

Design a Chiral Hologram using Metasurface

Products: MetaOptic Designer, RSoftCAD,
DiffractMOD RCWA

Applications: Displays and Imaging, Metamaterials

Introduction

Metasurfaces are a promising new optical technology with applications in AR/VR, biomedical imaging, and wearable consumer electronics. Owing to their planar profiles and versatility, they allow for a dramatic miniaturization of existing optical systems while realizing complex new optical functions.

Meta-atoms, the fundamental building blocks of a metasurface, can be engineered to impart variable amounts of phase on incident light, depending on their geometry. Consequently, a surface composed of meta-atoms of varying geometries has the capability to generate arbitrary phasefronts, and thus arbitrary intensity patterns. This phase freedom has been exploited to create a variety of applications, ranging from diffraction-limited imaging, holography, and vector beam generation.

Chiral metasurfaces provide invaluable tools for controlling structured light and enable complex optical functions from one surface using different polarization state of the incident light [1].

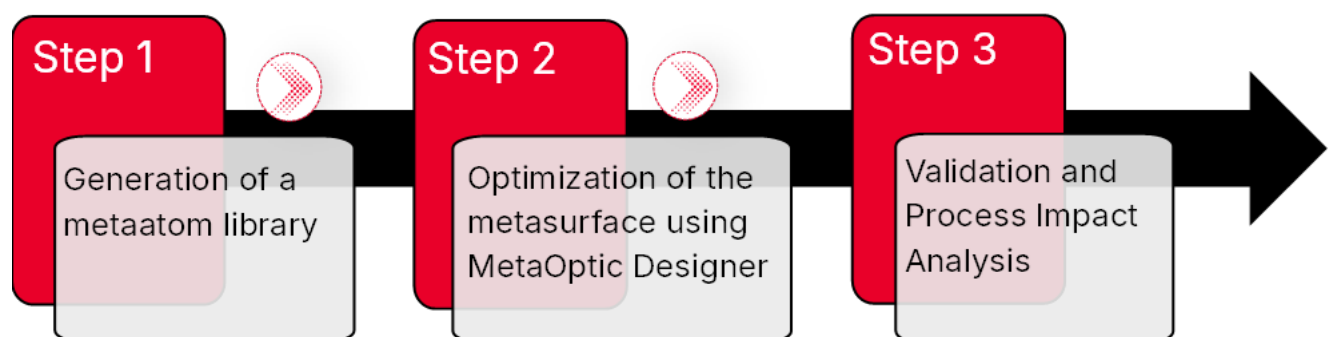
Flow Description

In this application notes, we will cover the established design process flow used in **RSoft Photonic Device Tools** for the design and optimization of metasurfaces.

We will first generate the MetaAtom Library using **DiffractionMOD RCWA** engine after the design of the geometry in RSoftCAD user interface.

Then, we will use this MetaAtom library in **MetaOptic Designer** to go for the optimization of the metasurface (in this case a chiral Hologram).

Finally, we will cover briefly the capability of validation of the design and investigation of the process impact on the optical performance of the metasurface.



Step 1: Generation of the MetaAtom Library

For a polarization sensitive hologram, the MetaAtom library must contain a symmetry breaking in the unitcell. It can be achieved in different ways, either by having a library based on rectangular shape of a MetaAtom where we scan the width and the height of the metaatoms in the library or it can be done using a specific rectangular cross section that will be rotated inside the unitcell as shown in the figure 1.

Both will generate a geometric phase (also called Pancharatnam–Berry phase) that will allow a different phase accumulation through for S-polarized light and P-polarized light.

