Determination of the lifetime of the $5\,^2P_{1/2}$ level of ^{85}Rb through the measurement of $n^{(2)}(T)$

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In this paper we present the values we obtained for the lifetime of the $5\,^2P_{1/2}$ level of ^{85}Rb using the Hanle effect. These measurements were carried out using two different methods: through a multichannel signal analyzer by photon counting and through a new method based on the determination of the normalized second-order factorial moment $n^{(2)}(T)$ of the fluorescence obtained. We discuss the results and advantages of the new method.

I. INTRODUCTION

So far, it has been possible to determine the structure constants and lifetimes of the states of many atoms through level-crossing spectroscopy initiated by Colegrove *et al.*[1] The most frequently used method for the detection of level crossings consists of measuring the intensity of the fluorescence emitted by the atoms under study (when the crossing magnetic field is varied) using a multichannel signal analyzer. As the fluorescence detected is generally weak and its variation with changes in the magnetic field small, the signal-to-noise ratio is usually low. To reduce the noise in the detection process, the magnetic field sweep is repeated periodically and synchronized with the multichannel analyzer sampling so that the random noise is averaged out on each channel.

On the other hand, photon correlation spectroscopy[2,3] has been successfully used in the analysis of intensity fluctuating light beams (i.e., scattered light by macromolecules in solution). The good results obtained by using photon correlation spectroscopy in the analysis of light with random intensity fluctuations leads one to consider the possibility of applying this technique to the analysis of light with intensity fluctuating deterministically with time. This occurs in a level-crossing experiment in which the magnetic field is periodically swept, since the fluorescence intensity becomes periodic and deterministic as a function of time t.

In a previous paper,[4] we proposed the application of photon correlation techniques to the detection of level crossings. To be exact, we studied a method of detecting the normalized second-order factorial moment $n^{(2)}(T)$ of the fluorescence obtained (T being the counting time). As we shall see later the experimental determination of $n^{(2)}(T)$ is easy and it gives us the variance of the temporal fluctuations of w (w being the integral of the intensity from the instant t to the instant $t+T$). In the above-mentioned paper a theoretical model was presented that allows the error in the crossing point to be evaluated as well as the error in the signal width when these two parameters are obtained from the determination of $n^{(2)}(T)$. The theoretical model was experimentally checked. Then we studied[5] the behavior of the crossing-point determination and signal-width errors when some parameters were varied in order to discover those experimental conditions where the smallest error values are obtained. After that we studied[6] level-crossing detection by measurement of the normalized intensity correlation function $g^{(2)}(\tau)$ or the Laplace transform of time-interval probability.

Although the theoretical model we used was experimentally checked, it is necessary to verify that photon correlation techniques can be useful in an actual level-crossing experiment. The aim of this paper is to examine the real possibility of extracting information from the determination of $n^{(2)}(T)$ in a level-crossing experiment and to check that this information agrees with that obtained through the method of measuring fluorescence intensity as a function of the magnetic field. To do this, we measured the Hanle effect in a $5\,^2P_{1/2}$ state of ^{85}Rb in order to determine its lifetime.

II. THEORETICAL CONSIDERATIONS

In a level-crossing experiment, when the magnetic field is varied around the crossing field, the variation produced in the intensity of the fluorescence is given by Breit's formula,[7] subsequently revised by Franken[8] and Rose and Carovillano,[9] *inter alia*. If only two levels cross in the excited estate the experimental layout can be arranged in such a way that the fluorescence intensity varies with ΔE (difference between the energies of sublevels that cross) in a dispersion profile, a Lorentzian profile or a linear combination of both profiles. In every case a constant-intensity background is superposed on the signal. In the case of the dispersion profile the fluorescence intensity can be expressed as a function of ΔE in the form

$$I(\Delta E)=C_1+\frac{C_2\Delta E}{(\Delta E)^2+(\Gamma/2)^2}\ , \tag{1}$$

where C_1 and C_2 are constants and Γ is the width of the crossing signal (the distance between the relative maximum and minimum) from which the lifetime τ can be derived through the equation

$$\tau=2\hbar/\Gamma\ . \tag{2}$$

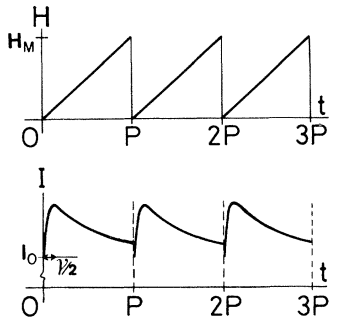

FIG. 1. Magnetic field sweep and fluorescence intensity when detecting Hanle effect with a dispersion profile by means of a multichannel analyzer.

