# "The color of a flower field changes with a butterfly's flight vector" is a metaphor for homochirality colorimetry via chiral nanostructure arrays

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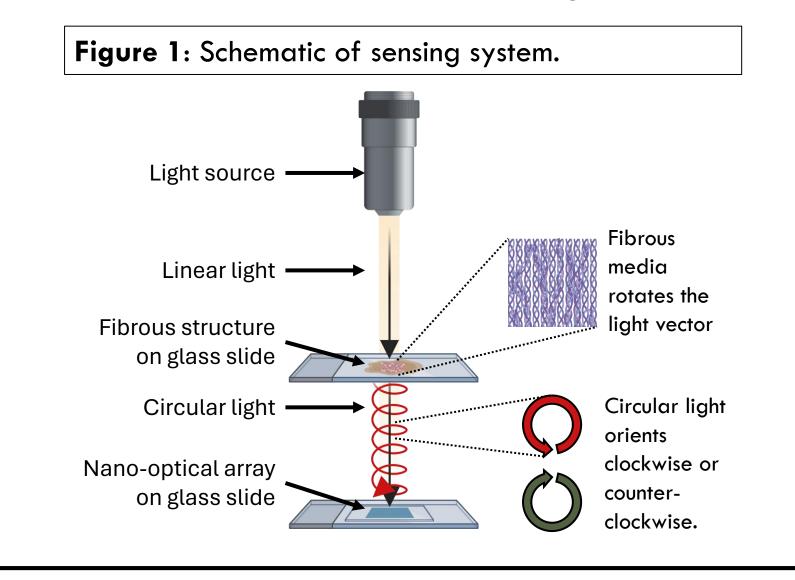
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## Introduction

Fibrous or filamentous biological structures, like microbial mats, can rotate a light wave's travel vector [1,2]. However, this rotation is too minimal to measure without meter-scale tools [3]. This work explores miniaturizing these tools to the nanometer level for in-situ applications.

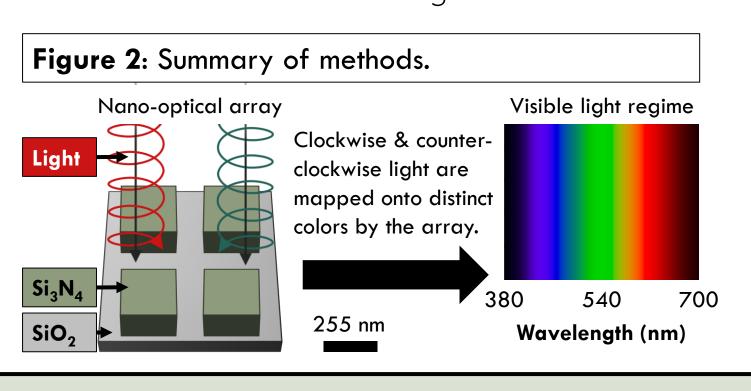
One possibility is rotating a light vector into a circular path, either clockwise or counterclockwise [3]. Homochirality is when an orientation of circular light is favored over the other [3,4,5]. Detecting homochiral light is an agnostic biosignature of life [5].

We investigate how this biosignature could be detected using arrays of nanoscale particles. By using visible light, our optical arrays also act as colorimetric sensors of homochirality [3,6,7].



## Materials and methods

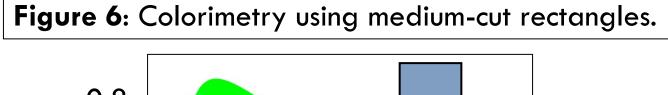
We investigate how a cut to one corner of square- and rectangle-shaped nanostructures affects their sensitivities to differentiating between incident clockwise or counterclockwise oriented circular light.

