A Zero-Degree Inline Optical Electron Polarimeter

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Abstract. We have used a new configuration for a noble gas optical electron polarimeter. This polarimeter is part of an experiment involving dichroic scattering of longitudinally polarized electrons from chiral molecules. Our polarimeter sits along the electron beam axis at the end of the apparatus and measures the polarization of noble gas fluorescence emitted at 0°. The polarimeter is maximally sensitive to longitudinal electron polarization, and it maintains the axial symmetry of our experiment.

INTRODUCTION

In a noble gas electron polarimeter, electrons collisionally excite a ground-state noble gas through exchange scattering. Because of spin-orbit coupling, the excited state spin angular momentum is partially transferred to orbital angular momentum. When the atom decays, it emits circularly polarized light represented by the Stokes parameter P_3. This parameter can be related to electron polarization P_e through the use of integrated-state multipoles [1]. For fluorescence emitted along the electron beam axis (0°), P_3 is given for the heavy noble gases by

$$P_3 = -\frac{\begin{Bmatrix} 1 & 1 & 1 \\ J & J & J_f \end{Bmatrix} \sqrt{2} \left\langle t(J)^{+}_{10} \right\rangle}{\dfrac{2(-1)^{J+J_f}}{3\sqrt{2J+1}} - \begin{Bmatrix} 1 & 1 & 2 \\ J & J & J_f \end{Bmatrix} 2\sqrt{\dfrac{1}{6}} \left\langle t(J)^{+}_{20} \right\rangle} \qquad (1)$$

The symbols $\{\ldots\}$ are $6j$ coefficients, and J and J_f are the total angular momenta of the excited and final states, respectively. The relative integrated-state multipole $\left\langle t(J)^{+}_{10} \right\rangle$ is the atomic orientation parameter which is proportional to P_e; and $\left\langle t(J)^{+}_{20} \right\rangle$ depends on the linear polarization fraction P_1, and is a measure of the alignment of the atomic charge cloud. With this information, we can relate electron polarization to light polarization by introducing the *analyzing power*, A, of the target gas: $P_e = P_3 / A$. We calculate A to be

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$$A \equiv \frac{2}{3}\left[\frac{1-0.254P_1}{1+P_1}\right]. \tag{2}$$

In this expression, P_1 is measured at 90° to the beam axis. Since our apparatus does not permit such a measurement, we must use data from another experiment [1, 2] performed at 90° to determine P_1.

PROCEDURE AND RESULTS

The electron lens portion of our optical electron polarimeter is shown in Fig. 1. As a preliminary test, we used argon as the target gas because argon has the largest analyzing power of the noble gases and is inexpensive [3]. The transition of interest in argon is $3p^5 4p\ ^3D_3 \rightarrow 3p^5 4s\ ^3P_2$ (8115 Å), with a threshold energy of 13.07 eV.

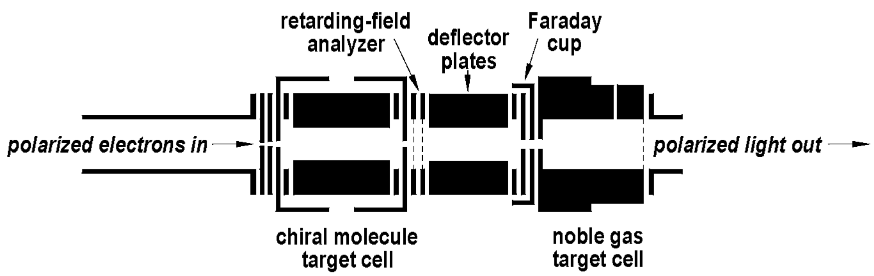

FIGURE 1. Electron lens configuration. When chiral molecule studies are being performed within the cell on the left, deflector plates send the transmitted electron beam onto the Faraday cup. When electron polarization measurements are necessary, electrons pass through the Faraday cup into the noble gas cell on the right. Noble gas fluorescence is collected outside the vacuum chamber by a photomultiplier tube with an appropriate interference filter. Polarization (P_3) is measured by rotating a quarter-wave plate that sits in front of a fixed linear polarizer.

We focus a circularly-polarized 785 nm diode laser onto a wafer of strained GaAs to produce an electron beam. After attenuating the beam by 1/e with argon, we ramp the electron energy and measure excitation functions (near threshold) for orthogonal settings of a quarter wave plate in our optical polarimeter (Fig. 2a). From these results, we calculate P_3 (Fig. 2c). To determine the electron polarization, we first fit the argon data of Wijayaratna [1, 2] for P_1 at 90° (Fig. 2b). Then we calculate the analyzing power for argon as a function of energy (Fig. 2d) and finally determine electron polarization (Fig. 2e).

Our first test shows that $P_e \approx 0.26$ for this strained GaAs crystal. This result is low when compared with a polarization of 0.55 for 785nm light reported by Maruyama *et al.* [4]. Unfortunately, our measurements were made with a GaAs wafer just before it needed to be replaced. The surface had fogged over significantly from repeated heat cleaning and activation sessions. More polarization tests will be made soon with a fresh wafer of the strained GaAs.

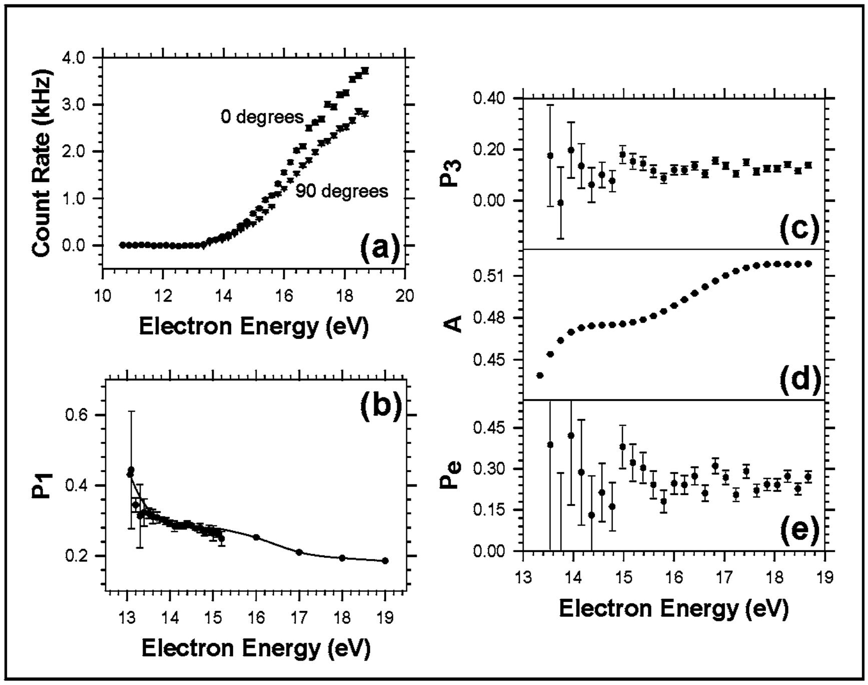

FIGURE 2. (a) Argon excitation functions near threshold for quarter-wave plate at 0° and 90°. (b) Fit to Wijayaratna's P_1 data for argon. (c-e) Polarimetry results (P_3, A, and P_e) for argon near threshold.

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