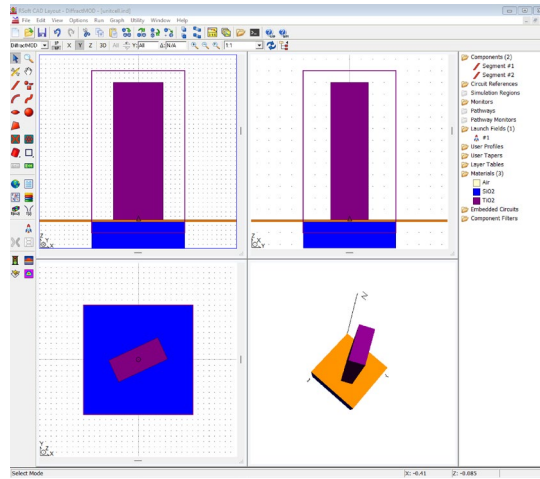


Figure 1. RSoftCAD implementation of the MetaAtom based on a TiO₂ nanofin on an SiO₂ substrate. The symbol “Angle” is the design parameter and is scanned in BSDF Utility to generate the MetaAtom library.

The effects of transmission through the meta-atoms used in this example, comprised of a nanofin, can be modeled by a Jones matrix J :

$$J(\theta) = R(-\theta) \begin{pmatrix} t_x & 0 \\ 0 & t_y \end{pmatrix} R(\theta) \quad (1)$$

where θ is the orientation angle of the atom, R is the rotation matrix, and t_x and t_y are the complex transmission eigenvalues for light polarized along the atom’s axes. If a meta-atom is optimized to act like a half waveplate ($t_x = 1$, $t_y = -1$), circularly polarized light will be converted to the opposite handedness with an additional geometric phase of $\pm 2\theta$, depending on the incident helicity. Therefore, a complete 2π phase coverage can be achieved as the nanofin is rotated from 0 to 180 degrees.

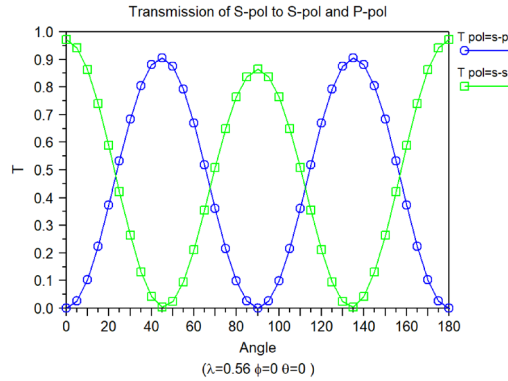


Figure 2. Transmission of S-polarization into S-polarization and P-polarization in function of the Angle of rotation of the nanofin in the unitcell.

The optimization of shape of the TiO_2 nanofin (pitch of 400 nm) has been performed in DiffractMOD RCWA to have a good conversion of S-polarization to P-polarization as explained in [2].

The generation of the MetaAtom library is executed through the BSDF Utility that allows an efficient process. And then the designer can analyze the behavior of the database. In figure 2, we can analyze the capability to convert S-polarization to P-polarization in transmission vs the angle of rotation of the nanofin in the unitcell.

Step 2: Optimization of the Metasurface

The design targeted is explained on the schematic of figure 3. Having incident light illuminating the metasurface a logo will be displayed on the image plane. The logo appearing would depend to the polarization state of the incident light: the word "META" for LCP (Left Circular Polarization) and the word "OPTIC" for the RCP (Right Circular Polarization).