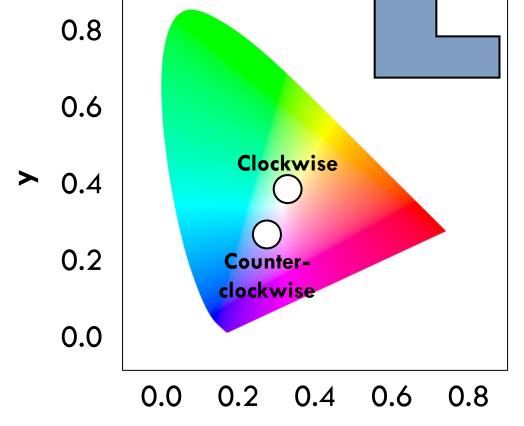


#### Results • Differentiation of clockwise and counter-clockwise polarization states of circular light was achieved. • Squares: Figure 3 shows cuts to the square structure affect the reflectance response but result in non-differentiable outputs. Table 1 displays the non-differentiable colorimetry results. Figure 4 examines the near-field response: cuts simplify the problem from a quadrupole to a dipole, which dampens the reflectance response due to a decreased energy output. • Rectangles: Simplifying the problem in rectangles from four nodes to two nodes extinguishes the longer-wavelength reflectance peaks, as shown in Figure 5's "Medium Cut" group. This unequally dampens the shorter-wavelength peaks of the two polarization states. Both these observations contribute to the differentiable colorimetry results in Table 2. **Table 1:** Colorimetry results Figure 3: Applying cuts to a square-shaped nanoparticle from Figure I reflectances. No Cut **Small Cut Medium Cut** Clockwise Both Counter-Clockwise polarization clockwise Counter-clockwise states show No Cut #598C18 The prior peak The two peaks splits into two collapse into dampened Small Cut #428716 one, but the amplitude doesn't recover. Medium Cut #1C6117 0.0 <sup>\_</sup> 380 536 550 550 380 Wavelength (nm) Wavelength (nm) Wavelength (nm) $\left|\left|\mathbf{E}_{0}\right|\right|_{2}^{2}$ Clockwise 200 ...... ...... 100 Counter-50.0 Figure 5: Applying cuts to a rectangle-shaped nanoparticle **Table 2:** Colorimetry results from Figure III reflectances. No Cut Small Cut Medium Cut —— Clockwise Counter-Clockwise ····· Counter-clockwise clockwise 0.8 #484564 No Cut The longer-wavelength The shorterpeaks are extinguished. wavelength peak #424059 #433F62 The clockwise polarization Both polarization of clockwise peak is disproportionately states show the polarization slightly dampens. dampened. same response. Medium Cut #31352A #343146 0.0 <sup>\_</sup> 380 646 380 440 Wavelength (nm) Wavelength (nm) Wavelength (nm)

## Conclusions

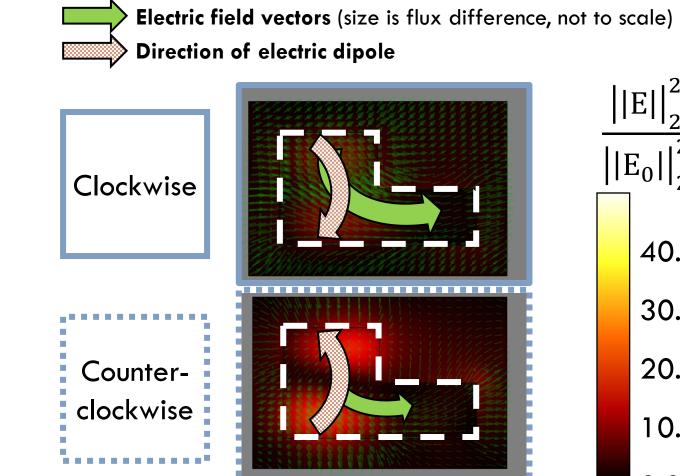
Biological media with fibrous structures can alter light polarization, an agnostic indicator of life [1,2]. Designing nano-optical arrays enables miniaturized optical sensors for polarized light, which may be useful for *in-situ* investigations. Our study showed that nano-optical arrays can differentiate clockwise and counter-clockwise circularly polarized light, allowing colorimetry homochirality detection (see Figure 6).



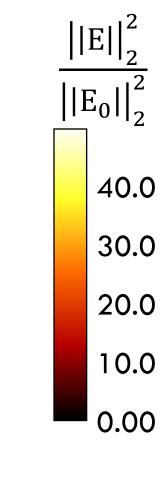


However, the reason for this remains unclear. Figure 7 suggests that under clockwise light, the dipole charge aligns with the sideways flux, reducing light reflected towards the imaging apparatus. Under counter-clockwise light, the dipole charge opposes this flux. This could explain the disproportionate dampening in reflectance and the distinct colorimetry results.

Figure 7: Near-field of medium cut rectangle.







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