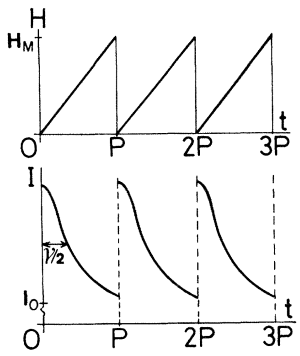

FIG. 2. As in Fig. 1 for a Lorentzian profile.

In the case of the Lorentzian profile

$$I(\Delta E)=C_3+\frac{C_4}{(\Delta E)^2+(\Gamma/2)^2}\ , \tag{3}$$

where C_3 and C_4 are constants and Γ is the width of the signal (width at half maximum).

Let us now consider a level-crossing experiment in which crossing occurs with $H=0$ (the Hanle effect). In this case, in order to deduce Γ it is sufficient to vary the magnetic field H between zero and a maximum value H_M. If ΔE varies linearly with H (as usual) we have

$$\Delta E=A_1H\ , \tag{4}$$

where A_1 is a constant. In general the fluorescence intensity is weak and its variation with the magnetic field is small. For this reason the signal-to-noise ratio is normally very small and it is necessary to repeat the experiment periodically. If several measurements of the fluorescence intensity corresponding to a fixed value of H are averaged the noise is reduced. To obtain a fluorescence intensity which is periodically modulated, we can vary H with time using a periodic ramp profile of period P

$$H=A_2t'\ , \tag{5}$$

where A_2 is a constant and

$$t'=t-JP\ , \tag{6}$$

J being a whole number so that $0\le t'\le P$. Using Eqs. (4)—(6) in Eqs. (1) and (3), we can obtain the fluorescence intensity $I(t)$ as a periodic function of time. In the case of the dispersion profile (Fig. 1) we find that

$$I(t)=I_0+\frac{C_2't'}{(t')^2+(\gamma/2)^2}\ , \tag{7}$$

where I_0 is the constant intensity background and

$$C_2'=C_2/A_1A_2\ ,\quad \gamma=\Gamma/A_1A_2\ . \tag{8}$$

In the case of the Lorentzian profile (Fig. 2) we find that

$$I(t)=I_0+\frac{C_4'}{(t')^2+(\gamma/2)^2}\ , \tag{9}$$

where

$$C_4'=C_4/(A_1A_2)^2\ . \tag{10}$$

The value of γ can be deduced if $I(t)$ is sampled and smoothed in a synchronous way (by means of a multichannel analyzer) and the values obtained are fitted to the theoretical ones. Using γ and Eq. (8) Γ can be determined and from Γ and Eq. (2) the lifetime τ can be calculated. As it is difficult to change H from H_M to zero value (at the instants $t=0,P,2P,\ldots$) in a negligible time interval, care must be taken to not measure $I(t)$ when the H value is near H_M.

We also can determine γ in Eq. (7) or Eq. (9) by means of photon correlation techniques. In order to do this one can measure the normalized intensity correlation function $g^{(2)}(\tau)$ which is defined as

$$g^{(2)}(\tau)=\frac{\langle I(t)I(t+\tau)\rangle}{\langle I(t)\rangle^2}\ , \tag{11}$$

where the angular brackets represent a temporal average performed in a nonsynchronous way with respect to the magnetic field sweep. The measurement of $I(t)$ and the evaluation of $g^{(2)}(\tau)$ are carried out by using a correlator. The value of γ can be deduced by evaluating $g^{(2)}(\tau)$ for various values of the time delay τ and fitting the theoretical values to the experimental ones.