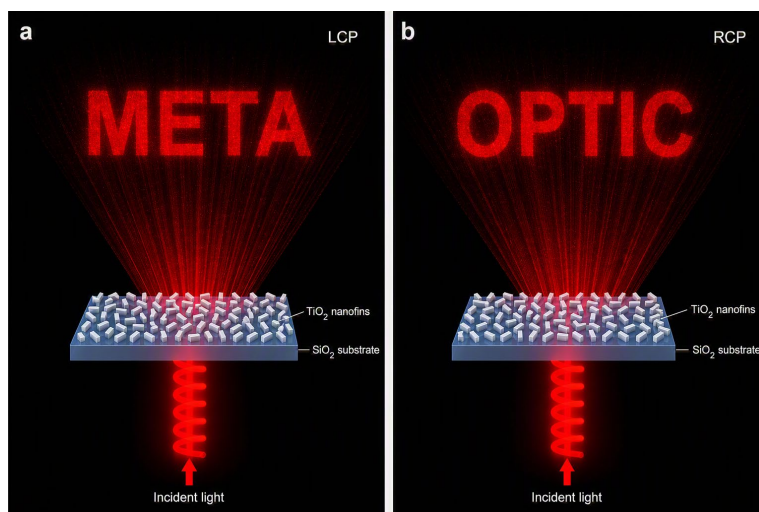


Figure 3. Schematic of the optical function of the chiral metasurface. Depending on the polarization state (LCP/RCP) the logo displayed on the image plane will be "META" or "OPTIC"

The implementation of optical system and the targets of optimization are extremely straightforward in MetaOptic Designer.

As shown on figure 4, the designer adds a metasurface loading the existing databased computed as explained above, the image plane is located at the distance of 100 μm (length) from the metasurface. Then the targets implementation are based on 2 lines of data (b) the first line can be interpreted as the following: the incident light is a planewave having left circular polarization definition and the target is a spatial data file called metaoptic_top.dat and this file is displayed in figure 5 and finally this test case is defined at 560 nm. The second line set the specification for the right circular polarization....

On the right of the figure 4, we can see the schematic of the optical system with the index value of the substrate on left to air on right: those indexes are defined logically from the database used for this project. The image plane is located at 100 μm from the metasurface.

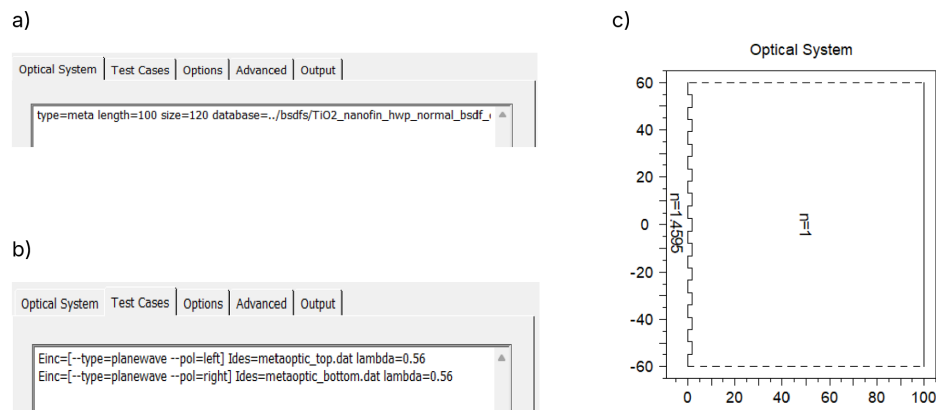


Figure 4. a) implementation of the optical system in MetaOptic Designer. b) Implementation of the targets that would conduct to the generation of the hologram and c) the schematic of the metasurface and the image plane located at 100 μm .

Figure 5 highlights the quality of optimization compared to the target for the polarization configuration. Other figures of merit as the field overlap vs the targets or the transmitted power are also available for a better analysis of the performance of the design.

