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LIFETIME AND ALIGNMENT OF THE 5^1D_2 STATE OF ^{4}He BY BEAM FOIL LEVEL CROSSING*

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Abstract:

The lifetime of the 5^1D_2 state of ^{4}He was measured by the beam foil zero field level crossing techniques. The result is compared with measurements based on conventional beam foil and level crossing methods. A multiparameter least-squares reduction of the data was used to determine the alignment in addition to the lifetime thus eliminating the need for separate measurements to determine the alignment.

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The beam foil method has the useful property that the atoms (ions) are excited at a precisely known position. This fact has been exploited to measure atomic (ionic) lifetimes by observing the exponential decay of excited states.[1-5] The method suffers from a serious drawback in that the measurements are sensitive to cascading from highly excited states which feed the state under observation. In the experiment reported here we have used another useful property of the beam foil interaction process to measure the lifetime of the 5^1D_2 state of ^{4}He. The atoms emerge from the foil in an aligned state so that application of a magnetic field perpendicular to the beam axis results in the creation of a coherent superposition of states with magnetic quantum numbers $+m_J$, $-m_J$. This leads to the quantum beat phenomena which has been exploited in the measurement of g factors and alignment[6] and to the Hanle effect which has been used to measure lifetimes.[7] In the present investigation we have used the zero field level crossing method (Hanle effect) to measure both the lifetime and alignment of the 5^1D_2 state of ^{4}He. Previously, alignment was determined from quantum beat experiments while lifetimes were determined from the Hanle effect. The purpose of the present measurement is to compare the lifetime as determined by the technique reported here to lifetimes based on conventional beam foil and level crossing methods. The lifetime of the 5^1D_2 state was previously measured by both the conventional beam foil[8] and level crossing methods.[9] It is of interest to compare these measurements since level crossing is inherently less sensitive to cascading.

A schematic of the experiment is shown in Fig. 1. A 3.5 μA 40 kV helium ion beam from the Berkeley mass separator was incident on a 6.7 μg/cm^2 carbon foil[10] and the light emitted by coherently excited 5^1D_2 ^{4}He atoms observed down stream from the foil thru a linear polarizer with axis parallel to the beam axis. The observation was along the magnetic field perpendicular to the beam axis. The detector viewed a 7 mm portion of the beam. Photon counts were collected in a multichannel analyzer sweeping synchronously with the magnetic field sweep. After completion of a predetermined number of field sweeps the foil was advanced by a small increament and data collected for the same number of field sweeps, the photon counts being added to those taken at the previous foil position. This procedure was continued until each point along a 7 cm segment of the beam with extreme limits 3.5 mm and 7.35 cm from the foil was viewed for the same length of time. The foil was advanced upstream and downstream to average out beam fluctuations and drift. Generally, the $^4He^+$ beam intensity drifted by $\gtrsim$ 10% in the time it took to cover the 7 cm beam path. By changing the direction of travel of the foil several times these beam excursions were largely averaged out. However, the excitation efficiency of the foil decreases as the foil ages and this introduced a slight slope to the signal. The slope was corrected for in the analysis.

The intensity of the 5^1D_2-2^1P_1 (4388 Å) transition when the observation is made thru a linear polarizer whose axis is parallel to the beam axis is given by

$$I(\omega,t) = Ae^{-\gamma t} (1 + B/A \cos 2\omega t) \tag{1}$$

where γ is the reciprocal lifetime in rad/sec, B/A is the alignment and $\omega = g_J \mu_o H/\hbar$. H is the magnetic field intensity and t is the time following excitation at which the observation is made. This relation holds for an infinitesimal detector slit width. When a finite segment of the beam is viewed, the signal observed is

$$S(\omega) = \int_{\ell_{min}/v}^{\ell_{max}/v} I(\omega,\ell/v)d(\ell/v) \tag{2}$$

where $\ell_{max} - \ell_{min}$ is the segment of beam intercepted by the solid angle of the detector, v is the beam velocity and $t = \ell/v$ is the time following excitation. In our experiment $\ell_{max} - \ell_{min}$ = 7 mm but by changing the foil-detector separation and summing up contributions from many overlapping 7 mm segments the integration path was effectively increased to 7 cm corresponding to 59 nsec of observation time or about one lifetime.

