“The color of a flower field changes with a butterfly’s flight vector” is a metaphor for homochirality colorimetry via chiral nanostructure arrays

Zaid Haddadin[1], Anna My Nguyen[2], Paula Kirya[2], Lisa V. Poulikakos[2,3]

1. Electrical & Computer Engineering, University of California San Diego, La Jolla, CA 92093
2. Mechanical & Aerospace Engineering, University of California San Diego, La Jolla, CA 92093
3. Program of Materials Science & Engineering, University of California San Diego, La Jolla, CA 92093

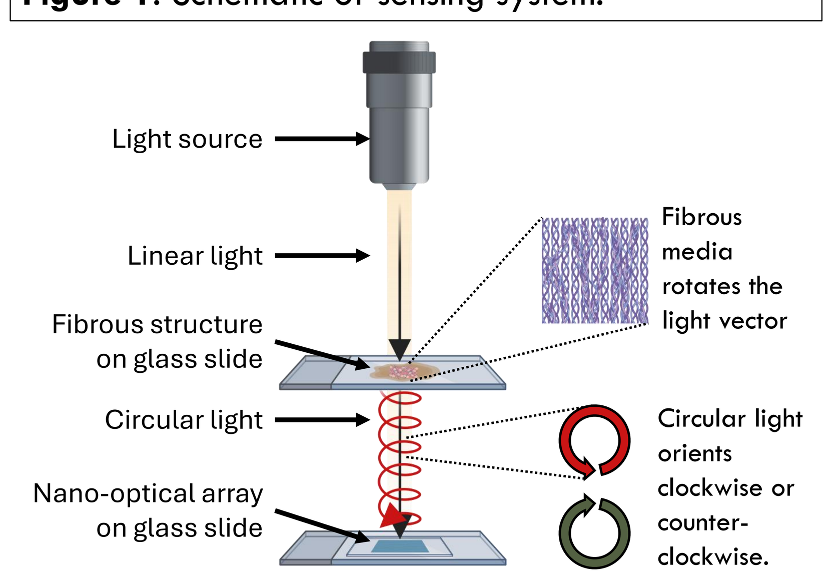
Introduction

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 counter-clockwise [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].

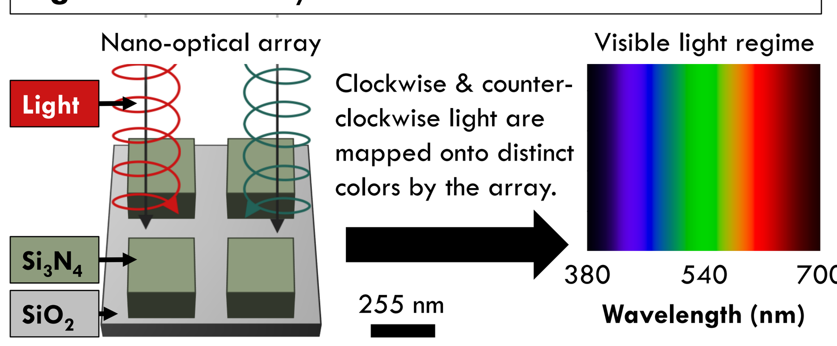
Figure 1: Schematic of sensing system.



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 counter-clockwise oriented circular light.

Figure 2: Summary of methods.



Results

- **Differentiation of clockwise and counter-clockwise polarization states of chiral 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 four to two nodes, which dampens the reflectance response due to a decreased out-of-plane energy output.
- Rectangles: Simplifying the problem in rectangles from a four nodes to nodes extinguishes the longer-wavelength reflectance peaks, as shown in Figure 5’s “Medium Cut” group. This also unequally dampens the shorter-wavelength peaks of the two polarization states. Both these observations contribute to the differentiable colorimetry results in Table 2.

