Measurement of Electron Beam Polarization Produced by Photoemission from Bulk GaAs Using Light with Orbital Angular Momentum

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Vortex Light

Light beams with azimuthal phase dependence can carry orbital angular momentum (OAM) [1]. Such light can possess arbitrarily large values of angular momentum ($\pm m\hbar$) whereas conventional circularly-polarized light possesses only one unit ($\pm\hbar$) of spin angular momentum per photon.

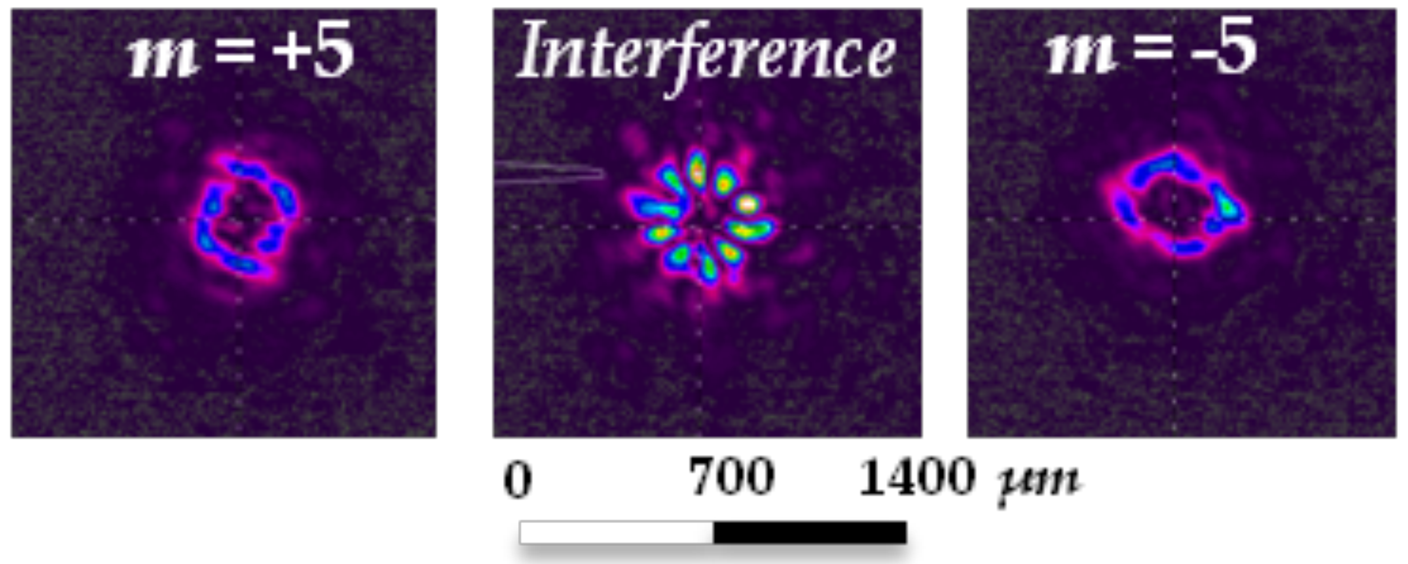

FIG. 1. Intensity patterns (left and right) for m = ±5 OAM beams and (center) interference pattern produced by combining these two.

GaAs Photocathode

When circularly-polarized light with near-bandgap energy illuminates a negative electron affinity (NEA) GaAs photocathode, spin-polarized electrons are emitted [2, 3]. The degree of polarization is defined to be

$$P = \frac{N\uparrow - N\downarrow}{N\uparrow + N\downarrow},$$

where $N\uparrow$ and $N\downarrow$ are the number of spin-up and spin-down electrons respectively.

For thick bulk GaAs illuminated with circularly-polarized light, the electron polarization is typically ~35% [4]. Using light with OAM, we explored the idea of imparting angular momentum to electrons in the conduction band of GaAs to create spin-polarized electron beams.

Experimental Setup

In our experiment, two linearly-polarized laser beams of comparable intensity were directed at diffraction gratings to produce two linearly-polarized Laguerre-Gaussian beams with varying amounts of OAM of opposite charge (see Fig. 2a). These beams were directed—one at a time—at a GaAs photocathode (Fig. 2b) to produce electron beams that were delivered to a compact retarding-field micro-Mott polarimeter [5]. The systematic error associated with beam misalignment, determined by displacing one linearly-polarized Gaussian beam relative to the other by a distance comparable to the spatial extent of the OAM beams, was ~2%.

