instrumental causes were ruled out by appropriate tests. The possibility of interference by other gamma-rays seems unlikely because the curve remained unchanged by lead absorbers around the source. It is possible that the coefficients of the angular anisotropy are reduced by some perturbation destroying the constancy of the magnetic quantum numbers of the intermediate state, particularly the hyperfine structure interaction. However, a magnetic field of about 10^4 gauss did not affect the correlation in Rh^{106} or any of the other substances. The experiment was performed only with moderate precision, and may not be entirely conclusive. The assignment of J values to Pd^{106} is important because Peacock[4] has based a strong argument for the validity of Gamow-Teller selection rules on evidence that the second excited state does *not* have $J=0$.

A complete discussion of the experimental method and of the results and their interpretation will be given in a paper to be submitted soon for publication in this journal.

The sources, except Y^{88}, were obtained from Oak Ridge.

* Supported in part by the Office of Naval Research.
[1] E. L. Brady and M. Deutsch, Phys. Rev. **72**, 870 (1947).
[2] Donald R. Hamilton, Phys. Rev. **58**, 122 (1940).
[3] Private communication.
[4] W. C. Peacock, Phys. Rev. **72**, 1049 (1947).

Correlation between Direction and Polarization of Successive Gamma-Ray Quanta*

MARTIN DEUTSCH AND FRANZ METZGER
Massachusetts Institute of Technology, Cambridge, Massachusetts
September 23, 1948

HAMILTON[1] has calculated the expected correlation between the polarization of one quantum and the direction of emission of the other for two successive gamma-rays. We have succeeded in observing this effect. The apparatus is shown schematically in Fig. 1. A, B, C represent the naphthalene crystals of three Kallmann counters. Counters A and B, connected in coincidence, form the polarimeter determining the polarization of γ_1, while γ_2 emitted simultaneously at the angle θ with respect to γ_1 is counted in counter C. If γ_1 experiences a Compton encounter in A, a scintillation is counted due to the recoil electron e. The scattered quantum γ_c is most likely to move in the plane perpendicular to the electric vector of γ_1; if γ_c is in or near the common midplane of A and B, it is very likely to cause a count in B because of the high efficiency of the Kallmann counter for soft quanta. Thus A and B define the "ϕ-plane" making an angle φ with the "θ-plane" formed by the two rays γ_1 and γ_2. Coincidences are most likely to occur between A and B when the electric vector of γ_1 is perpendicular to the ϕ plane. Exactly the same argument is valid if γ_1 strikes crystal B and γ_c enters A.

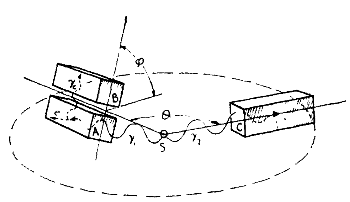

FIG. 1. The coincidence polarimeter.

The polarimeter was tested with gamma-rays of Co^{60} and Cs^{134} scattered through 90° by an aluminum scatterer. The observed difference in counting rate when the polarimeter was rotated through 90° indicated that for perfectly plane polarized radiation the ratio of the counting rates in the two perpendicular positions would be $D=2.1\pm0.3$. D measures the effectiveness of the polarimeter.

The actual experiments consisted of observing the triple coincidence rate $N(ABC)$ for $\varphi=0°$ and $\varphi=90°$ for various values of θ. The single counting rates and the twofold coincidences $N(AB)$, $N(AC)$, and $N(BC)$ were also counted to correct for slight asymmetries due to the difference in the effective value of θ in the two positions and to evaluate the chance coincidence rate. $\varphi=90°$ corresponds to the electric vector of γ_1 being in the θ-plane and the counting rate $N(ABC)$ in this position is denoted by $N_{\parallel}$. The counting rate for $\varphi=0°$ is denoted by $N_{\perp}$. Typical values of $N(ABC)$ are between 5 and 15 c.p.m. It follows from the Klein-Nishina formula that the polarimeter should be most efficient for low energy gamma-rays. Also strong polarization effects are expected in general when[1] the angular correlation between the gamma-rays is very anisotropic. Thus our first significant results have been obtained with Rh^{106}, which shows very anisotropic angular correlation[2] and emits rather soft gamma-rays.[3] Figure 2 shows the ratio $N_{\parallel}/N_{\perp}$ as a function of θ.

The dotted line is calculated from Hamilton's paper[1] (Eq. 12b) on the assumption that both quanta are electric quadrupole. The experimentally observed coefficients[2] of the angular correlation were used in the calculations. The eeffectiveness of the polarimeter was assumed to be that determined as described above, i.e., $D=2.1$. The solid line

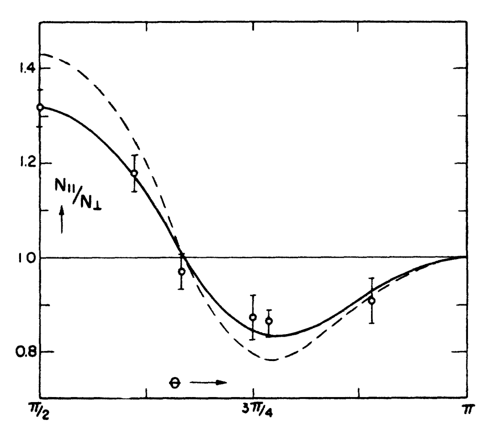

FIG. 2. Polarization of Rh^{106} gamma-rays. Solid line: $D=1.76$. Dotted line: $D=2.1$.

was constructed in the same manner except that D was adjusted to give the best fit. The value $D=1.76$ is not inconsistent with the uncertainty in our calibration. Our results indicate that the parity of the second excited state of Pd^{106} is the same as that of the ground state. If the two transitions are quadrupole, they are electric. The radioactive material was obtained from Oak Ridge.

