Generation of a superchiral near-field from an achiral cavity-coupled plasmonic system.

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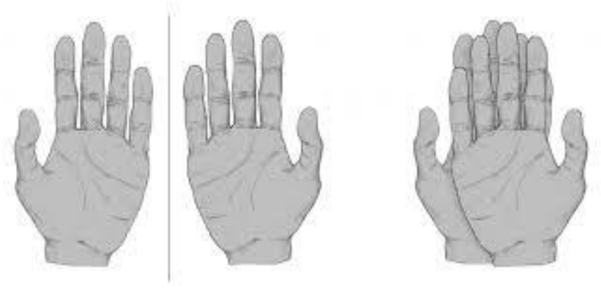
Introduction

Chiral body, found in all biological systems, does not have a superimposed mirror image. A great example of chirality is human hands. Left and right just like two enantiomeric configurations: left (sinister, s-) and right (dexter, d-) of a chiral molecule, each have their own ordinary properties.



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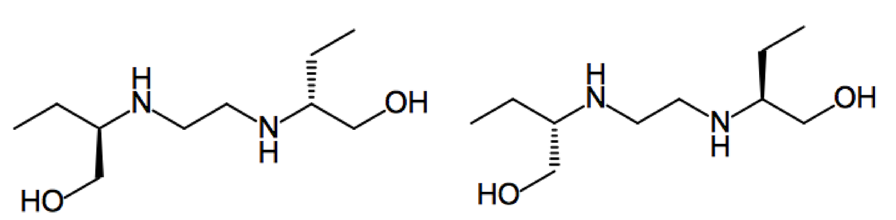
Common spectroscopic techniques are not able to differ between enantiomers. Fortunately, introducing another pair of enantiomers to the system allows for the differentiation of sinister and dexter [3].



(*R,R*)-(-)-ethambutol (*S,S*)-(+)-ethambutol

Ethambutol sinister causes blindness, while its dexter treats tuberculosis, demonstrating the importance of differentiating enantiomers of a chiral molecule.
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An enantiomer pair can be also found among electromagnetic fields, such as **circularly polarized light (CPL)** with its right and left component. Introducing free propagating CPL into systems allows limited chiral light-matter interactions and creates a chiral field. **Circular dichroism spectroscopy** describes the way right- and left- circularly polarized light is absorbed by a chiral molecule [1].

One of the ways to generate **superchiral field** that is larger than a chiral field and allows for stronger interactions is by creating:

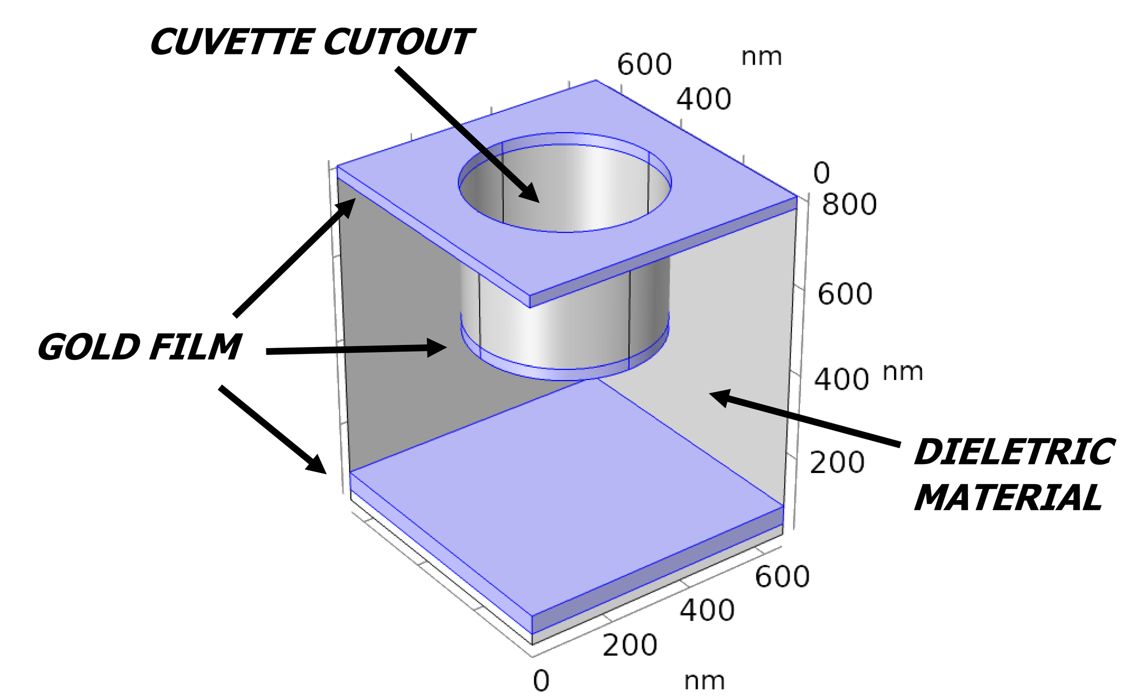
1) **Chiral nanostructures** which present difficulty in distinguishing the effect of the molecules and the structure, due to the chirality of all components.