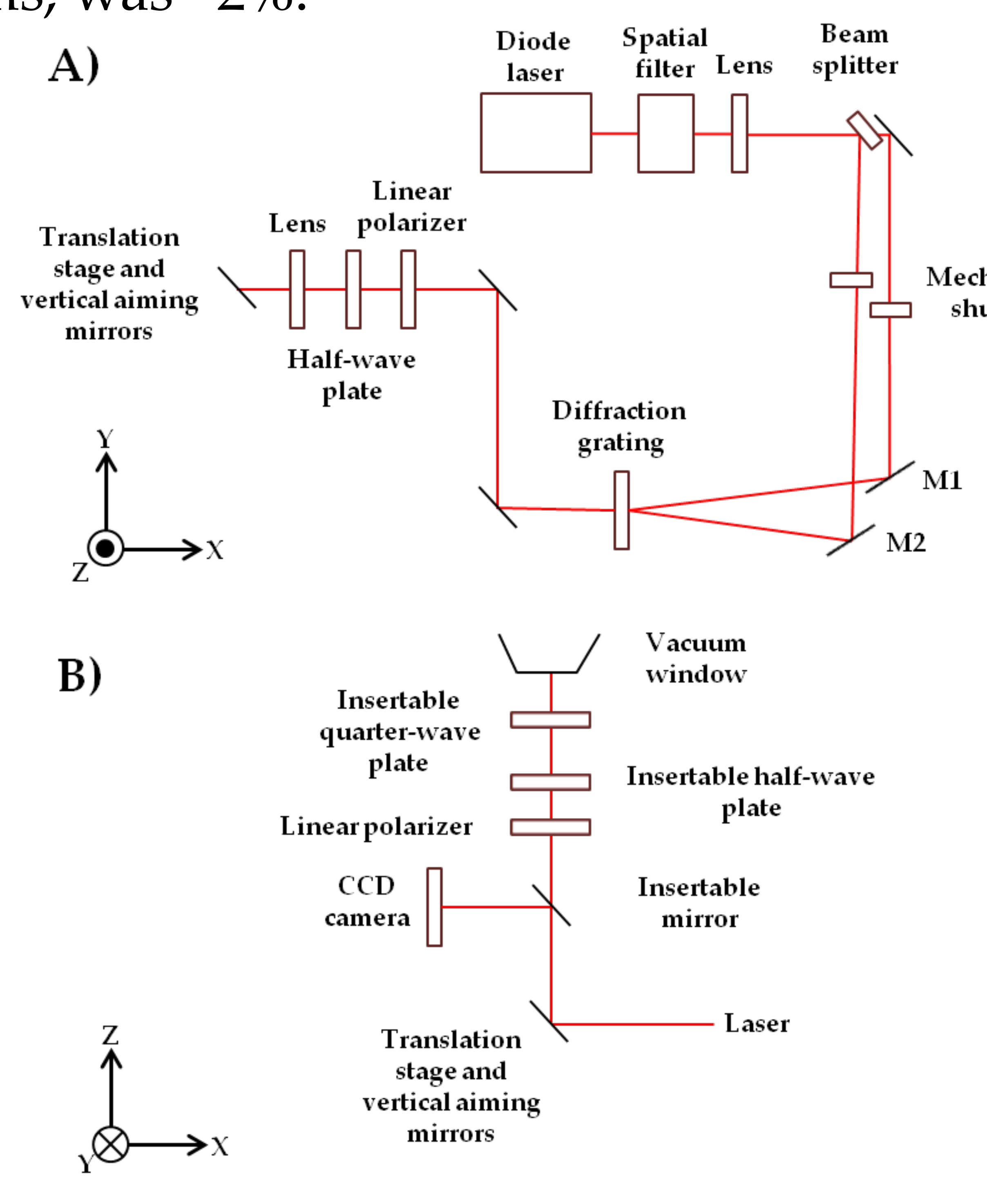

FIG. 2. Experimental setup used to measure electron polarization produced in photoemission from NEA GaAs using OAM light. Insertable elements only used when investigating systematic errors.

Results

The polarization of electrons emitted from GaAs using OAM light was measured to be less than 2.5% for all topological charges tested (Fig. 3). This is compared to ~35% polarization for circularly-polarized light. Given the systematic spatial displacement uncertainty, our measurements were consistent with zero, suggesting that OAM light does not couple to the extended (delocalized) electron states in a semiconductor, at least when the laser beam diameter is ~100 μm or larger.