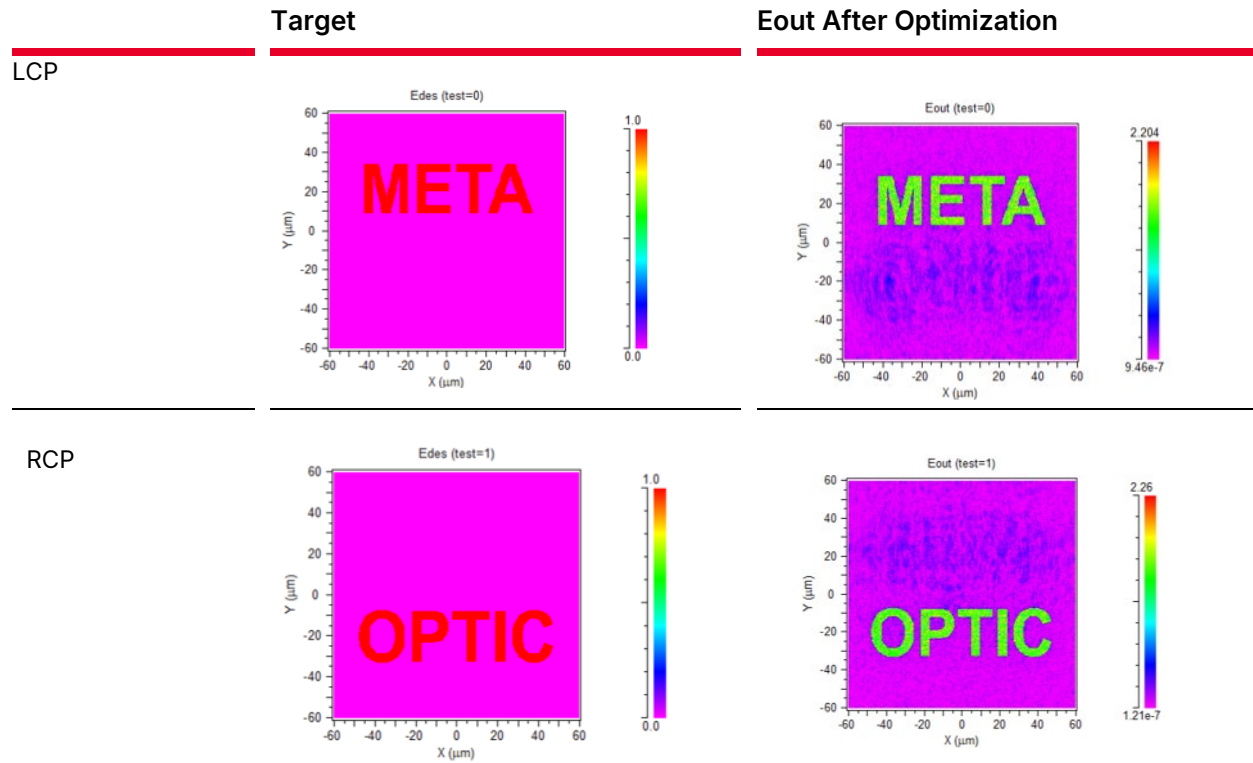


Figure 5. On the left the targeted field for the optimization and on the right the field at the image plane after optimization. At the top for LCP incident light and RCP incident light at the bottom.

Step 3: Validation and Process Impact Analysis

After an optimization in MetaOptic Designer, a design file can be generated for the purpose of validation and **FullWAVE FDTD** engine can be used for the simulation of the entire metasurface. This step is now accessible thanks to the GPU acceleration implemented in FullWAVE FDTD [3].

When the designer is satisfied with the performance, the last step is to generate the layout (figure 6) either in GDS or Oasis format to go then to the final step of the fabrication.

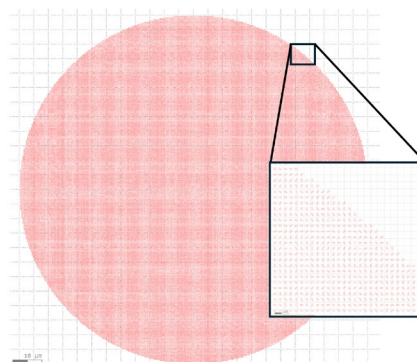


Figure 6. GDS of the metasurface optimized for the chiral hologram.

Though metasurfaces are a promising advance in scaling down the size of optical systems, there are challenges, both in their design and preparing them for high volume manufacturing. Both the etch and lithography processes impact the geometric fidelity of the manufactured device [4].