Figure 3: Applying cuts to a square-shaped nanoparticle

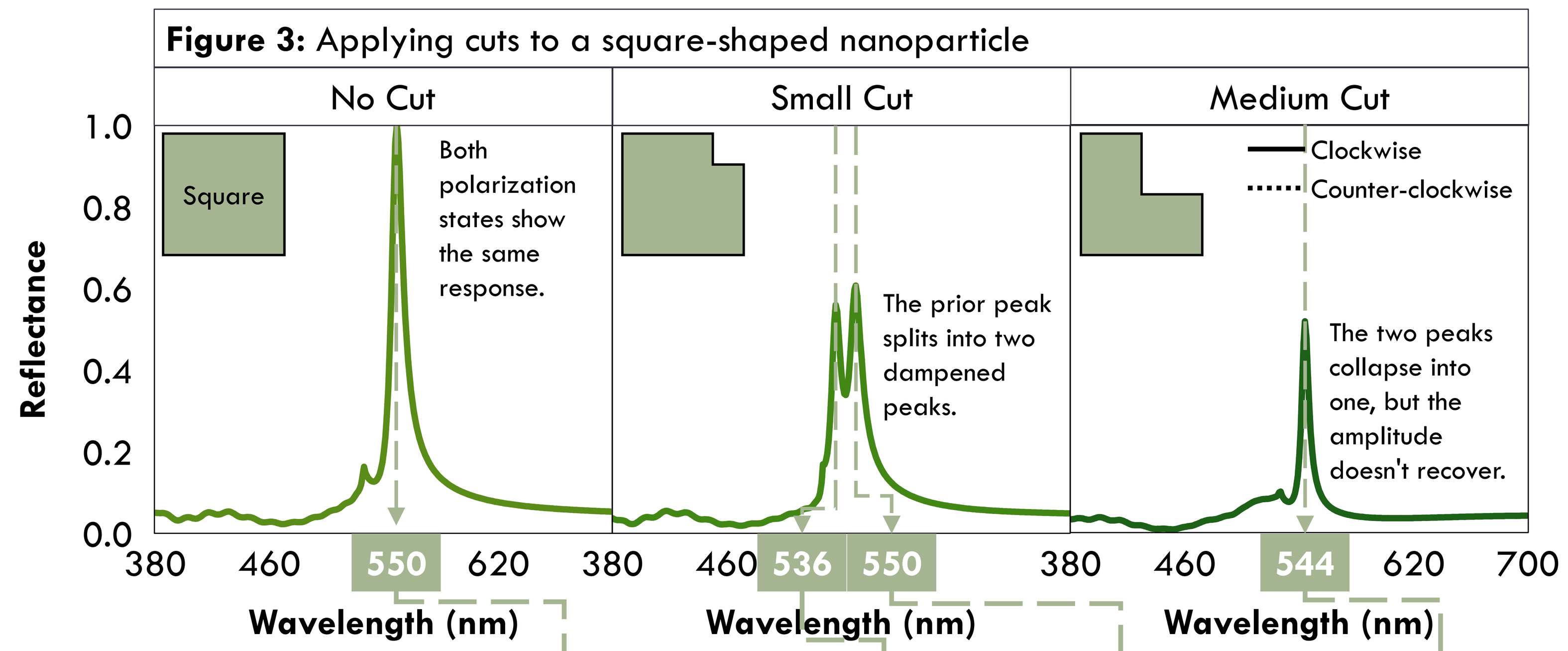


Table 1: Colorimetry results from Figure I reflectances.

	Clockwise	Counter-clockwise
No Cut	#598C18	
Small Cut	#428716	
Medium Cut	#1C6117	

