A Study On Metaoptics

Oumou Toure, SULI – Mentors: Carlos Escobar, Alexander Kish

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Introduction

Metasurface is a new nano-fabricated material, which can manipulate properties of light to the point of achieving negative refraction. Metalenses are flat optics devices composed of sub-wavelength nanostructures that allow to locally control the properties of transmitted light wave (amplitude, phase, and polarization). Majors development have been made with metalenses in the last few years; for a recent review see [1].

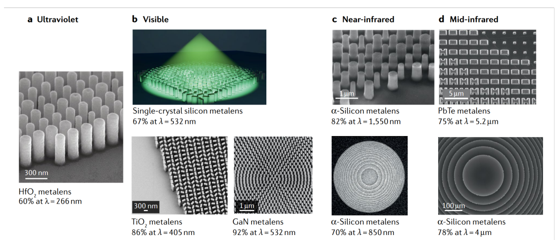


Fig 1

Examples of metalenses for different wavelengths [1].

Goals

1. Exploit light concentration with metalenses for high-energy physics applications, and in particular for particle detectors based on liquid and gaseous argon.

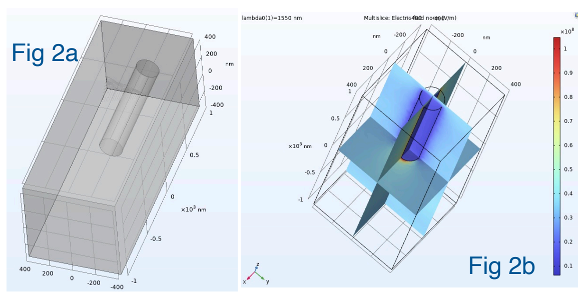
2. Tune design parameters for a metasurface for the purpose of solar photovoltaic power generation [2].

Both applications require light concentration but do not require imaging performance.

The study is performed with COMSOL Multyphysics simulation software with wave optics mnodule, based on finite element analysis.

Comsol Multiphysics solves the problem of the interaction of a light front with the metasurface by integrating Maxwell's equations using finite element approach know as Finite-Difference Time-Domain (FDTD). The user does not access this machinery but rather controls the simulation by specifying the geometry, materials, wavelength, boundary conditions and mesh resolution.

Here we present results of some of simulations, with cylindrical nanopillars of different dimensions and materials, and demonstrate how these choices depend on the wavelength of the incident light. These are the first steps towards the simulation and design of a proper device.



Model of a single nano pillar in COMSOL simulation and simulated electric field

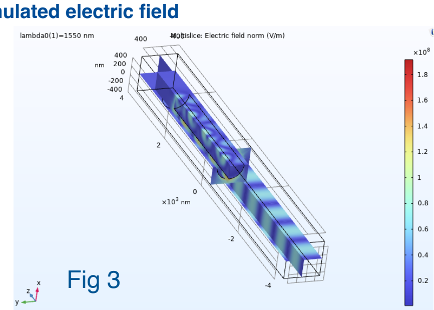


Fig 3

Results

Material	Wavelengths(nm) Dimensions(Radius/Height)	Dimensions (Radius/Height)	Reflectance order[0,0] (1)	Reflectance order[0,0] (1)	Transmittance Order [0,0] (1)	Total Transmittance (1)	Total reflectance and Transmittance (1)	Absorptance (1)	abs(ewfd.S21) (1)
Silicon, Air	1550	100/940	4.0219×10^{-20}	4.0219×10^{-20}	1.0000	1.0000	1.0000	-6.219×10^{-8}	0.9989
	1550	300/3000	0.80377	0.80377	0.19623	0.19623	1.0000	9.404×10^{-14}	0.9989
	400	100/940	0.077765	0.07765	0.92223	0.92223	1.000	$2..138 \times 10^{-13}$	0.99885
	400	30/300	5.1745×10^{-5}	5.1745×10^{-5}	0.99995	0.99995	1.0000	5.9508×10^{-14}	0.99885

Results of a meta surface simulation using two different wavelength

For easy visualization of the results, we compared fig 2a and fig 2b with fig 3. Fi 2a and 2b illustrate a sub-wavelength structure showing that it adequately transmit the power while fig 3 shows an extreme case of a structure that is not sub-wavelength which does not perform adequately. This results can be read from the above table.

Conclusion

Simulations were performed with Comsol of the meta-structure building blocks to be employed in the design of a metasurface that could be used for the purposes stated in the goals..

Acknowledgements

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References

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2. Non-imaging Metaoptics, I. Moreno, . Avendano-Alejo and C. P. Castaneda-Almanza, Optics Letters **45** (10) 2744, May 2020.
3. Flat optics with dispersion-engineered metasurfaces, W. T. Chen, A. Y. Zhu and F. Capasso, Nature Reviews Material **5** (8), June 2020.
4. https://www.comsol.com/

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