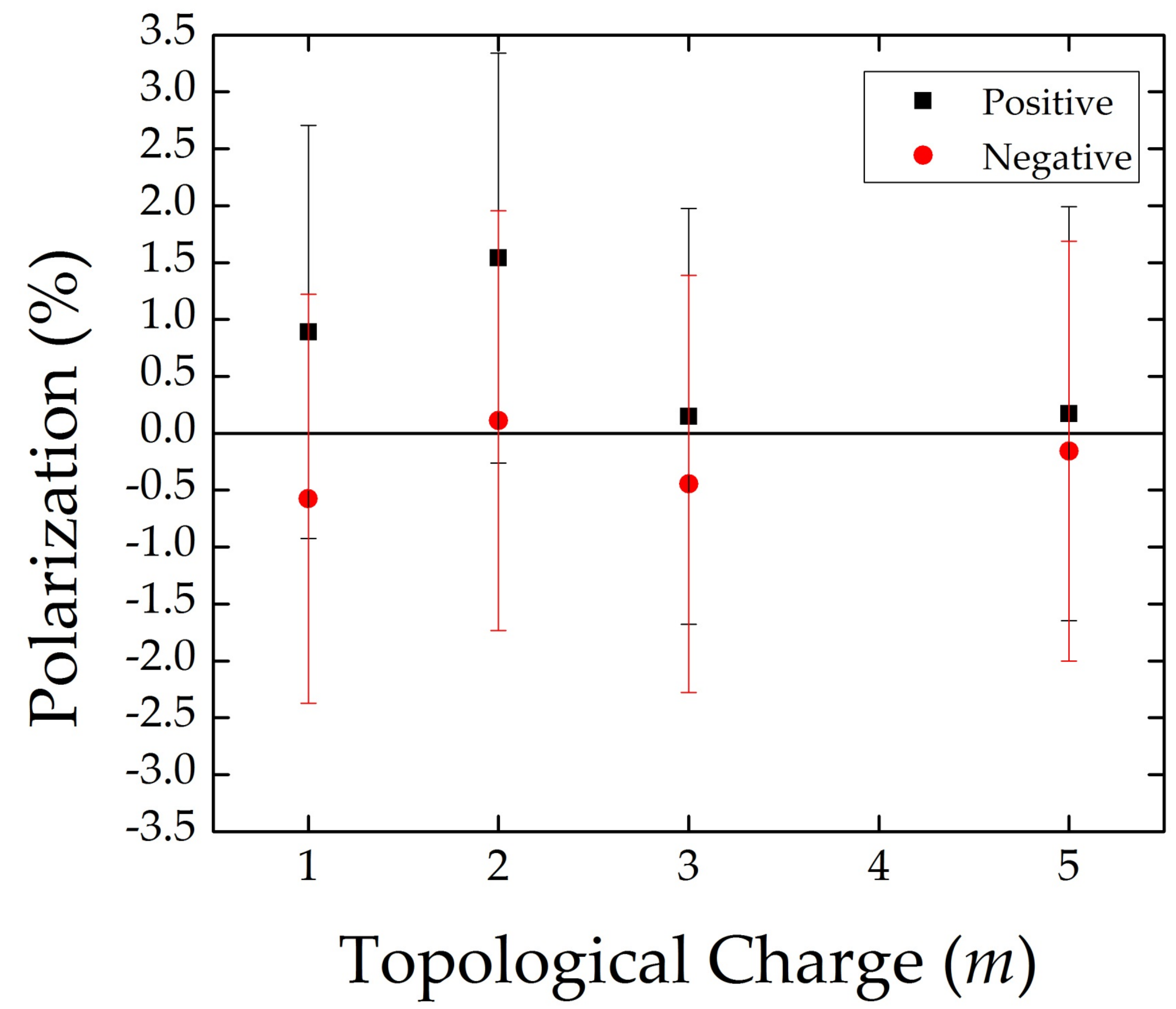

FIG. 3. Electron polarization produced by various OAM beams.

References

[1] L. Allen *et al.*, Phys. Rev. A **45**, 8185 (1992).
[2] D.T. Pierce *et al.*, Appl. Phys. Lett. **26,** 670 (1975).
[3] C.K. Sinclair *et al.*, PRST-AB, **10**, 023501 (2007).
[4] C.Y. Prescott *et al.*, Phys. Lett. B **77**, 347-52 (1978).
[5] J.L. McCarter *et al.*, Nucl. Instr. and Meth. A **618**, 30 (2010).

Funding: NSF PHY-0821385, DOE DE-AC05-84ER40150, and DE-FG02-97ER41025