Figure 4: Near-field plots

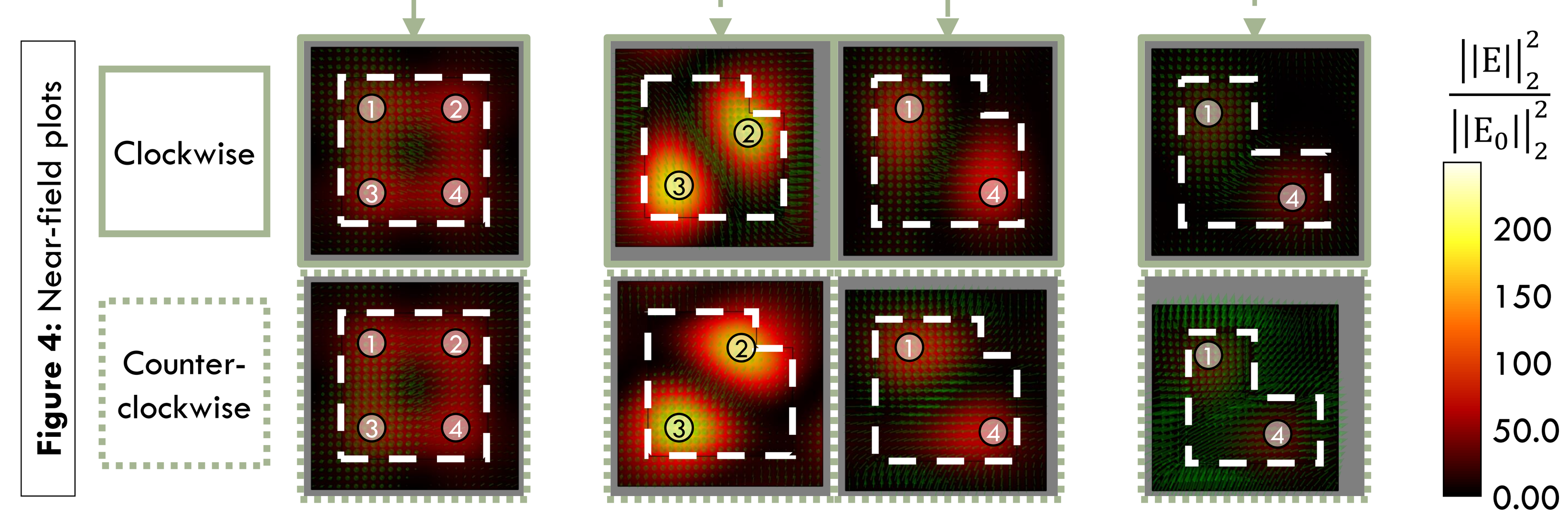


Figure 5: Applying cuts to a rectangle-shaped nanoparticle

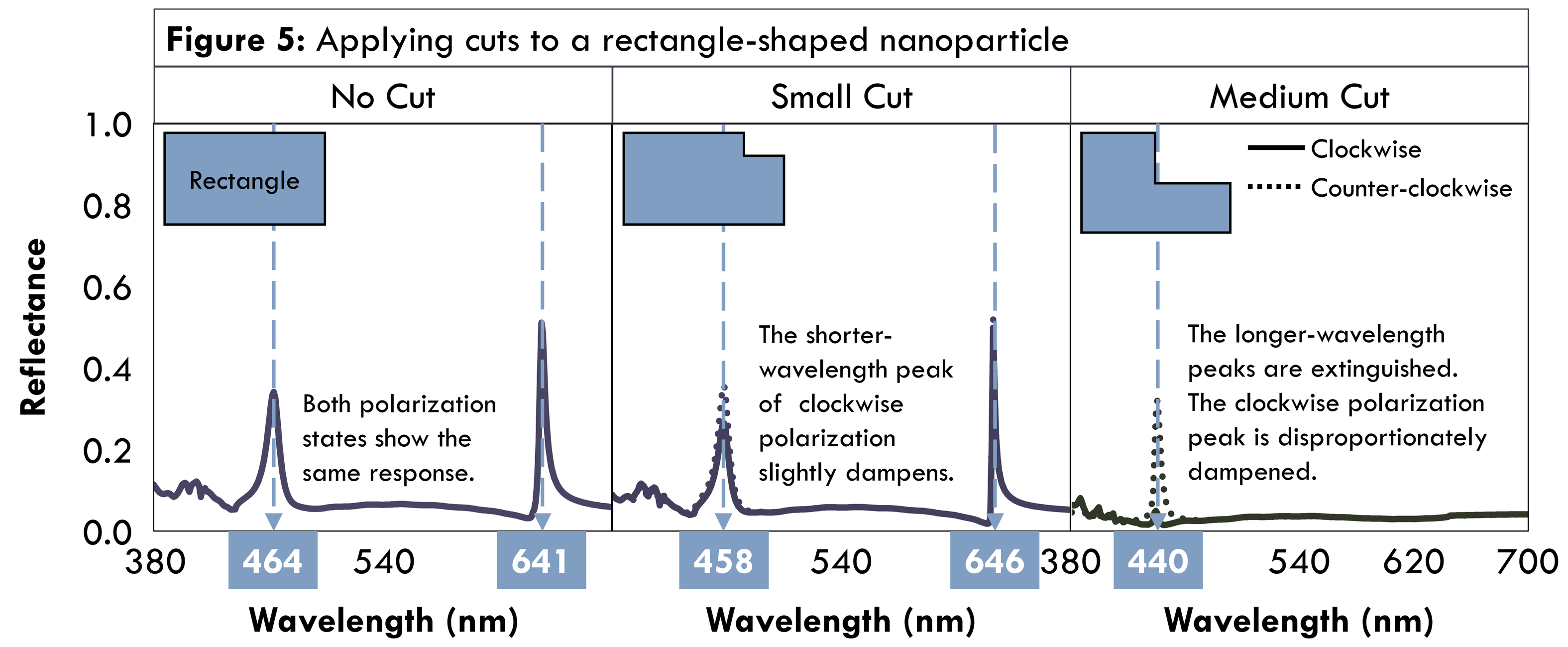


Table 2: Colorimetry results from Figure III reflectances.

	Clockwise	Counter-clockwise
No Cut	#484564	
Small Cut	#424059	#433F62
Medium Cut	#31352A	#343146

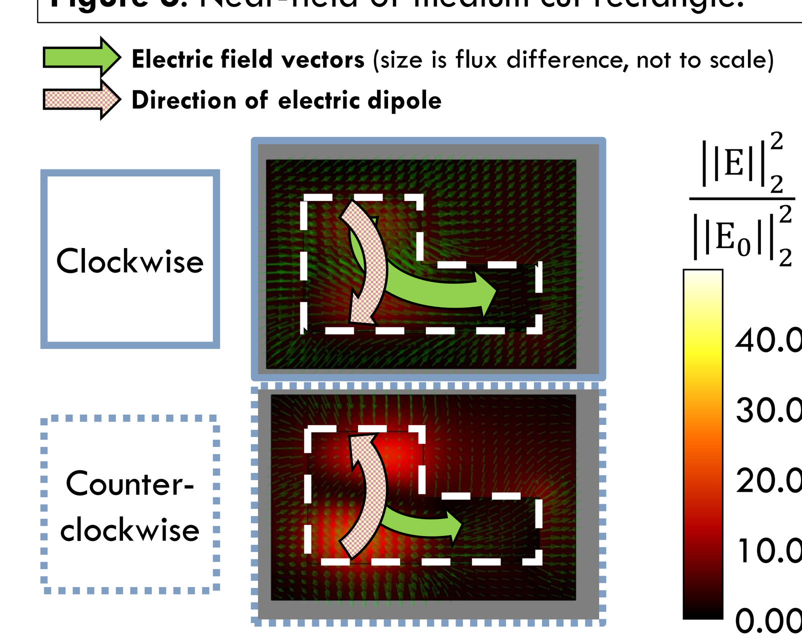
Conclusions

Biological media with fibrous or filamentous structures can alter light polarization, an agnostic indicator of life [1,2]. The purposeful design of nano-optical arrays makes it possible to create miniaturized optical sensors for polarized light, which may be useful for *in-situ* investigations.

This investigation showed that nano-optical arrays can differentiate clockwise and counter-clockwise circularly polarized light, enabling homochirality detection. However, there remains the open question of why this was achieved.

Figure 6 suggests that under clockwise light, the dipole charge aligns with the outward flux to the nanoparticle sides; thus, reducing the amount of light reflected towards the imaging apparatus. Under counter-clockwise light, the dipole charge opposes the outward flux to the nanoparticle sides. If so, this could explain the disproportionate dampening in reflectance and the discriminatory colorimetry results.

Figure 6: Near-field of medium cut rectangle.



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Further information

Contact me at zalhadda@ucsd.edu if you have any further questions or comments.

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ABGRADCON24 CORNELL UNIVERSITY