2) **Achiral nanostructures** that can produce a superchiral field, as simple as a circularly polarized plane wave reflected off a standard mirror [2].

Inspired by work of Vazquez and Chandra, this research focuses on designing an achiral structure that generates superchiral field in the visible range of light [3].

Methodology

Our model, simulated using FEM software COMSOL, represented a unit cell of the array of squares.



DESIGN OF THE STRUCTURE

- **An optical cavity** was created from top and bottom layer of gold, capturing the EM field within the structure
- The interaction between the moving charges of free electrons in the gold and photons, called a **surface plasmon polariton**, allowed for the strong confinement of EM energy at the interface between a metal (gold) and any dielectric material
- The increased density of EM energy caused a **stronger light-matter interaction**
- **CPL excitation** concentrated the EM field and accumulated a higher degree of chirality than the incident plane wave would have, potentially leading to a **stronger chiral interaction**

Chirality of the EM field was quantified by a conservative quantity called chiral density, expressed (in harmonic domain) as [3,4]:

$$C(\mathbf{r}) = -\frac{1}{2}\varepsilon_0 \omega \mathrm{Im}(\mathbf{E}^* \cdot \mathbf{B})$$

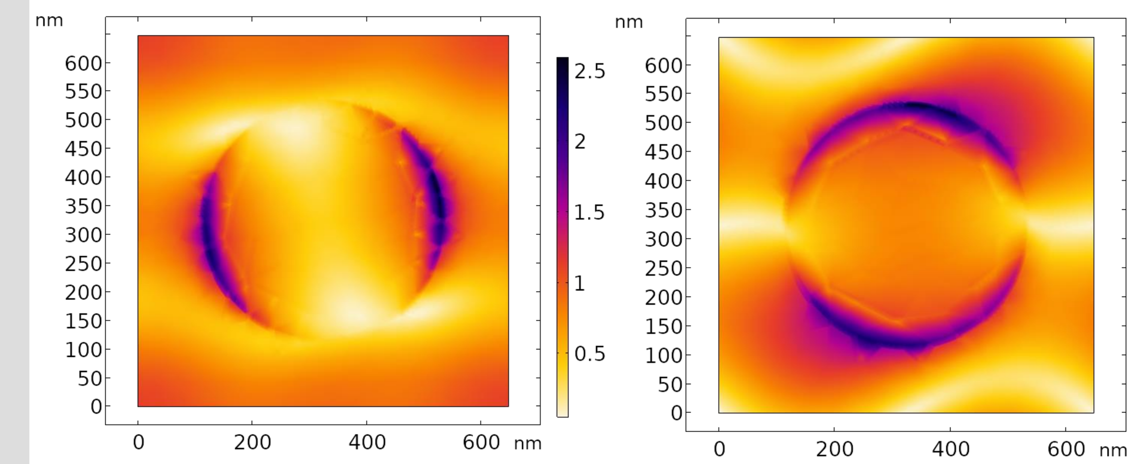
To analyze the model we checked for the presence of an electric and magnetic field 5nm above the cuvette. The lack of either field would prevent us from solving for chiral density.

The absorption and chiral density of the structure were integrated over the volume of cuvette and cavity for one unit cell.

