Magneto-Optical Characterization of ZnSe Bandgap

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Abstract

The Verdet constant of ZnSe was experimentally determined in the visible to infrared wavelength range corresponding to 480-980 nm. In addition to the values obtained utilizing phase sensitive detection and an ac magnetic field, we have also analyzed and compared all other known data. This work is intended to characterize the dispersion of the Verdet constant and extract the energy bandgap from existing theories. The values tend to agree with newer theories assuming a quasiparticle and/or quantum dot (nanoparticle structure), which assume a smaller crystalline size and stronger energy confinement than the older models.

1. Introduction

The Faraday Effect, named for physicist Michael Faraday, is a magneto-optical phenomenon characterizing the rotation of the plane of polarization of light—a form of optical activity due to Zeeman splitting.

2. Experimental Method (cont.)

Figure 4. Verdet constant of ZnSe reported from all known published data [9], in addition to this work (blue squares, black circles, yellow triangles, and green diamonds). The smooth line represents Balkansky, et. al. data which was reverse engineered from published fitting parameters and the grey circles is data from Wunderlich, et. al. The inset graph represents a BHL fit to the eBay 2021 sample. The bandgap extraction procedure requires graphing the product of the refractive indices and Verdet constant against the wavelength.

3. Apparatus

Two different theories were used to analyze, via nonlinear curve fitting, the dispersion of the Verdet constant for the ZnSe glass sample: BHL

\[ BHL \rightarrow nV = E \left[ \left(1 - \xi \right)^{2} - \left(1 + \xi \right)^{2} \right] \left(1 - \xi \right)^{-1} \]

KLN

\[ KLN \rightarrow nV = K \left[ \left(1 - \xi \right)^{2} - \left(1 + \xi \right)^{2} \right] \left(1 - \xi \right)^{-1} \left(1 - \xi \right) \left(1 + \xi \right) \]

A detailed discussion of the theories and significance of the fitting parameters is beyond the scope of this presentation. Nevertheless, BHL and KLN are fitting parameters (\( \xi = \alpha / \lambda \)), n is the refractive index and \( \xi = \alpha / \lambda \) is the refractive index.

Interestingly, an energy gap can be calculated from the fitting parameter, \( \xi = \alpha / \lambda \), and the refractive index.

Finally, the refractive index, n, is also a dispersive quantity (i.e. depends on \( \lambda \), which we calculate using the Marple equation from https://refractiveindex.info/.

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5. Results

<table>
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<th>( \lambda_{\text{BHL}} )</th>
<th>( \lambda_{\text{KLN}} )</th>
<th>( \lambda_{\text{KLN}} )</th>
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<tr>
<td>2.97 eV</td>
<td>3.15 eV</td>
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</tbody>
</table>

Table 1: Fitting parameters resulting from the BHL and KLN theories providing the most comprehensive data set associated with magneto-optic bandgap characterization of ZnSe. The bandgap energy levels are closer to those resulting quasiparticle [10] and nanoparticle [11], rather than those expected of crystalline structures. Essentially, quasiparticle and nanoparticle bandgap levels tend toward a 10% increase, reflecting a reduced crystalline size and stronger valence electron confinement when compared to bandgap energies obtained for quasi-crystalline ZnSe via standard optical measurements (e.g., absorption).

6. Conclusion

Faraday rotation experiments afford valuable exposure to advanced undergraduate and graduate student researchers. The experimental methodology incorporated into this investigation utilizes phase sensitive lock-in regarding the general problem associated with data extraction of signals buried in noise. Summarizing, we have found that the dispersive characteristic of the Faraday rotation in ZnSe can well be described by the effects of direct allowed transitions between a simple valence and conduction band (e.g., BHL and KLN theories). Our measurements, in conjunction with intensive data mining, provides the most comprehensive set of magneto-optical parameters for the dispersion of the Verdet constant, in addition to “magneto-optic based” bandgap energy of ZnSe to date.

Citations