The effects of the internal structure of the He^4 on this type of experiments have been calculated by Goldberg and found to be very small.[4]

The electron anomalous magnetic moment which has origin in electromagnetic corrections is not seen in these high-energy electron scattering experiments because it has a spatial structure of length determined by the Compton wavelength and consequently a form factor that decreases very rapidly for high q.[5] The electron scattering method investigates structures of much smaller size. If one asumes α to be independent of q,[6] the limit established by our experiment for an electric dipole moment of the electron is $\leq 10^{-15}$ e cm. If α is a function of q it must decrease from $\lesssim 8\times 10^{-5}$ (at $q\sim 0$) to $\leq 3\times 10^{-5}$ for $q=0.44\times 10^{13}$ cm^{-1}.

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Alternate Method of Measurement of the Polarization of Light Emitted by Helium Atoms Excited by Energetic Electrons*

ROBERT H. MCFARLAND AND EDWARD A. SOLTYSIK†
Lawrence Radiation Laboratory, University of California, Livermore, California

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Previous measurements on the polarization of helium light emitted by atoms excited by an electron beam have resulted from the observation of the intensity of the light at right angles to the direction of the electron beam. Polarization was determined in terms of the relative intensities of the components of this light whose electric vectors were oriented parallel to and at right angles to the direction of the electron beam. Because of the disagreement between experiment and theory, an alternate method in which the angle θ between the line of observation and the electron beam could be altered was used. After correcting the effective volume of the reaction region observed, the total intensity of light at a given angle is related to that observed at 90° by the relationship, $I_\theta=I_{90}(1-\pi\cos^2\theta)$, where π is the polarization. Results given show that for $\lambda=4922$ Å, relative changes of polarization with electron energy are similar to those observed with the previously described more sensitive method. The trend of the polarization toward zero at the onset of excitation was again observed.

INTRODUCTION

EARLIER work[1-6] on the measurement of the polarization of light emitted by helium atoms excited by an electron beam has produced three distinct anomalies, involving zero polarization at threshold, magnetic field dependence of the diffuse singlet transitions, and the unexpected energy dependence of polarization of the $\lambda=3889$ Å line. Because of these unexpected results, it was considered desirable that a different method be used for making a confirmative measurement. All of the above references utilized observations made at right angles to the electron beam. The relative intensities of the emitted light with electric vectors oriented parallel and perpendicular to the electron beam were measured; the percentage polarization π was then computed by use of the equation,

$$\pi=[(I_{\parallel}-I_{\perp})/(I_{\parallel}+I_{\perp})]\times 100\%. \quad (1)$$

In the experiment to be described, use was made of the relationship,

$$I_\theta=I_{90}(1-\pi\cos^2\theta). \quad (2)$$

This relates the intensity I_θ of light from a point source and observed at an angle θ to the direction of the electric vector to that observed at 90°.

EXPERIMENTAL METHODS AND RESULTS

Figure 1 illustrates the procedure used in this measurement. An electron gun was mounted in a solid block of soft iron machined to provide an interaction chamber and ports for observation of the intensity of light at selected angles. Light was channeled from the interaction region through $\frac{3}{8}$-in. diameter drilled and reamed light pipes $4\frac{1}{2}$ in. long. The electron beam was collimated by 0.06-in.-diam holes in the accelerating electrode

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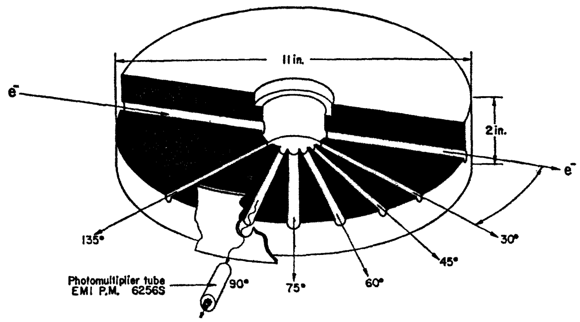

FIG. 1. A sketch of the soft iron interaction region which simultaneously provided magnetic shielding and collimation for the experiment.