There is another interesting way to determine γ by photon correlation techniques. We can measure the intensity $I(t)$ by photon counting and then determine the normalized second-order factorial moment. In photon counting each photon absorbed by the photomultiplier produces a voltage pulse and an electronic counter counts the number $n(t,T)$ of pulses which are produced in the interval $[t,\ t+T]$, T being a fixed time interval. The normalized second-order factorial moment $n^{(2)}(T)$ is defined as

$$n^{(2)}(T)=\frac{\langle n(t,T)[n(t,T)-1]\rangle}{\langle n(t,T)\rangle^2}\ . \tag{12}$$

In order to comment what $n^{(2)}(T)$ means physically, we can use a well-known property[10] in photon statistics:

$$\begin{aligned}&\langle n(t,T)\rangle=\langle w(t,T)\rangle\ ,\\ &\langle n(t,T)[n(t,T)-1]\rangle=\langle[w(t,T)]^2\rangle\ ,\end{aligned} \tag{13}$$

where

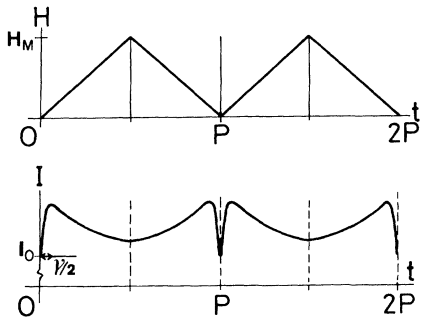

FIG. 3. Magnetic field sweep and fluorescence intensity when detecting Hanle effect with a dispersion profile by measuring $n^{(2)}(T)$.

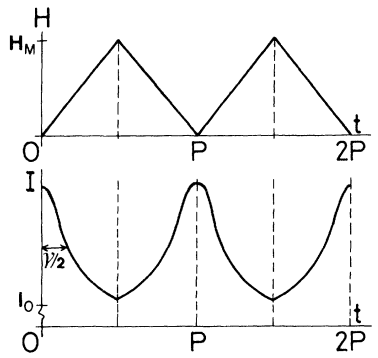

FIG. 4. As in Fig. 3 for a Lorentzian profile.

$$w(t,T)=\int_t^{t+T} I(\theta)d\theta \ . \tag{14}$$

Taking into account Eqs. (12)—(14) we obtain

$$n^{(2)}(T)=1+\frac{\langle[w(t,T)-\langle w(t,T)\rangle]^2\rangle}{\langle w(t,T)\rangle^2} \ . \tag{15}$$

From Eq. (15) it is clear that $n^{(2)}(T)$ gives us the relative variance of the temporal fluctuations of $w(t,T)$. As $I(t)$ is a function of γ, the temporal fluctuations of $w(t,T)$ and therefore its variance are related with the value of γ. So the experimental determination of $n^{(2)}(T)$ allows us to obtain γ. Furthermore, the well-known relation[11]

$$\frac{d^2}{dT^2}[T^2 n^{(2)}(T)]=2g^{(2)}(T) \tag{16}$$

shows the equivalence between the determination of $g^{(2)}(\tau)$ and $n^{(2)}(T)$. So $n^{(2)}(T)$ is related with the correlation properties of $I(t)$. To evaluate experimentally Eq. (12) it is sufficient to take N samples of $n(t,T)$ at the instants $t=t_i$ $(i=1,2,\ldots,N)$, taking into account that

$$\begin{aligned}\langle n(t,T)\rangle &= \frac{1}{N}\sum_{i=1}^{N} n(t_i,T) \ , \\ \langle n(t,T)[n(t,T)-1]\rangle &= \frac{1}{N}\sum_{i=1}^{N} n(t_i,T)[n(t_i,T)-1] \ .\end{aligned} \tag{17}$$

It is convenient to make some comments on the advantages of photon correlation techniques over the measurement of $I(t)$ by means of a multichannel analyzer. On the one hand, in photon correlation techniques there is no need to synchronize the fluorescence signal sampling with the magnetic field sweep. On the other hand, the determination of $n^{(2)}(T)$ has an additional advantage: only one memory channel to store the values of $\langle n(t,T)\rangle$ and another to store the values of $\langle n(t,T)[n(t,T)-1]\rangle$ is required. For these reasons the determination of $n^{(2)}(T)$ can be carried out with a low-cost device made up of a pulse counter and some microprocessor units. This paper deals with level-crossing detection by means of the experimental determination of $n^{(2)}(T)$.