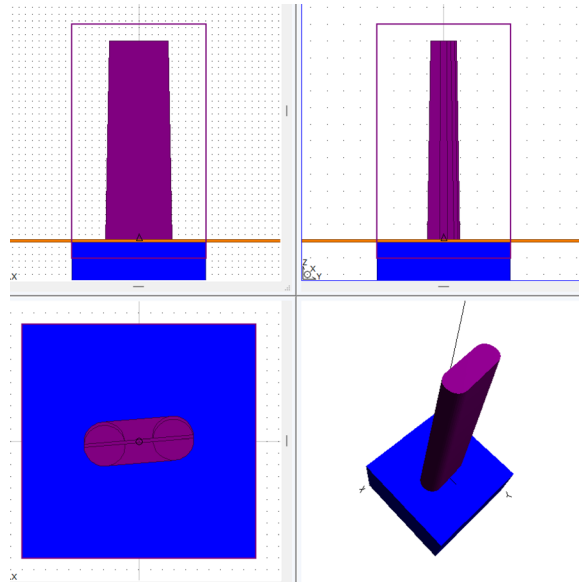


Figure 7. MetaAtom having rounded corners and SideWall Angle to mimic realistic defect related to the litho process.

As a demonstration of the impact of a litho process, rounded corners (radius 40nm) and SideWall Angle of $\sim 6^\circ$ have been added to the metaatoms and a second MetaAtoms library have been generated using DiffractMOD RCWA (figure 7).

Having now a database closer to real shape of MetaAtoms, we can now evaluate the impact of the defects on the performance of the chiral hologram metasurface. On figure 8, we can see side by side, in log scale to mimic eye response the performance of the ideal Metaatoms database (no rounded corners) vs the same layout with rounded corner and SideWall Angle of 6° MetaAtoms (middle column). We can notice noise in the logo and more noise in the region that is supposed to remain dark.

As a last step, the designer can re-optimized using the “realistic” database to go for a compensation (at least partly) of the artifact related to the rounded corners and SWA.