structure and passed from the interacting region to the collecting anode through a ½-in.-diam opening. The local magnetic fields (approximately 3G) produced during machining were removed by heating the iron block to 750°C in a vacuum oven for several hours prior to assembly in the vacuum chamber. This reduced the residual magnetic field within the reaction region to less than 0.01 G and allowed collimation and collection of the electron beam which had less than a 5 deg spread. All surfaces adjacent to the reaction region were coated with Aquadag and maintained at ground potential. Light was conducted from the reaction chambers through the channels in the iron block and through quartz windows in the vacuum chamber wall. The light intensity was measured by use of a movable EMI 6256S phototube in a light protected outer chamber. Bausch & Lomb interference filters were used for isolating helium spectral lines. Vacuum was provided by a stainless steel system pumped by a liquid nitrogen trapped oil diffusion pump during pump down and bake out. A liquid nitrogen cooled zeolite pump and trap were used to remove impurities from the system during the experiment. The electron beam was square wave modulated at 100 cps. The photomultiplier tube output was amplified and phase detected as described previously.[4,5]

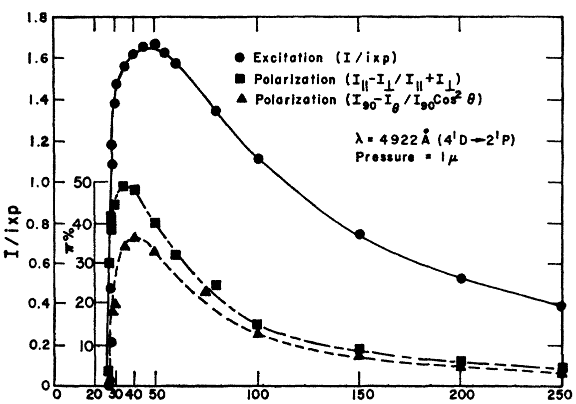

FIG. 2. Polarization and excitation vs energy. Note that the energy scale has not been corrected to spectroscopic appearance potential values.

To a first approximation, the observed intensity I_θ could be corrected for the larger volume observed at an angle other than 90° by multiplying by sin θ. Experimentally, the electron beam focus and spreading as well as possible reflections within the chamber affected the intensity observed. Thus correction for all of these effects was accomplished by normalizing the ratio of I_θ/I_{90} for the lines measured to that for the 4713 Å line of helium for which the polarization is zero and the radiation emitted is isotropic. After normalization the polarization was calculated from Eq. (2).

Although intensities were measured at 30°, 45°, 60°, 75°, 90°, and 135° to the direction of the electron beam, measurements made at 30° were inherently most accurate due to the $\cos^2\theta$ term.

Figure 2 shows a comparison at 1 μ pressure between measurements of polarization of the radiation measured in this fashion at 30° and those made previously for the $\lambda = 4922$ Å line of helium. That the measured polarization is not as great in magnitude as previously measured is not surprising as the spectral resolution of the interference filter is not as great as that for the monochromator previously used (50 Å half-breadth as compared to 15 Å). In all other respects the two curves are comparable within the accuracy expected of the new method.

Measurements made at other angles than at the 30° as shown in Fig. 2 were similar, but exhibited greater errors. Measurements made at 45° were comparable to those at 135° as expected by the symmetry of the experiment.

In conclusion, although the described method is less sensitive and accurate than our previous measurements and is probably applicable only to lines whose polarizations are greater than a few percent due to the $\pi \cos^2\theta$ term, it provides independent experimental confirmation of the threshold anomaly observed in inelastic scattering of electrons by helium.

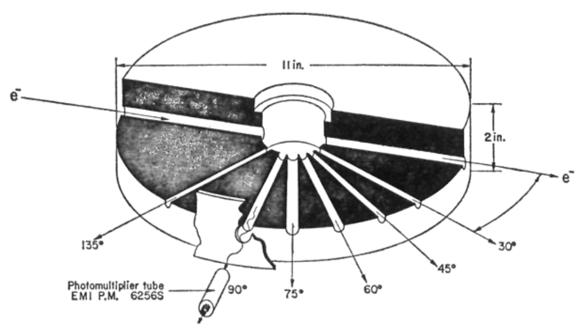

FIG. 1. A sketch of the soft iron interaction region which simultaneously provided magnetic shielding and collimation for the experiment.