As the sampling of $n(t,T)$ is carried out in a nonsynchronous way, we cannot avoid the measurement of $n(t,T)$ when the value of H is near H_M. In order to remove this difficulty the magnetic field sweep must be carried out with a triangular rather than a ramp profile:

$$H=A_2\,|\,t''\,| \ , \tag{18}$$

where

$$t''=t-JP \ , \tag{19}$$

J being a whole number so that $-P/2\le t''\le P/2$. Taking into account the above considerations Eqs. (7) and (9) become

$$I(t)=I_0+\frac{C_2'\,|\,t''\,|}{(t'')^2+(\gamma/2)^2} \ , \tag{20}$$

for a dispersion profile (Fig. 3) and

$$I(t)=I_0+\frac{C_4'}{(t'')^2+(\gamma/2)^2} \ , \tag{21}$$

for a Lorentzian profile (Fig. 4). In order to calculate $n^{(2)}(T)$ theoretically we can use Eqs. (13) and (14) in Eq. (12), bearing in mind that $I(t)$ is a periodic function of period P and therefore the temporal averages in Eq. (13) can be carried out by means of the relation

$$\langle w(t,T)^r\rangle=\frac{1}{P}\int_{-P/2}^{P/2} w(t,T)^r dt \ . \tag{22}$$

By determining experimentally $n^{(2)}(T)$ for various values of T and carrying out a fitting between experimental and theoretical values [later obtained from Eqs. (12)—(14), (22), and (20) or (21)], we can deduce the value of γ, from which the lifetime can be obtained as we have explained above.

So far we have studied level-crossing experiments in which a dispersion-shaped or a Lorentzian-shaped intensity profile is obtained. If the experimental layout is not arranged to work so, a linear combination of both profiles will be obtained. In this case it is more difficult to obtain γ by means of a multichannel analyzer that measure $I(t)$ or by means of the determination of $n^{(2)}(T)$ since there are more unknown parameters which cause the fitting to be more difficult. This is why the experimental layout is usually arranged to obtain a dispersion profile or a Lorentzian profile, which can be always carried out.

If one is to measure the Hanle effect at the $5\,^2P_{1/2}$ level

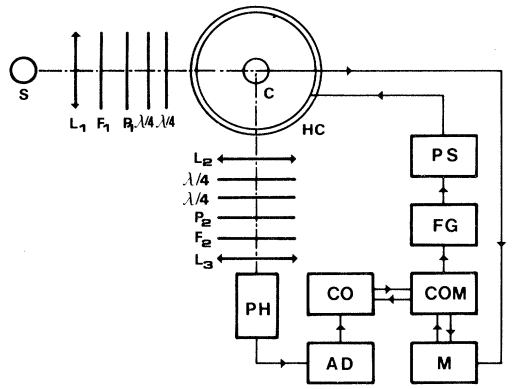

FIG. 5. Experimental layout used, consisting of a light source (S), lenses (L_1, L_2, and L_3), interference filters for the D_1 line (F_1 and F_2), polaroids (P_1 and P_2), natural Rb cell (C), Helmholtz coils (HC), photomultiplier (PH), amplifier-discriminator (AD), pulse counter (CO), desktop computer (COM), function generator (FG), power source for coils (PS), and digital multimeter (M).

of Rb, the atoms must be excited by a light with a wavelength of $\lambda = 7947$ Å (line $D\,1$), corresponding to the transition from $5\,^2S_{1/2}$ to $5\,^2P_{1/2}$, and the fluorescence intensity of the same wavelength must be detected. The equations of Rose and Carovillano[9] may be used to discover the necessary excitation and detection directions and polarizations. Using these equations, we find that the intensity of the fluorescence as a function of ΔE (the energy differences of the crossing hyperfine magnetic sublevels) shows a Lorentzian profile if the excitation and detection directions coincide with each other and are perpendicular to the direction of the magnetic field, and shows a dispersion profile if the directions of excitation, detection, and the magnetic field are perpendicular to each other. Since, in the first of these cases, the exciting light would directly reach the detector together with the fluorescence light, it is necessary to operate with a dispersion profile. Excitation and detection have to be carried out with circularly polarized light, with only crossings between contiguous sublevels ($\Delta M = \pm 1$) being detected.