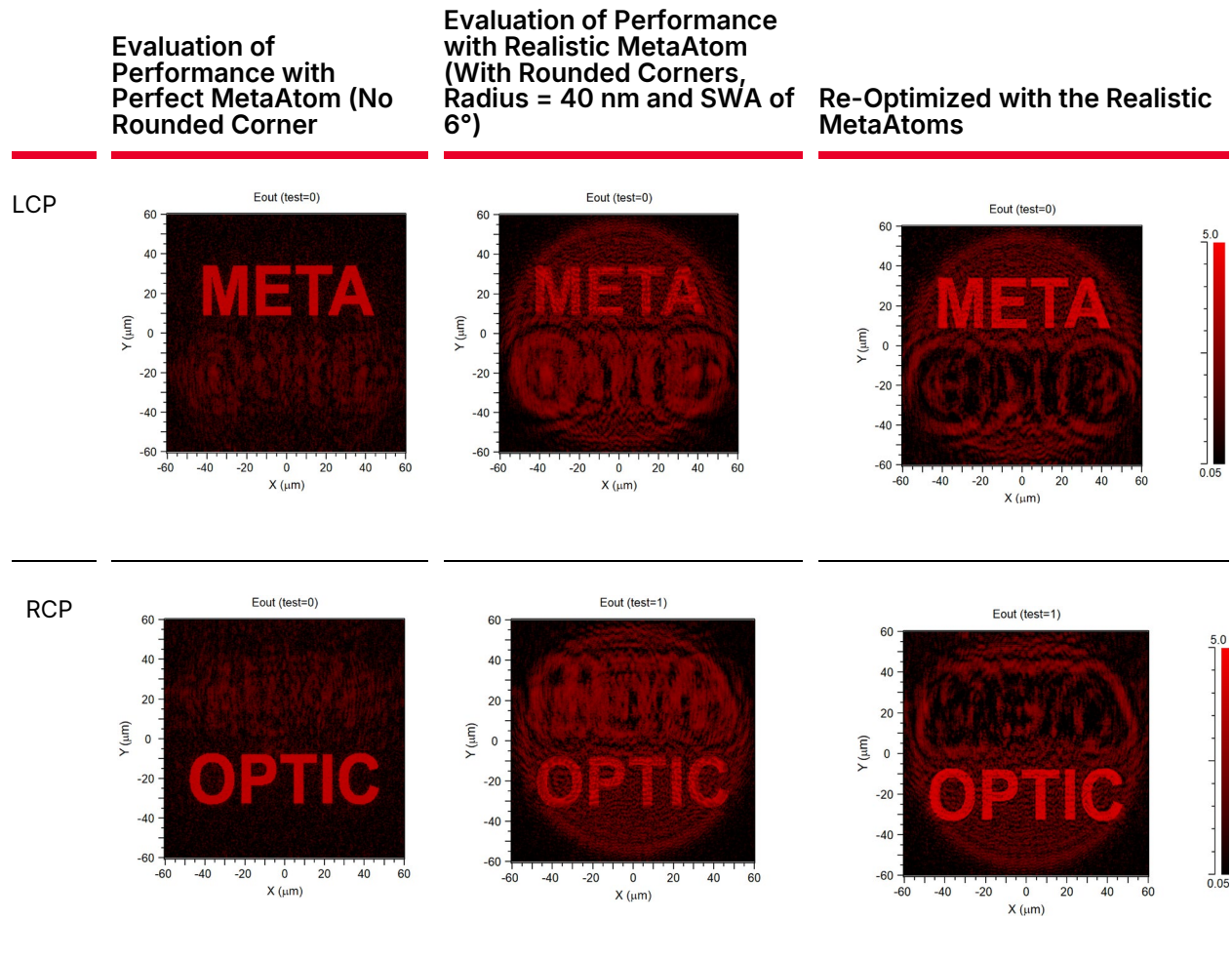


Figure 8. Visualization in log scale of the intensity of the field at the image plane. On left, using perfect sharp corner metaatoms as optimized is Step2, at the middle evaluation of the existing design using more realistic metaatoms with rounded corner radius of 40nm and SideWall Angle of $\sim 6^\circ$ and on right re-optimized configuration using the realistic meta-atom library.

Conclusion

MetaOptic designer is a powerful tool for designer who want to investigate in the technology of the metasurface.

With an easy implementation of the conditions and targets, the tool can optimize complex design as chiral hologram. It allows the validation of the design as well as the investigation of the process impact related to the inherent lithography manufacturing defects as rounded corner or Side Wall angle.

Having this full design and test capability, the designer would be then able to generate the layout file for the foundry.

Example Files

Supporting Files for RSoft Application Note: Chiral Hologram

References

- [1] Asefa, S.A.; Shim, S.; Seong, M.; Lee, D. Chiral Metasurfaces: A Review of the Fundamentals and Research Advances. Appl. Sci. 2023, 13, 10590. <https://doi.org/10.3390/app131910590>
- [2] N. Achuthan, M. Bahl, R. Scarmozzino, E. Heller, J. Bos, and C. Xu, "Automated Design of Optical Systems with Metalenses," in Frontiers in Optics + Laser Science 2022 (FIO, LS), Technical Digest Series (Optica Publishing Group, 2022), paper JW5A.51.
- [3] FullWAVE UserGuide Keysight, chapter 7.
- [4] M. Chalony, B. Küchler, R. Zimmermann, et al. "Optical and manufacturing design aware flow for metalenses", Proc. SPIE 12741, Advanced Materials, Biomaterials, and Manufacturing Technologies for Security and Defense, 1274105 (17 Oct 2023); <https://doi.org/10.1117/12.3000524>

As a mission-critical design enablement partner, Keysight connects design, emulation, and test so customers can solve the world's most complex engineering challenges. Accelerate innovation at www.keysight.com.



This information is subject to change without notice. © Keysight Technologies, 2026, Published in USA, August 3, 2026, 3126-1481.EN