# Measurement and Reduction of Instrumental Asymmetries in an Electron Circular Dichroism Apparatus

J. Feeks[a], E. Litaker[b], T.J. Gay[b]

[a]*University of St. Thomas, Department of Physics*

[b]*University of Nebraska-Lincoln, Department of Physics and Astronomy*

A type of molecule which has great significance in biology and organic chemistry is one that has no reflection plane of symmetry. This type of molecule is called a 'handed', or chiral molecule. Opposite-handed chiral molecules differ in how they scatter polarized light. For example, they can exhibit "circular dichroism", meaning that the index of refraction of a solution of these molecules will be unequal for light waves with opposite circular polarization. As a result, light with right-hand circular polarization will be absorbed differently than light with left-handed circular polarization. In 1980, Farago laid the foundation for a new phenomenon analogous to optical circular dichroism, this time concerning electrons of opposite longitudinal spin [1]. He called it "electron circular dichroism" (ECD), which describes how a beam of longitudinally polarized electrons will be attenuated based on the parallel or antiparallel relationship between their spins and momenta, and the target chirality. The first experimental work on ECD was done by Campbell and Farago in 1985, when they observed an asymmetry in the transmission of longitudinally-polarized electrons of opposite spin through a camphor vapor [2]. The significance of this research is mainly in its contribution to the understanding of molecular structure and basic collision physics, but it can also give us clues about the curious phenomenon of homochirality in biochemistry: the fact that all essential biopolymers exist with only one type of chirality. This applies to proteins, DNA, and RNA.

Since Farago's initial findings, both Kessler's group and Gay's group have performed similar experiments with camphor [3,4]. In recent years, Fabrikant *et al.* have attempted to minimize the helicity-dependent intensity asymmetry of light used to produce the polarized electrons in these experiments, in order to reduce instrumental asymmetries below the threshold of the theoretical limit for observing ECD [5]. This

asymmetry reduction technique focused mostly on intensity variations. However, both spatial and intensity variations related to helicity are of concern in the optical setup (Fig. 1). Spatial variations can arise because the light is split into orthogonal linear polarization states by a beam splitter, which each pass through a single chopper oriented such that only one polarization state is transmitted at a time, and are then recombined spatially at a second beam splitter. Any spatial variations can cause an instrumental asymmetry if the photoemission efficiency of the gallium arsenide crystal (which emits the polarized electrons) varies across its surface. Even if the beam were perfectly recombined such that no spatial variation occurred, a helicity dependent laser intensity variation could also mimic the asymmetry expected as a result of ECD. As such, both need to be minimized.

To quantify the spatial variation of the laser beam we used a position sensitive photodiode interfaced with a computer. Beginning with only the laser, the variations were measured as each optical component was added to the set up, in order to determine which component(s) cause appreciable variation. In particular, it was important to quantify laser stability as laboratory conditions varied. This report will discuss the results of the data taken, as well as potential improvements to the setup that will minimize the instrumental asymmetry as a result of the optics in the apparatus.

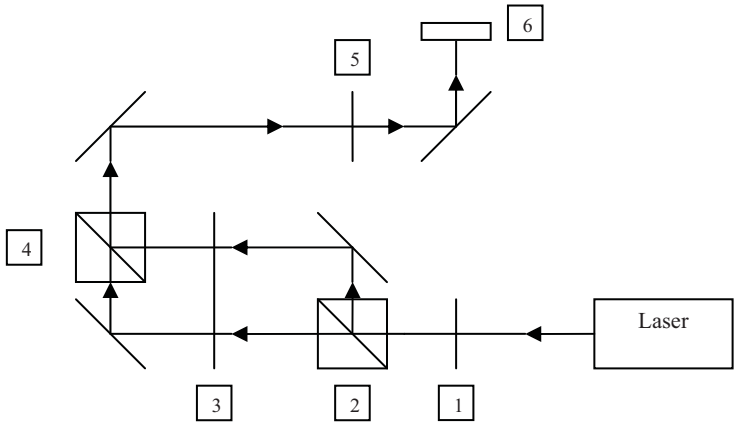


Fig. 1 – Optical Setup. The laser passes through a liquid crystal variable retarder (1) which adjusts for intensity asymmetry, then is split into orthogonal linear polarization states by a beam splitter (2). Only one state is allowed to pass through the chopper (3) at any given time. The beam is then recombined spatially by another beam splitter (4), but the oppositely polarized beams are not recombined temporally. The quarter-wave plate (5) converts the beam to orthogonal circular polarization states, which then reach the crystal or a detector (6).


[1] P.S. Farago, J. Phys. B **13**, L567 (1980).

[2] D.M. Campbell and P.S. Farago, Nature **318**, 52 (1985)

[3] S. Mayer and J. Kessler, Phys. Rev. Lett. **74**, 4803 (1995)

[4] K.W. Trantham *et al.*, J. Phys. B **28**, L543 (1995)

[5] M.I. Fabrikant *et al.,* Appl. Opt. **47:13**, 2465 (2008)