Using the values of the hyperfine structure constants and of the Landé factors g_J and g_I compiled by Arimondo, Inguscio, and Violino,[12] we calculated the energies of the hyperfine magnetic sublevels of the $5\,^2P_{1/2}$ level of ^{85}Rb and ^{87}Rb and we found a linear behavior with respect to H for the range of values used in the experiment (from $H = 0$ to $H \simeq 50$ G), the deviations from this linear behavior being less than 1%. We therefore consider that $\Delta E = \text{const} \times H$, as a result of which the intensity of fluorescence as a function of H will be the sum of a constant term and several dispersion terms (one for each crossing between two contiguous sublevels at $H = 0$).

In our experiment we used natural Rb in both exciting lamp and the sample. In the sample, the isotopic abundance of ^{85}Rb (72.7%) is much greater than that of ^{87}Rb (27.3%). Furthermore, the ratio between the intensities of the D_1 lines emitted by ^{85}Rb and ^{87}Rb in a natural Rb lamp is approximately equal[13] to the ratio between the isotopic abundances. Consequently, the contribution of ^{87}Rb to the crossing signal is very small and we can ignore it in the same way as Schmieder *et al.*[14] Also, if we do not take into account the contribution of g_I, we find that the ΔE differences between the energies of contiguous hyperfine magnetic sublevels ($\Delta M = \pm 1$) of the $5\,^2P_{1/2}$ level of ^{85}Rb prove to have the same absolute value. If we also take into account the fact that the lifetimes of all the hyperfine magnetic sublevels of a given level are practically the same, then all the dispersion terms involved in the fluorescence intensity vary with respect to ΔE in the same way. Therefore, the fluorescence intensity is reduced to a constant plus a dispersion term [Eq. (20)] and $n^{(2)}(T)$ can be calculated from Eqs. (12)—(14), (22), and (20).

III. EXPERIMENTAL WORK

Taking the foregoing considerations into account, our experimental work was carried out using the layout schematized in Fig. 5. The light from a natural Rb radio-frequency source (S) is collimated through a lens L_1, filtered through an interference filter F_1, which selects line D_1 ($\lambda = 7947$ Å), and circularly polarized. The resultant light falls onto a spherical Pyrex cell (C) measuring 5 cm in diameter and containing natural Rb, the lower end of which is placed in an oven set at 38 °C. The cell lies in the center of a Helmholtz coils (HC) system with an average diameter of 28 cm which produces a vertical magnetic field (perpendicular to the plane of the figure) of $24.6 \pm 1\%$ G/A with an inhomogeneity within the cell of less than 0.13% (theoretical calculations).

The fluorescence emitted by the atoms is selected in a direction perpendicular to the directions of excitation and the magnetic field, collimated through a lens L_2, and analyzed with the aid of a circular analyzer (which selects that component which is orthogonal to that produced by the excitation polarizer to eliminate any strange light). The resultant light is filtered through another interference filter F_2, which selects the D_1 line, and focalized through lens L_3 onto the photocathode of a RCA C31034 photomultiplier (PH) for photon counting. The photomultiplier is fed by a stabilized Hewlett-Packard model 6525A power supply and is located within a refrigerated housing kept at −30 °C which is electromagnetically shielded (Products for Research RT TSA). The voltage pulses produced in a 50-Ω load resistance pass through an amplifier-discriminator (AD) E. G. and G.—P.A.R. model 1120 and are fed into a Hewlett-Packard models 5300B, 5308A, and 5312A pulse counter (CO) which counts the number of photons absorbed by the photomultiplier photocathode during the counting time T. A Hewlett-Packard model-9815A desktop computer (COM) orders the counter to carry out the measurements and performs the necessary operations with these data.