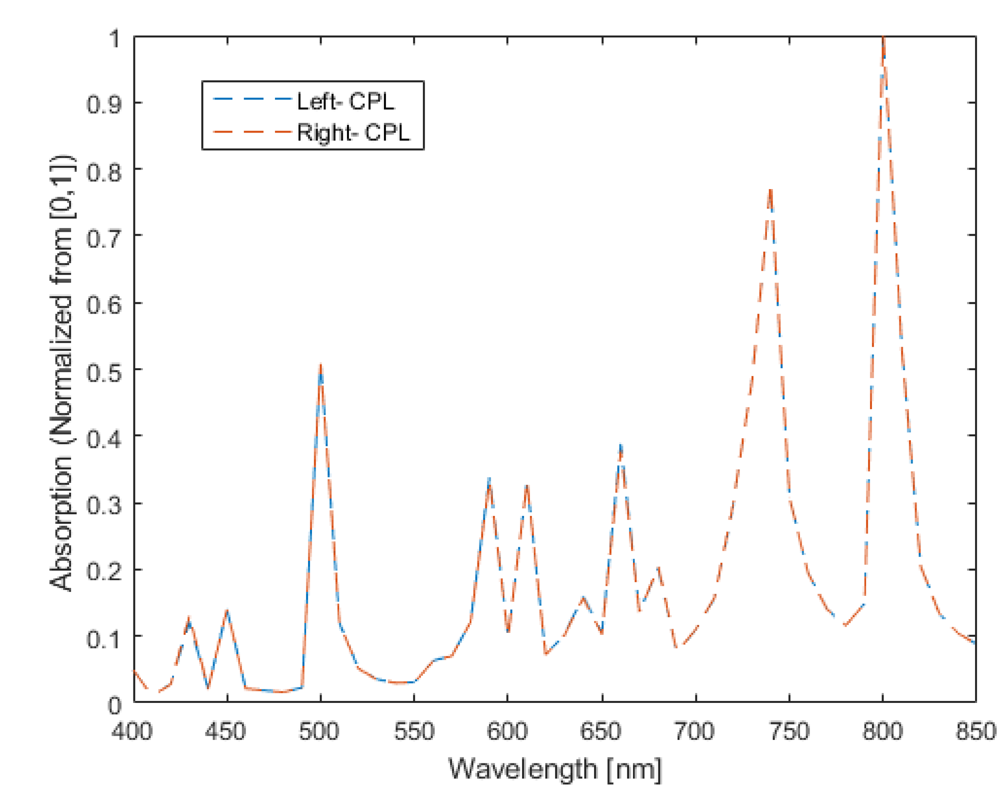
Results

Amplitude of the field 5nm above the cuvette

Magnetic Field [V/m] **Electric Field [V/m]**



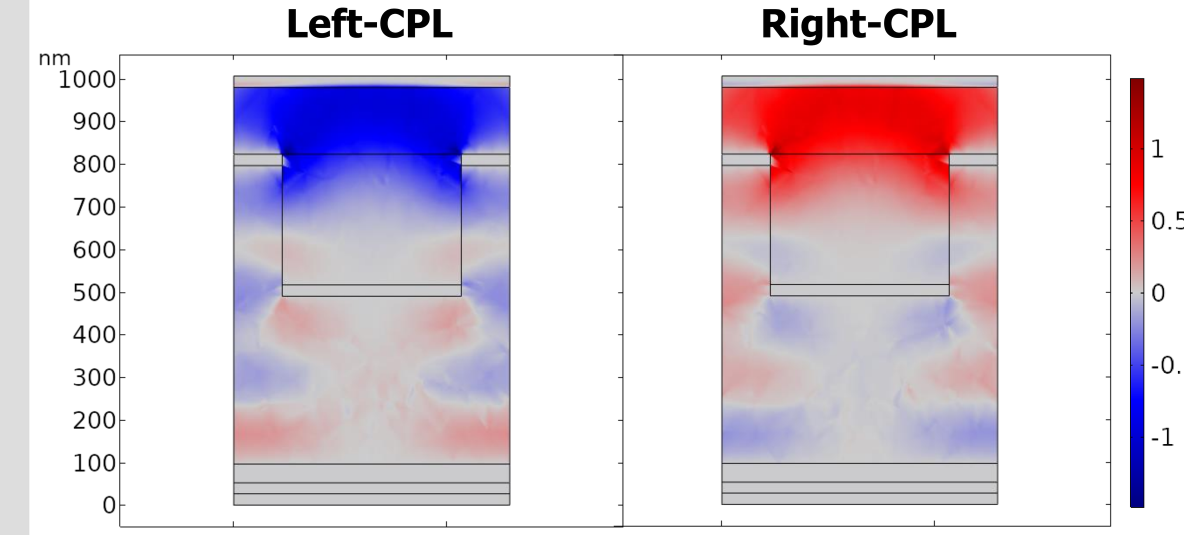
Electric and Magnetic fields exist at the same location; thus it is possible to calculate chiral density.