The result is shown in Fig. 2 along with a least-squares fit of the data to Eq. 2. The lifetime is summarized in Table I along with previous measurements and is seen to be in better agreement with conventional level crossing than with the conventional beam foil determination. A source of uncertainty in the type of experiment reported here is the velocity of the atoms since the foil thickness is known to at best 5% and furthermore there is an uncertainty in the calculated energy loss. We used initially the theoretical velocity $v = 1.30 \times 10^8$ cm/sec calculated from the energy loss and then adjusted the velocity to obtain the best fit. The best fit was obtained for a velocity 1% lower than that calculated. In addition to the lifetime we also determined the alignment of the 5^1D_2 state resulting from the beam foil interaction at 40 kV. The alignment was found to be 12%.

In conclusion the beam foil level crossing method combines the best features of the beam foil and level crossing technique. On the one hand beam foil offers a universal means of producing coherently excited states, bypassing the technical difficulties of electron excitation in magnetic fields, on the other hand, level crossing in inherently more accurate for lifetime determinations. Furthermore, the alignment induced in the beam foil interaction process can be determined simultaneously with the lifetimes. It is of interest that the measured lifetimes tend to be lower than the theoretical value which is based on calculated oscillator strengths[11] and this may indicate that systematic effects such as cascading are still of importance. The method is being extended, in the case of the triplet states, to high field level crossing.[12] In the latter case the effects of cascading vanish in first order.

FOOTNOTES AND REFERENCES

*Work performed under the auspices of the U. S. Atomic Energy Commission, and by the Office of Naval Research.

1. W. S. Bickel and S. Bashkin, Phys. Letters 20, 488 (1966).
2. A. S. Goodman and D. J. Donahue, Phys. Rev. 141, 1 (1966).
3. S. Bashkin, ed., Beam-Foil Spectroscopy, Proceedings of the 1st Intl. Beam-Foil Conf. (Gordon and Breach, New York, 1968).
4. Proceedings of the 2nd Intl. Conf. on Beam-Foil Spectroscopy, Nucl. Instr. Methods 90, (1970).
5. Proceedings of the 3rd Intl. Conf. on Beam-Foil Spectroscopy (to be published in Nucl. Instr. Methods).
6. C. H. Liu, S. Bashkin, W. S. Bickel, and T. Hadeishi, Phys. Rev. Letters 26, 222 (1971).
7. D. A. Church, M. Druetta, and C. H. Liu, Phys. Rev. Letters 27, 1763 (1971).
8. I. Martinson et al., J. Opt. Soc. Am. 60, 352 (1970).
9. M. Maujean et M. Jean-Pierre Descoubes, C. R. Acad. Se. Paris 264B, 1653 (1967).
10. The foils were obtained from the Arizona Carbon Foil Co.
11. W. L. Wiese, M. W. Smith, and B. M. Glennon, Atomic Transition Probabilities, Vol. I, NSRDS-NBS4 (U. S. Govt. Printing Office, Washington, D. C., 1966).
12. T. Hadeishi, M. C. Michel, J. Yellin, and E. Genaux in Ref. 5.

Table I. Comparison of the lifetime of the 5^1D_2 state of He as determined by conventional beam foil (BF), level crossing (LC) and level crossing combined with beam foil (BF-LC).

		Lifetime (nsec) of 5^1D_2 state of He					
BF[(a)]	LC[(b)]	BF-LC[(c)]	(d)	(e)	(f)	(g)	Theory[(h)]
66±4	49±5	52±6	43±15	79±6	63±9	46±3	71.9

[a]Ref. 8, [b]Ref. 9, [c]Present measurement.

[d]P. T. Kindlmann and W. R. Bennett, Bull. Am. Phys. Soc. 8, 87 (1963).

[e]W. R. Pendleton, Jr. and R. H. Hughes, Phys. Rev. 138, A683 (1965).

[f]K. A. Bridgett and T. A. King, Proc. Phys. Soc. (London) A92, 75 (1967).

[g]L. A. Osherovich and Ja. F. Verolainen, Opt. Spectrosc. 24, 81 (1968).