The power to the coils (HC) that produce the crossing field is supplied from a Hewlett-Packard model 6224B current-stabilized power supply (PS) and is programmed by a Hewlett-Packard model 3325A function generator (FG) controlled by the desktop computer. We carried out sweeps of H for values falling between 0 and a maximum

TABLE I. Experimental values of $n^{(2)}(T)$ and lifetimes obtained from these values.

$\bar{I}$ (pulses per sec)	$n^{(2)}$	τ (nsec)
77 530	1.000 080 29	32.27
77 363	1.000 074 16	30.20
79 019	1.000 079 57	32.02
80 127	1.000 079 20	31.90
80 757	1.000 084 72	33.84
81 065	1.000 082 18	32.93
81 443	1.000 080 62	32.39
82 081	1.000 089 45	35.61
82 530	1.000 089 17	35.51
82 196	1.000 086 55	34.51
81 171	1.000 093 56	37.28
80 896	1.000 089 68	35.71
79 798	1.000 085 40	34.09
79 060	1.000 096 20	38.43
78 394	1.000 094 96	37.88

of $H_M \simeq 50$ G. The temperature of the cell (C) is controlled by means of a TNC and a Hewlett-Packard model 3438A digital multimeter (M) controlled by the minicomputer (COM).

Before making these measurements, the stability of the layout had to be studied since the values expected from a measurement of the Hanle effect at the $5\,^2P_{1/2}$ level of ^{85}Rb by means of $n^{(2)}(T)$ differ very little from unity; to give a specific example, $n^{(2)}(T) \simeq 1.0001$ for $T/P \simeq 0.1$. As, on the other hand, the theoretical value of $n^{(2)}(T)$ in the absence of any variation of the magnetic field [$I(t)=$const] is 1, the layout had to be sufficiently stabilized to ensure that no instabilities would mask the small difference (0.0001) that the crossing signal adds to $n^{(2)}(T)$. By stabilizing the feed to the radio-frequency lamp we were able to obtain $n^{(2)}(T)=1.000\,01$ in a reproducible way when the magnetic field was not varied, this being sufficient to ensure that the effect of the crossing signal would not be masked.

To detect the Hanle effect of the $5\,^2P_{1/2}$ state of ^{85}Rb from the value of $n^{(2)}(T)$, the desktop computer orders the function generator (FG) to supply a periodic triangular voltage to the power supply (PS). In this way, periodic triangular sweeps of H were obtained, producing a fluorescence intensity that varied periodically with time as indicated by Eq. (20). The minicomputer instructed the counter to make an unsynchronized collection of samples of the number of counts $n(t,T)$ in a time interval T and to calculate $n^{(2)}(T)$ by using Eqs. (12) and (17). We also set up another measurement system that used the same layout as in Fig. 5 but operated as a photon-counting multichannel analyzer. The minicomputer commanded the function generator (FG) to produce a linear voltage ramp and then commanded the counter to carry out the measurement of $n(t,T)$ (T being the integrating time on each channel) for equally separated values of t. The field sweep and the sampling were repeated in synchronism several times and, finally, the different results for each channel were averaged out. So we measured the integrated intensity $w(t,T)$ [see Eq. (14) for $w(t,T)$ and Eq. (7) for $I(t)$] for various values of t (each value of t corresponds to a channel).

TABLE II. Half-width (hw) of the Hanle-effect signal as a function of H, and lifetime τ of the $5\,^2P_{1/2}$ level of ^{85}Rb.

Multichannel system		$n^{(2)}$ system	
hw (G)	τ (nsec)	hw (G)	τ (nsec)
30.0±0.5	34.1±0.6	29.8±1.7	34.1±1.9

The definitive measurements were taken at $\bar{I} \simeq 80\,000$ pulses per sec with sweeps of H between 0 and 50.4 G. When obtaining $n^{(2)}(T)$, the period of the triangular sweep was $P=10.332$ sec and in each series of measurements 1000 measurements of $n(t,T)$ were taken with a counting time of $T=1$ sec (total effective measurement time $T_e=1000$ sec). The duration of the voltage ramp when using the photon-counting multichannel analyzer was 5.166 sec and in each series of measurements 256 sweeps of H were carried out, with 39 channels on each sweep, a counting time of $T=0.1$ sec on each channel and a delay between two consecutive channels approximately equal to 0.03 sec (total effective measurement time $T_e=998.4$ sec). Thus the effective measurement time in each series proved to be approximately the same with both methods. Under these experimental conditions, we carried out 15 series of measurements with each method. Table I shows the 15 values obtained for $n^{(2)}(T)$.