* Assisted by the joint program of the Office of Naval Research and the Atomic Energy Commission.

1 Donald R. Hamilton, Phys. Rev. **74**, 782 (1948).
2 E. L. Brady and M. Deutsch, Phys. Rev. **74**, 1541 (1948).
3 W. C Peacock, Phys. Rev. **72**, 1049 (1947).

Decay Times of Scintillations

George B. Collins*
Brookhaven National Laboratory, Upton, Long Island, New York
September 23, 1948

MANY investigators have reported the effectiveness of phenolic compounds when used as phosphors in scintillation counters, but because of their extreme speed only an upper limit has been set for the decay times of these substances. The purpose of the work reported here was to obtain quantitative values for these decay times which could serve as a basis for the use of these phosphors in extremely high speed counting circuits.

The phosphor under investigation was attached to the envelope of a selected 931-A photo-multiplier tube, the output of which was connected directly to the deflecting plates of a microoscillograph.[1]

This instrument was an essential part of the experiment. By virtue of the fact that the electron beam traces are recorded directly on a photographic plate the oscillograph has ample writing speed, and more important, it has the very high voltage sensitivity of 2 volts per line width. This high sensitivity plus operation of the 931-A at 150 volts per stage made unnecessary any amplifier and the time resolution of the equipment was limited only by the photomultiplier tube and leads to the oscillograph.

The voltage divider for the 931-A was made up of 100,000-ohm resistors and 0.001-μf condensers were connected across the last two dynodes. The anode to deflecting plate connection was less than 10 cm long over all, and had a total capacity of 1.1×10^{-11} farad. The combination was connected to ground by a 100,000-ohm resistor. The time constant ($RC\sim 10^{-6}$ sec.) was thus long compared to the events to be measured and the deflection of the trace represented the time integral of the current. In most of the work the 931-A and phosphor were near liquid nitrogen temperatures as this reduced the noise current and permitted stable operation of the 931-A at higher voltages.

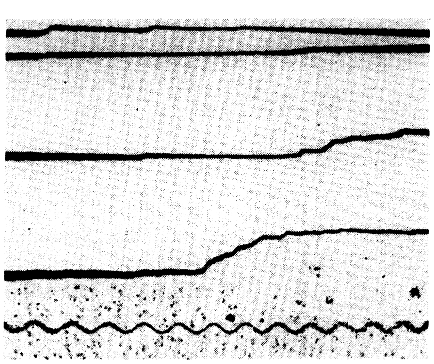

Fig. 1. Representative traces showing steps (a, b) resulting from thermal emission and deflections (c, d) resulting from light pulses from anthracene.

The use of delay lines would have reduced the signal voltage to an unreadable level and thus triggered sweeps could not be employed. Instead it was necessary to establish a random counting rate sufficient to insure a satisfactory pulse from the 931-A at least once every 10 to 20 sweeps. A counting rate of about 2 million counts/sec. with amplitude in excess of 20 volts was required and this was obtained by placing a 10-mc radium source about 4 cm from the phosphor. Sweeps with over-all time durations of between 0.15 μsec. to 1.0 μsec. were used. Sweep speeds were calibrated by connecting the deflecting plates to a 130 Mc/s signal generator and relying on uniformity of performance from sweep to sweep. This was found to be better than 3 percent.

The resulting traces show steep, short steps and slowly rising larger deflections (Fig. 1). The slowly rising deflections result from light emitted by the phosphor and the steps seem to result from single (or at most a few) electrons leaving the cathode of the 931-A. These steps are found with no source present and the 931-A at room temperature, or with the source next to a cooled 931-A without phosphor. They are absent when the 931-A is cooled and no source present. Examination of these steps permits the time response of the 931-A plus associated circuit to be determined. Figure 2 shows one of these steps enlarged together with its 130 Mc/s timing trace. The rise time is about 2×10^{-9} sec. This is considerably slower than the rise time of 6×10^{-10} sec. as calculated by Sard.[2] This slow rate of rise is probably set by the constants of the output circuit corresponding to the ringing frequency of 200 Mc/s seen in Fig. 2. Space-charge limitation at the last dynode is also not far from limiting the rise time. The step shown corresponds to about 10 volts and with $C=1.1\times 10^{-11}$ farad and $t=2\times 10^{-9}$ sec. the peak current must be about 50 ma, which is within a factor of two of the expected saturation

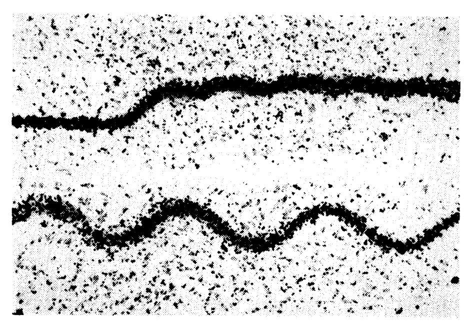

Fig. 2. Highly enlarged step showing ringing.