[h]Ref. 11.

FIGURE CAPTIONS

Fig. 1. Schematic of the beam foil level crossing experiment.

Fig. 2. Zero field level crossing signal for the 5^1D_2 state of He. The circles are experimental points and the x's are the calculated points from a least-squares fit. The slope of the curve is due to foil aging and was corrected for in the curve fitting.

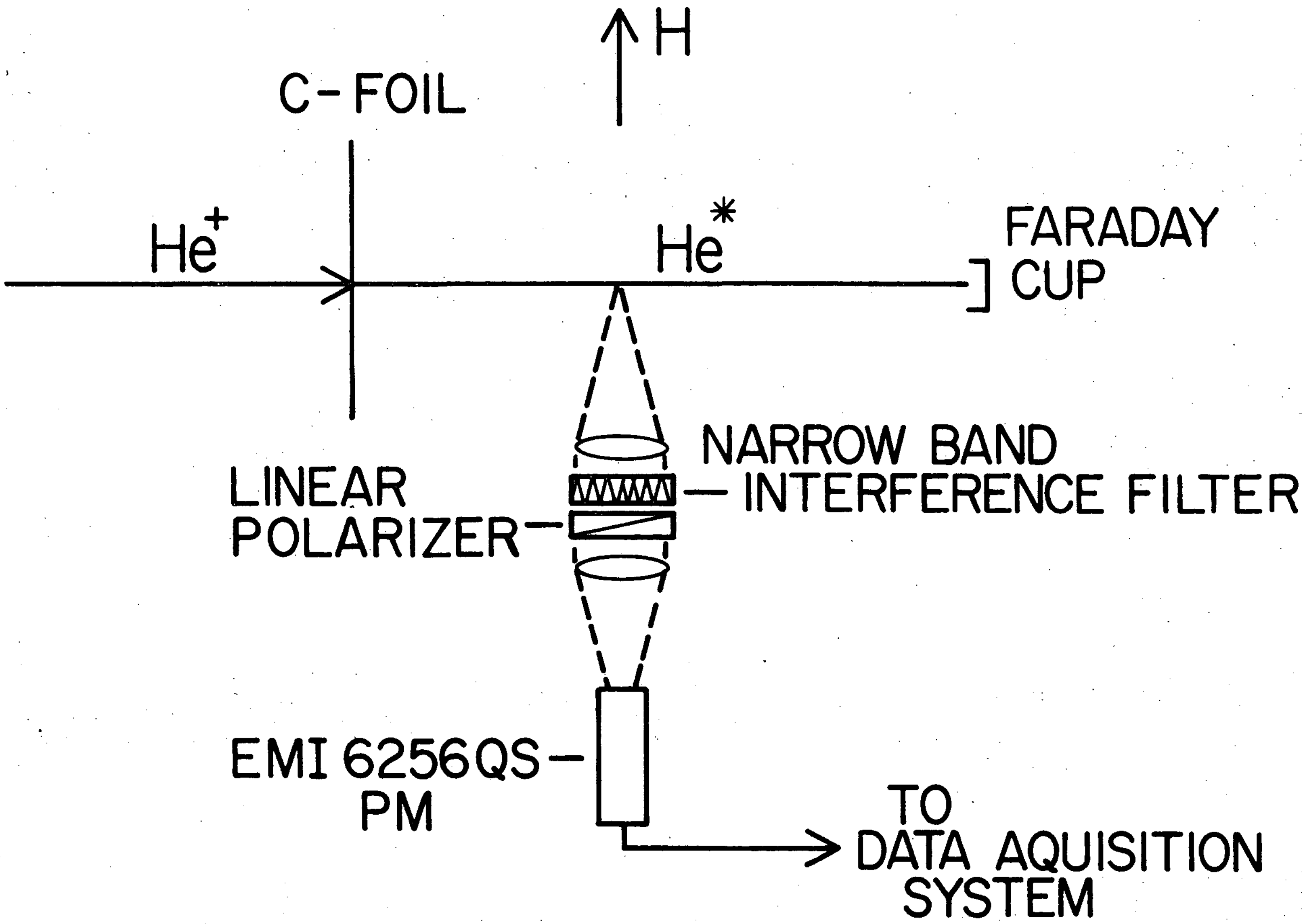

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Fig. 1

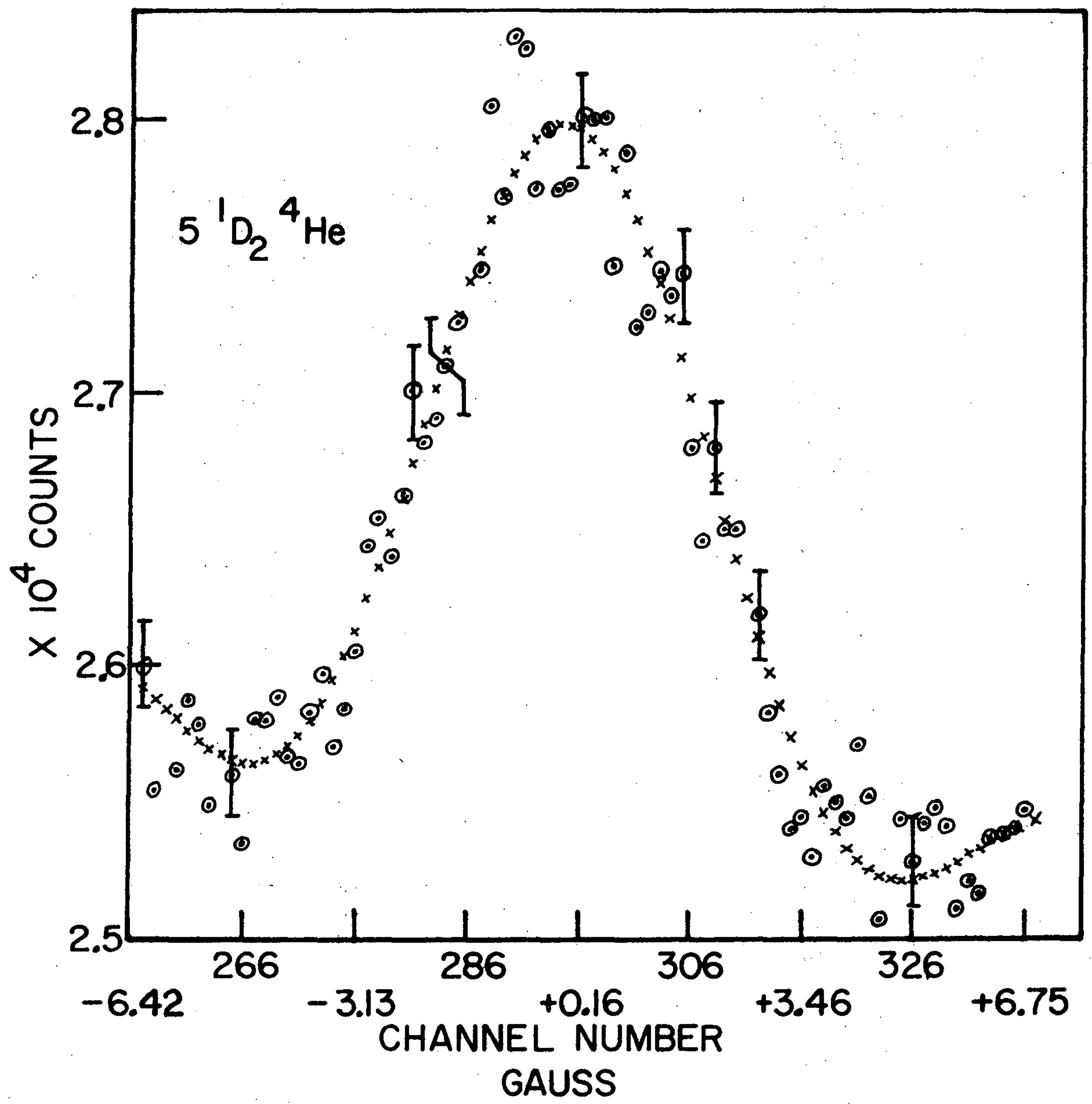

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Fig. 2

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