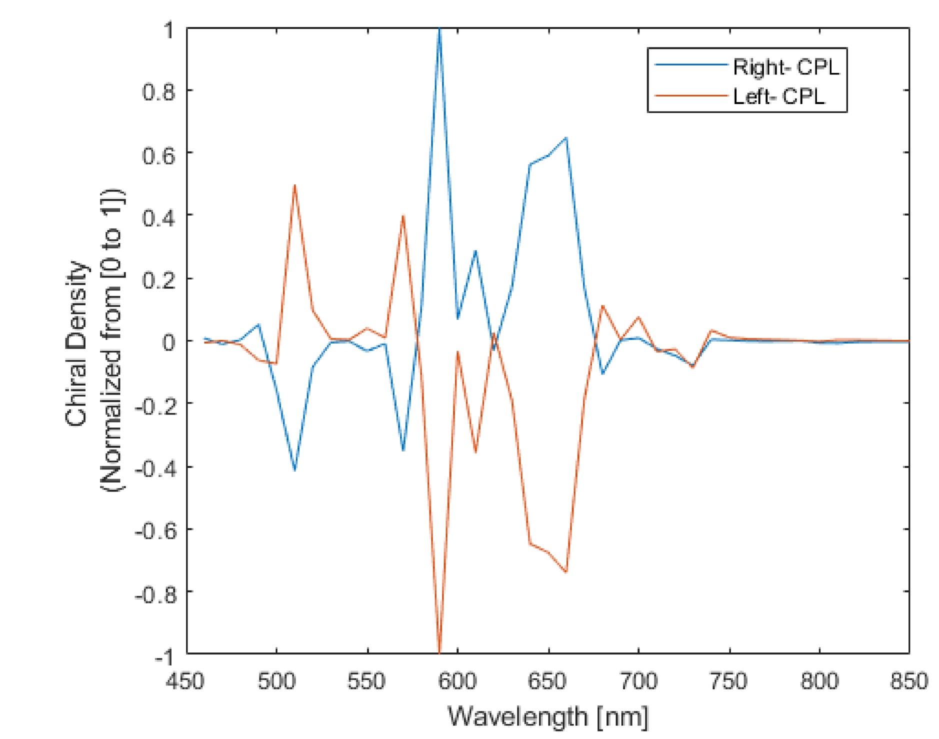
The bare structure is not chiral and therefore we observe no dissymmetry in the metasurface intristic absorption for left- and right-handed light.

Chiral Density plotted at lambda=660nm
(Normalized from [0 to 1])

Left-CPL **Right-CPL**



The key observation is that chiral density maintains uniform handedness within the upper part of the cuvette designated for the sample.



Integrated chiral field density plot shows the opposite maximum value for right- and left- CPL.

Conclusion

This research demonstrates that a **single-handed superchiral near-field can be generated on an achiral cavity-coupled plasmonic system** in the visible range of light.

A change of the handedness in the CPL **doesn't affect the absorption rate**, thus placing a chiral molecule inside the cuvette within the chiral density field, which would cause differentiation of enantiomers.

Left- and right- CPL produces the exact opposite **chiral density of the field**, which proves that an achiral nanostructure design supports interaction between the localized surface plasmon and the cavity, resulting in the **generation of a superchiral field.**

We envision conducting this experiment in the laboratory to confirm our findings and optimize the design of the structure. We hope further increments will lead towards controlling the emission of light by luminescent chiral molecules placed inside the model. This method and its results would be highly relevant in quantum information processing.

References

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Acknowledgements

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