Fitting the measurements made with the multichannel analysis method to the theoretical values of $w(t,T)$, we obtained the values for γ, I_0, and C_2'. From γ we deduced Γ and from Γ we deduced the lifetime τ with a probable statistical error of 0.7%, to which must be added an error of 1% resulting from the operation for the calibration of H. Using Eqs. (12)—(14), (22), and (20), as well as the values of I_0 and C_2' obtained from the multichannel analysis experiment, we can calculate theoretically $n^{(2)}(T)$ as a function of γ. We varied γ until the theoretical value calculated for $n^{(2)}(T)$ coincided with the experimental value of $n^{(2)}(T)$. This was done for each of the experimental values of $n^{(2)}(T)$ found in Table I. Thus we obtained 15 values for γ and from them 15 values of τ which allows us to calculate the mean value of τ and the corresponding probable error. The probable statistical error proved to be 4.6%, to which must be added an error of 1% for H. The final results obtained are summarized in Table II where a good agreement can be observed between both methods, demonstrating that the measurement of $n^{(2)}(T)$ provides perfectly reliable results.

IV. CONCLUSIONS

We have measured the Hanle effect in the $5\,^2P_{1/2}$ state of ^{85}Rb by obtaining experimentally the value of $n^{(2)}(T)$ for a fixed value of T. Assuming the other parameters are known we have deduced the lifetime of the $5\,^2P_{1/2}$ state from the value of $n^{(2)}(T)$. Table II shows a good agreement between this result and the one obtained from the multichannel method. So, we have proved it is possible to extract information from the determination of $n^{(2)}(T)$ in a level-crossing experiment and we have checked that this information agrees with that obtained from the multichannel method. In order to obtain the crossing point,

the signal width, and other unknown parameters in a level-crossing experiment, $n^{(2)}(T)$ must be determinated for several values of T.

On the other hand, Table II shows that the error in the results are greater when $n^{(2)}(T)$ is measured. But we must consider that we have carried out the determination of $n^{(2)}(T)$ for only one value of T, by using a measurement system with a nonzero delay time between two consecutive samples. If a measurement system with a zero delay time is available, we can perform N consecutive samples of $n(t_i,T)$ $(t_i=t_0+iT;\ i=0,1,\ldots,N-1)$ and from these samples we can determine $n^{(2)}(T)$. But from the same collection of samples we can also obtain $N-1$ samples for a counting time $2T$, by means of the relation

$$n(t_i,2T)=n(t_i,T)+n(t_{i+1},T)\ ,\quad i=0,1,\ldots,N-2$$

and from $n(t_i,2T)$ we can determine $n^{(2)}(2T)$. In the same way we can obtain $N-K+1$ samples of $n(t_i,KT)$ by means of

$$n(t_i,KT)=\sum_{j=0}^{K-1} n(t_{i+j},T)\ ,\quad i=0,1,\ldots,N-K$$

and from here we can determine $n^{(2)}(KT)$. By using this method we can obtain $n^{(2)}$ for several values of T without increasing the number of measured samples. A similar method is used to compute the correlation function $g^{(2)}(\tau)$ for several values of τ $(\tau=KT)$ when $n(t_i,T)$ is measured.

By using the above-mentioned method for determining $n^{(2)}(KT)$, the errors in level-crossing detection can be improved. We expect the errors obtained from $n^{(2)}(T)$ will become smaller than the ones obtained from the multichannel method. On the other hand, as we saw before, the determination of $n^{(2)}(T)$ can be carried out with a low-cost device. Thus the experimental determination of $n^{(2)}(T)$ can be a precise low-cost technique in level-crossing spectroscopy.

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